Final Report

Educating healthcare professionals on Australian Melons

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Educating healthcare professionals on Australian Melons - VM20003

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Public summary

This 3-year project (2021-2024) 'VM20003 Educating healthcare professionals on Australian Melons' addresses the ambition '*Improved consumer perceptions of melon quality to support increased domestic demand.'* (Outcome 1 in the Melons 2016-2021 SIP). Using the investment of the industry's national R&D levy funds to educate health professionals (HPs) about the nutrition benefits of melons to support their recommendation to their clients/followers (the end consumer) is a key SIP success pathway.

The project was strategically executed across four pillars; strategic planning & evaluation, scientific research, resource development, and communication & education. Key outputs included the completion of an umbrella review, technical report and nutrition gaps analysis; the development of five HP resources (fact sheets, videos, educational animations), establishment of an online resource hub and engaged HP database, an engaging communication plan (including nine EDMs), digital outreach campaign and three educational activities (FOODiQ webinar and two podcasts); and ongoing evaluation via two audience sentiment research (ASR) surveys at baseline and project end.

All intermediate and end-of-project outcomes were successfully met. The project increased HP knowledge of the nutritional benefits of melons along with their intent to recommend them to clients. Specifically:

- The number of HP that were very familiar with the nutrition benefits of melons and able to specify (44%) increased by nearly 80% during the project (KPI: 50% increase).
- Resources were key to enhancing HP familiarity and knowledge. HPs were around 1.5 times more likely to recommend melons if they accessed the project resources (85%) than if they didn't (55%).
- Across the board, there were 30-40 percentage point increases in knowledge on key nutrition benefits compared to baseline.
- At project end, 89% of HP agreed melons can play a role in improving colour variety in the diet (KPI: 80%).
- 27% of HP had accessed the resources (KPI: 50%) with 100% finding them useful.

This project clearly demonstrated that the nutritional benefits of melons are important drivers of recommendation, hence validating efforts to drive awareness of these with HPs, as a valuable strategy to unlocking and driving industry growth. While this project has been a successful first step in educating this important stakeholder influencer group, further consistent investment is recommended to ensure sustained behaviour change. Further investment will maximise the current ROI and help secure melons a stronger position in health promotion.

Future investment is recommended to have short-, medium- and long-term strategic approaches. In the short to medium term, maintaining top-of-mind awareness with the established highly engaged HP database is vital, with opportunities to drive further penetration of key messages to more HPs and extend communication to consumers to establish melons 'nutrition and health' position in the horticultural landscape. Medium to longer-term strategies include investment in research to further build the evidence base supporting melons to maximise its growth potential.

Keywords

Health professional; Melons; Education; Communication; Health; Nutrition

Introduction

The growth and sustainability of the melon industry hinge on increasing consumption. Central to this objective is the Melon Strategic Investment Plan (SIP) 2016-2021, which prioritised 'Improved consumer perceptions of melon quality to support increased domestic demand.' (Outcome 1). A pivotal strategy within this framework involved the allocation of the industry's national R&D levy funds towards compiling and disseminating evidence highlighting the positive nutrition and health attributes of Australian melons to health professionals. This initiative was realised in this project VM20003: Educating Health Professionals on Australian Melons, which commenced in July 2021 and spanned a three-year period.

In today's digital age, while consumers increasingly turn to the internet for nutrition and health guidance, health professionals (HPs) remain a trusted and preferred source of information. Amidst a landscape inundated with information and misinformation, consumers seek clear, concise, and credible advice. HPs serve as pivotal guides, offering authoritative insights that enhance consumer awareness, knowledge, and ultimately influence purchasing decisions. Therefore, establishing credibility with HPs is critical to bolstering any concurrent consumer communication strategies.

Melons, encompassing varieties such as Watermelon, Rockmelon, Honeydew, and Piel de Sapo, are renowned as refreshing summer fruits. Despite their popularity, there is very little human research directly examining their health benefits. Melons lack a distinct health positioning, and little effort has been directed towards communicating their nutritional credentials to HPs or consumers prior to this project. Our baseline research indicated that HPs possess limited knowledge beyond melons' water content and vitamin C levels. Additionally, despite being appreciated for their natural sweetness, melons face misconceptions regarding their sugar content and glycemic index.

An additional challenge for the project was to break through the clutter of competing messages that exists in today's nutrition and health landscape. With a plethora of content promoting various foods, diets, and health trends, lesser-known foods like melons, with little research on direct health benefits struggle to garner recognition. The opportunity for the melon industry was to craft a memorable, credible, and newsworthy positioning that allows each variety of melon to shine individually.

In reviewing the opportunity, it was identified melons have a distinct advantage: melons span five vibrant colors—red, orange, yellow, green, and white—each rich in bioactive compounds such as lycopene, beta-cryptoxanthin, carotenoids, chlorophyll, flavones, and citrulline, linked to various health benefits. In recent decades there has been increasing appreciation and understanding of the coloured bioactive pigments that exist in fruit and vegetables and their links with positive health benefits. It has been a nutrition truism that 'eating the rainbow' is important for good health, but little substantiation to support this statement. While traditional nutrients remain pivotal, attention is increasingly shifting towards comprehending the diverse array of bioactive constituents in foods, which collectively contribute to positive health outcomes. Bioactives and colour variety were emerging as trending nutrition topics.

The opportunity for melons identified was to leverage its colour advantage, champion the "eat the rainbow" recommendation and educate on the value of bioactives and the health benefits derived from those in melons to indirectly communicate its health benefits. Baseline research underscored the significance HPs attribute to colour diversity, with 80% acknowledging its importance for health. Moreover, 75% of HPs agree that Australians' fruit intake lacks sufficient variety, viewing melons as a crucial addition to diversifying dietary fruit choices. Pivotal to achieving this new positioning was to develop world-first research to substantiate the "eat the rainbow" message. This served to establish a compelling narrative that not only captured attention but also enabled the credible communication of the health benefits of melons indirectly through their colorful bioactive constituents.

Born out of strategic review and stakeholder collaboration was the health-related positioning "Melons – Goodness in Every Colour". It represented a potent health positioning that melons could own and develop, that celebrates the melon family, elevating them from insignificance to prominence in the nutritional landscape.

Methodology

The project targeted Australian health professionals (HP). It was strategically developed and executed across 4 key pillars; strategic planning & evaluation, scientific research, resource development and education & communication. The project was conducted with a continuous improvement mindset with modifications to the project implemented based on learnings from activations and research insights.

Strategic planning & evaluation

The initial phase of the project involved finalisation of key project planning elements in conjunction with Hort Innovation, including the project risk register, program logic, and monitoring and evaluation plan. Communication to Hort Innovation on project progress including outputs and outcomes were provided 6 monthly through benchmarking reports.

As part of the monitoring and evaluation plan, and to help inform strategy and evaluate the effectiveness of the communications plan, a detailed audience sentiment survey (ASR) was designed. The research was planned strategically throughout the project; project start (Oct 2021), and project end (May 2024). The ASR sought to help establish current and changing attitudes, knowledge and propensity to act of health professionals with regards to Australian melons over time. The surveys consisted of a detailed questionnaire designed to extract both qualitative and quantitative data from the responses. Each question was crafted around a core objective to ensure information collated was robust to help inform and guide the overall approach. Each person who participated in the research was incentivized through a chance to win mechanism.

A snapshot at baseline served to provide a benchmark of HP knowledge, attitudes and behaviour around melons, with the snapshot at project end allowing a comparison and assessment of project effectiveness, insights and learnings. The baseline survey also sought to garner insight into HP attitudes around food safety concerns for melons and value of colour variety for health and role melons could play. It also sought to understand HP needs and preferences around receiving education and resources. The project end survey captured knowledge levels of the nutritional properties benefits of melons related to key project communications and behaviour around recommending melons, including facilitators and barriers.

Based on FOODiQ's commitment to continuous improvement, the project strategy was reviewed ongoing, and the plan strategically adjusted accordingly. These strategic changes were aligned with the Hort Innovation R&D Manager, along with the Project Reference Group (PRG) as needed.

Scientific Research

In year 1, the science base to support the development of key evidence-based communication messages and the over-arching communication strategy 'Melons – Goodness in every colour' was developed and finalised. To support the development of evidence-based key messages, a technical report was developed that brought together evidence from a scientific literature database search containing any relevant scientific literature specific to Australian melons and their nutrition and health benefits, a commissioned umbrella review, and a 'Gaps Analysis', providing updated composition knowledge on the nutritional and the colour-associated bioactive composition of melons.

The umbrella review was a world-first research project that investigated the health effects of natural bioactive pigments found in fruit and vegetables (those that give fruit and vegetables their colour). The gaps analysis reviewed the nutrient data available for four melon types readily grown and to available in Australia; watermelon, rockmelon, honeydew (yellow/gold rind or green rind) and Piel de Sapo to inform the education campaign and identify opportunities for any additional nutritional testing. The nutritional information available for these fruits (peeled, flesh only) and their components (e.g., watermelon seeds) were collated via three sources which included Australian and international nutritional databases: (i) Australian Food Composition Database, (ii) United States Department of Agriculture (USDA) FoodData Central, (iii) United Kingdom Composition of Foods (CoFID), (iv)Phenol-Explorer, and (v) USDA Database for the Flavonoid Content of Selected Foods, published scientific literature, and nutrient and bioactive analyses conducted by researchers at Curtin University as part of ST19036.

Resource development

Throughout the project, collateral was developed as the key mechanism to educate HPs and increase their knowledge and understanding on the nutrition, health and culinary properties of melons. Along with specific resources to improve HP knowledge, collateral was developed to support the dissemination of this knowledge to their clients. Based on the ASR learnings, different types of collateral were developed to help support engagement and interest including fact sheets, video, podcasts and two animations. Strategically developed over the 3 years, the collateral served as new 'news' to maintain interest and an ongoing conversation with the project's owned HP database.

Communication & Education

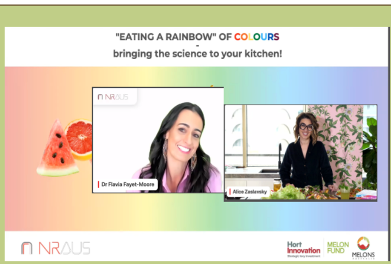
A **database** was initially established at the start of project when people participated in the ASR. The database served as the project's central core target audience with a key objective and outcome to continuously build the database throughout the project. This database was developed during the project via recruitment of HPs attending our own educational events, and social media lead generation mechanics.

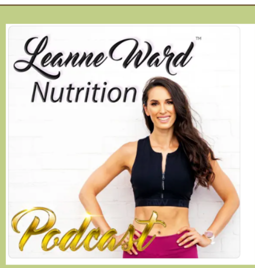
An **educational activity plan** of events including webinar and podcasts was planned at project start, and an **ongoing periodic communication and end-of-project digital activation** program was developed and executed to target both HPs and growers throughout the 3 years. The communication plan included regular EDMs to the database along with an end of project HP targeted digital activations campaign utilising social media, relevant third-party channels and key opinion leader influencers. For growers, periodic communication to keep them informed on the project's progress and milestones was planned, developed and executed in conjunction with Melons Australia via news articles.

Results and discussion

Educational events

A total of three educational activities were held during the project, including FOODiQ HP webinar and two podcasts. **See Table 1** for results.





FOODiQ Webinar
October 2022

Leanne Ward Nutrition Podcast
June 2023

Dietitian Connection Podcast
October 2023

TABLE 1: Summary survey results from educational events

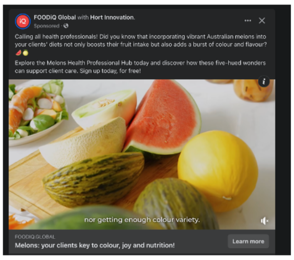
	Audience	**Event 'Excellent or Very good' Overall**	**Event 'Extremely or Very' Engaging**	**Event 'Extremely or Very' Informative**	**Event 'Extremely or Very' Useful**	**Intend to recommend MELONS for colour variety**
FOODiQ Webinar*	279 register (KPI:200); 88 live; 420 views	100%	100%	100%	97%	100%
	Downloads	**Benchmark**				
PODCAST – Leanne Ward	>13, 770	Top 3% of podcasts				
PODCAST – Dietitian Connection	2955 At 8 months					

* Target = >80%

Digital activation campaign

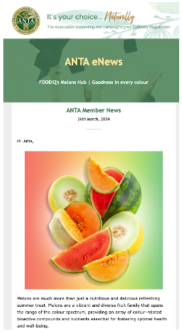
At project end in March 2024, a communications outreach campaign targeted to HP was undertaken to drive reach and awareness of the resources. The campaign utilized social media, channel advertising, and KOL activation. See **Table 2** for results.

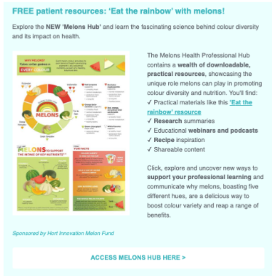
Social Media



Activation: 26 March – 4th May 2024

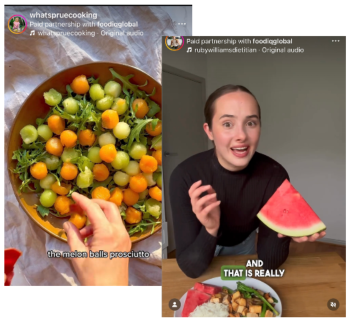
Channel comms





Melons HP Database EDM: April 2024
Australian Naturopath Association solus EDM: March 2024
Dietitian Connection solus EDM: March 2024

KOL Influencer



Activation: March 2024

Over the past 6 months, HPs have been directed to the HP hub. In this time there were over 2308 unique visits and 217 downloads of resources.

TABLE 2: Digital Outreach Campaign Performance

	Audience	Open rate %	Reach	Total clicks	CTR %	
Dietitian Connection	12, 149	45%	5414	183	1.5%	
Australian Natural Therapists	7000	28.1%	1960	154	2.2%	
		Impressions	**Reach**	**Total clicks**	**Av CTR%**	**Sign up database**
Social media (HP)		128,000	49, 940 (KPI:20,000)	4328	3.37%	38
		>50% view				
Animation		11, 545 (KPI: 15,000)				
KOL influencers	5000 views					

Health Professional Database

The HP database was originally commenced at start of project with initial acquisition via the baseline audience sentiment survey. The database has grown throughout the project via recruitment strategies at webinar and the digital outreach campaign. At project end the HP database sits at a total of 369 subscribers which is 43% increase on baseline (KPI: 30%).

Electronic Direct Mail (EDM)

Nine electronic direct emails were sent to the Melons HP database throughout the project to maintain a connection and keep melons top of mind. The EDMs open rates ranged from 29-52%, consistently performing well above average open rate (25%). See **Table 3** for results.

TABLE 3: EDM open rates

	Topic	Date sent	Open rate
EDM 1 *	Recruitment to ASR	2022	52.1%*
EDM 2*	Umbrella Review published	August 2022	47.8%*
EDM 3	Umbrella Review published	24th August 2022	28.6%
EDM 4	Webinar invite	28th October 2022	29.8%
	Factsheets	12th April 2023	52%
EDM 5	Podcasts	10th July 2023	40%
EDM 6	Video on UR	15th Dec 2023	38.2%
EDM 7	Animations	8th March 2024	*43%*
EDM 8	End of Campaign - Hub	19th April 2024	41.2%
EDM 9	ASR Recruit	19th June 2024	40.7%

*EDM 1 sent to FOODiQ database for recruitment. Open Rate Target >25%

End of project Evaluation

An audience sentiment research (ASR) survey was undertaken at project start and end. It aimed to assess HP knowledge, awareness and confidence in Australian melons nutrition and health benefits for project evaluation. Full results are in the full report in Appendix 2. See Figure 1-6 for key results.

FIGURE 1: Health professional familiarity with nutrition and health benefits baseline Vs project end (accessed versus did not access resources)

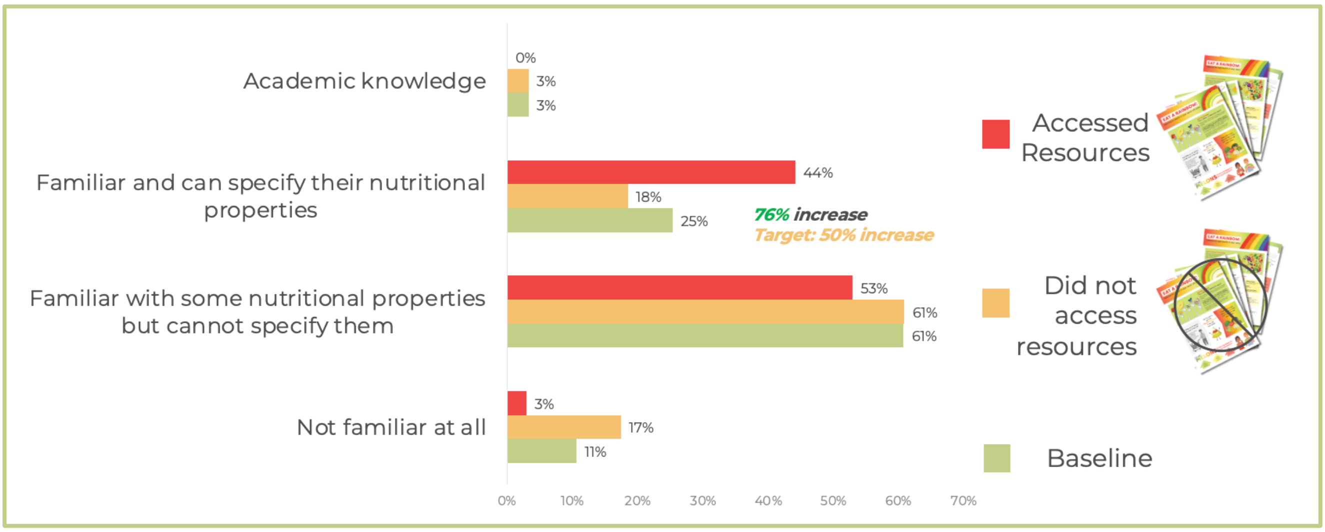


FIGURE 2: Health professionals recommending Melons at project end (accessed versus did not access resources)

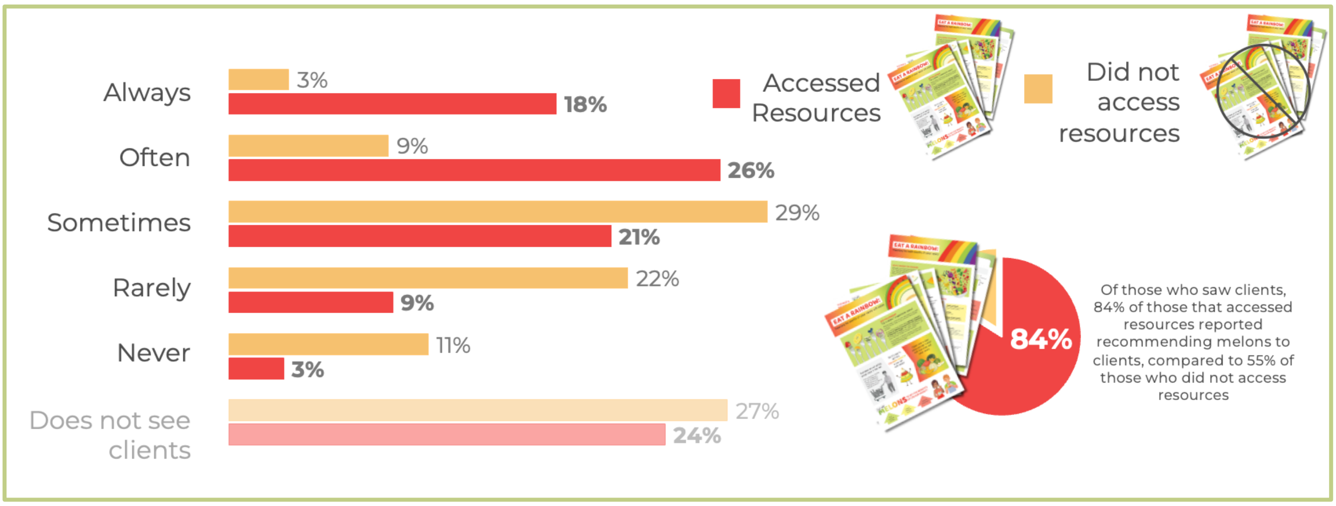


FIGURE 3: Proportion of health professional aware of specific melon nutrition benefits baseline Vs project end (accessed vs not accessed resources)

FIGURE 4: HP agreement 'That melons can play a key role in improving colour variety in the diet'

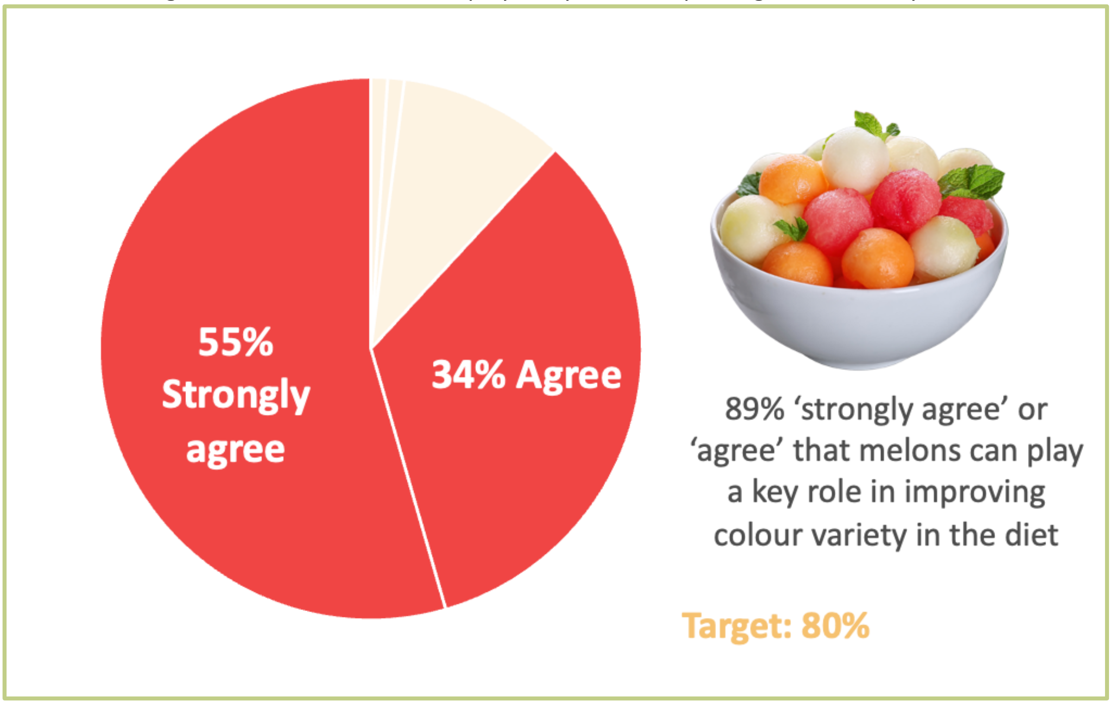


FIGURE 5: Project resources usage and perception by Health Professionals

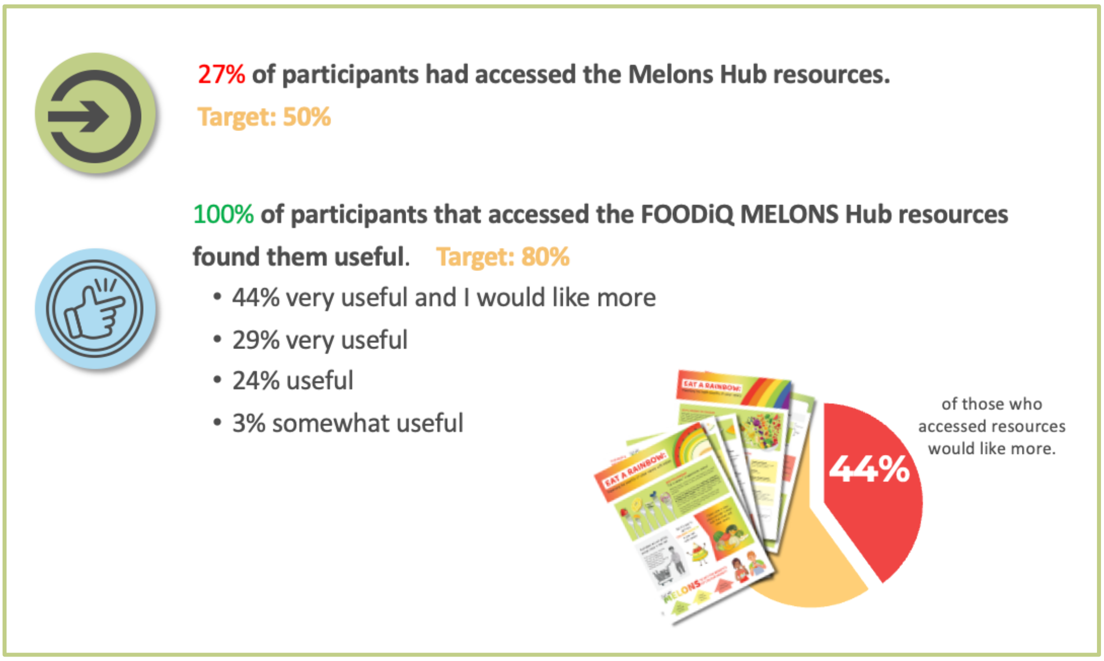
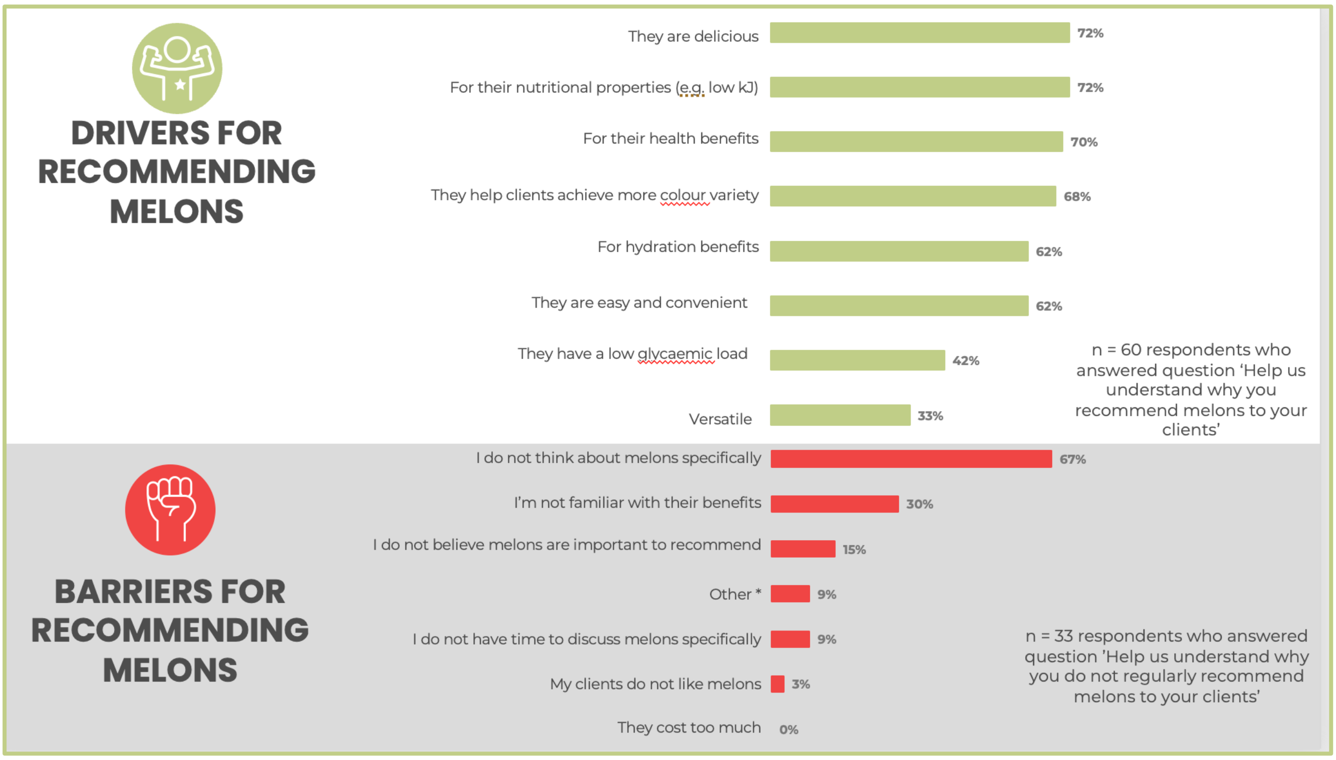


FIGURE 6: Drivers and Barriers to HP Melon Recommendation



In summary, there was a significant increase (76%) in HP who reported they were not only familiar but could specify melon nutrition benefits and significantly less (64%) who were unfamiliar compared to baseline. HP knowledge regarding the key project education messages increased the most for those accessing the resources, supporting that resources were effective. Only 26% respondents reported that they had accessed the hub compared to target of 50%. The baseline survey and the post-project survey were independent cross-sectional surveys, involved different, though overlapping, audiences. This difference might account for variations in database access, as new or different respondents captured in the project end survey might not have been as engaged or informed about the database. The low access could also reflect low awareness and represents a future project investment recommendation to support further and ongoing digital outreach campaigns. For those who accessed the resources, the key drivers for reasons to recommend were more likely to be the key messages communicated throughout project, including colour variety, low GI and versatility (culinary benefits), whilst those that had not accessed the resources were more likely to say taste.

Accessing resources & education correlates well with increased knowledge and recommendation. The resources played a pivotal role in enhancing HP familiarity and recommendation, with those accessing the resources 1.5 times more likely to recommend melons (85%) compared to those who did not (55%). Resource access appears to have been powerful for changing knowledge and recommendation, with reasons for not recommending related to melons not being top of mind or unaware of benefits. The number of participants who had accessed the resources, however, was lower than expected. Increased dissemination is likely to amplify impact. Furthermore, ongoing continuous HP communication and extension to consumer communications is recommended to maintain top-of-mind awareness and continue to build reach.

The educational webinar was rated highly for information, usefulness and engagement and the podcasts performed above average benchmarks. The webinar, along with the digital outreach served as a valuable strategy to drive database recruitment to disseminate further resources. Leveraging the digital format offers the benefit of securing an evergreen resource that can be leveraged with future audience acquisitions.

Outputs

Output	Description	Detail
Audience Sentiment Research – Baseline	Baseline findings HP awareness and knowledge in Australian melons nutrition and health benefits. Baseline findings used to help set M&E targets and direct project strategy. **Target audience:** Hort Innovation	Date conducted: October 2021 Survey responses: 339 (KPI: >200) Report **(Appendix 1)** submitted to Hort Innovation on 15th January 2022.
Audience Sentiment Research – Project end	End of project findings HP awareness and knowledge in Australian melon benefits, usage of resources and recommendation for project evaluation. **Target audience:** Hort Innovation	Date conducted: May 2024 Survey responses: 175 (KPI:>200) Report **(Appendix 2)** presented at PRG 6 and submitted to Hort Innovation as part of this final report.
Umbrella literature review publication	A comprehensive systematic review of systematic reviews, that synthesized the evidence on the health effects of a variety of colour-associated bioactive pigments found in fruit and vegetables (carotenoids, flavonoids, betalains and chlorophylls), compared to placebo or low intakes. **Target audience:** Hort Innovation and project team	The umbrella review manuscript was accepted for publication on the 14th June 2022 **(Appendix 3).** The findings were leveraged throughout the project in development of evidence-based key messaging for educational events and resource development.
Melons Technical report	Scientific summary report nutrition and health benefits melons able to be leveraged to support communication translation across collateral and event development. **Target audience:** Hort Innovation and project team	Date submitted: 12th August 2022 (**Appendix 4)**.
Gaps Analysis report	Nutritional matrix of melons & melon products and identification of gaps in nutrient information and recommendations for additional testing. **Target audience:** Hort Innovation and project ST19036	Date submitted: 15th July 2022 (**Appendix 5)**.
Melons Hub Webpage	Single webpage serving as digital repository of the project resources on the FOODiQ website for HPs. **Target audience:** HP	A melons hub webpage on the FOODiQ Website was developed August 2022 and maintained ongoing. The resource outputs will remain available on the FOODiQ hub for as an access point available for health professionals ongoing. All the outputs have also been provided to Melons Australia for their usage and storage on the health professional webpage on the Melons

		Australia website.
Melons Australia HCP Website	Copy and directional imagery provided for newly created consumer and healthcare professional nutrition and health webpages as part of updated Melons Australia website. **Target audience:** HP & Consumer	A report was compiled consisting of consumer and healthcare professional relevant copy along with creative examples and inspirational direction on how this could be brought to life **(Appendix 6).**
Factsheets	2 x Factsheets **(Appendix 7)**; 1 x HP Melons & Colour Variety and 1 x Consumer facing were developed. The HP factsheet educated at a macro level on bioactives and linked health effects, the importance of colour variety in the diet, and how melons can help. **Target audience:** HP	Available on the Melons Hub and sent out via the HP database, distributed to attendees at webinar, and communicated in HP channel communication and social media activation.
FOODiQ HP Webinar	1-hour professional development webinar. **Target audience:** HP	Webinar was held on 22nd November 2022. Webinar was held on 30th October 2024. See **Appendix 8** for evaluation. 275 registrations and 89 attended live. 100% reported they learnt something new 100% rated webinar 'excellent' or 'very good' overall (KPI >80%). 100% found event 'extremely informative' or 'very informative' (KPI>80%) 100% found event 'extremely engaging' or 'very engaging' (KPI>80%) 97% found information presented 'extremely useful' or 'very useful' (KPI>80%) 100% intend to recommend melons to clients to help improve colour variety
Leanne Ward Podcast	35-minute conversational episode with Accredited Practicing Dietitian, Leanne Ward on her popular podcast Leanne Ward Nutrition. Target audience: HP	Podcast live event: 5th June 2023. Currently exists as evergreen resource. To date there has been 13, 770 downloads.
Dietitian Connection Podcast	30-minute conversational episode with Dietitian Connection dietitian Brooke Delfino. **Target audience:** Dietitians	Podcast live event: 22nd December 2023. Currently exists as evergreen resource. To date there has been 2955 downloads.
Video	1.5 minute video communicating the findings of the umbrella review publication and linking its findings to the benefits of melons. **Target audience:** HP	Available both on the FOODiQ Melon hub, YouTube channel and Melons Australia website. The video sent out via the HP database and communicated in channel and social media activation

Animations	Two 2-minute digital animations. One animation educated on why melons, educating on their key overall nutritional composition and a strong call to action to recommend melons more. The second animation focused on how to get the most out of melons, with practical and no waste aspects messages providing guidance on storage, preparation and usage. **Target audience:** HP	Available both on the FOODiQ Melon hub, YouTube channel and Melons Australia website. The animations were sent out via the HP database and communicated in channel and social media activation.
Digital Activation Campaign	Communications outreach campaign targeted to HP to drive reach for the awareness of the resources, utilising social media, channel advertising and KOL activation. **Target audience:** HP	Over March and April 2024, a 4- week paid social media campaign took place along with advertisement to Dietitian Connection (DC) membership and Australian Natural Therapist Association (ANTA) and influencer campaign. See **Appendix 8** for evaluation. Total reach: 128,000 Social CTR %: 3.4% (KPI:1-2%) DC CTR %: 1.5% (KPI: 2%) ANTA CTR%: 2.2% (KPI: 2%) KOL reach: followers 4000
Electronic Direct Mail (EDM)	An electronic direct email sent to the melons HP database ongoing regular basis. **Target audience:** HP	9 x EDMs **(Appendix 10)** were sent to the HP database throughout the project. The EDMs served to keep melons top of mind with HP and communicate nutrition and health benefits. 24th August 2022, 24th August 2022, 28th October 2022, 12th April 2023, 10th July 2023, 15th December 2023, 8th March 2024, 19th April 2024, 19th June 2024
Health Professional database	A final database built during the project to enable an ongoing conversation with HP. **Target audience:** HP	At project end the HP database (**Appendix 11** sent separately) had 369 subscribers which was a 43% increase on baseline (KPI: 10% increase each year).
Project Reference Group (PRG) Meetings	6 monthly meeting with appointed project stakeholders/advisors to inform and consult on project. **Target audience:** HP, Industry, Hort Innovation	6 x Meetings **(Appendix 12)** were held where project deliverable outcomes and learnings discussed and consultation for future plans discussed and aligned. 8th December 2021, 23 February 2022, 8th July 2022, 1st December 2022, 19th June 2023, 26th June 2024.
Melons Industry News	Project update story published in Melons industry news communicated to growers. **Target audience: Industry**	6 x articles **(Appendix 13)** were prepared. 26th October 2021, 4th May 2022, 14th November 2022, 23rd May 2023, 15th November 2023, 30th May 2024.
NiQ Science	6-monthly summaries on the latest	4 x Scientific searches **(Appendix 14)**

Summaries	science. **Target audience:** project team, Hort Innovation	prepared for Hort Innovation every 6 months to stay abreast of the latest clinical developments and advances in melons and health. MS104, MS105, MS106 and MS107 reports.

Outcomes

Table 4. Outcome summary

Outcome	Alignment to fund outcome, strategy and KPI	Description	Evidence
Materials loaded into the Melon Hub	KPI: All resources uploaded	The nine resources; umbrella review publication, 1 x webinar recording, 2 x factsheets, 2 x animations, 1 x video, and 2 x podcasts were all uploaded onto FOODiQ Melons Hub.	Melon Hub
The HP database increased 44% from baseline to achieve 369 subscribers at project end.	KPI: >10% increase in database subscribers/ year	The HP database acquisition commenced via the baseline audience sentiment survey recruitment. The database has grown throughout the project via targeted strategies via webinar and the digital outreach campaign. The database is a key and central strategy to gain direct line communication with the target audience to a maintain cost effective and ongoing connection that ensures melons remains top of mind to secure recommendation and continue to support long term industry growth.	Database management
EDM open rates 29-52%	KPI: 25%	Nine EDMs were sent out 3-6 monthly to an engaged melons HP database over the project as evidenced by the above average open rates.	Campaign management
49,940 reach social media	KPI: 20,000 total reach	The digital outreach primary campaign aim was to increase HP awareness of the resource hub. It also aimed to recruit to the HP database.	Meta data analytics
11, 545 video views (>1min)	KPI: 15,000 30 second video plays	The animation was communicated to HP via direct EDM to Melons HP database, and via digital activation outreach campaign. The animations and video are a key engaging and evergreen resource targeted for the digital arena, increasingly a key channel source of information for HP. As an engaging hook they garner consideration to melons messages in digital outreach campaigns whilst also educating key melon messages and driving awareness of hub and resources.	Online data analytics

27% of HP aware of the Berry Hub and resources with 100% finding them useful.	KPI: 50% aware	The Melon Hub is the repository for all project resources which aim to increase knowledge and understanding on melons. The melon hub was communicated via direct EDM to the owned database, at the webinar and via digital outreach campaign. The evaluation research supports that when awareness is engaged and knowledge increases, intention for recommendation increases. Increasing HP awareness of hub is key and there is opportunity to further drive this.	Audience Sentiment Survey
97% of HP utilizing resources rated themselves familiar with melons nutrition benefits with 44% rating themselves as also able to specify which was 76% increase from baseline.	KPI: 50% increase from baseline on being familiar and able to specify.	HP familiarity with the nutrition benefits was driven through the developed resources which were disseminated via channel and social communications, and educational events. Increasing familiarity is key to driving understanding and recommendation.	Audience Sentiment Survey
89% believe that melons can play a key role in improving colour variety in the diet with 84% of those seeing clients, recommending melons to clients.	KPI: 80%	Sentiment to increase recommendation of melons results from increasing HP awareness and knowledge of the nutrition, health and culinary benefits of melons. This was the main strategy for the project which involved development of credible evidence-based resources and educational events that were communicated and disseminated via comprehensive communication plan. HP fulfil an important role in consumer decision-making and purchasing, providing trusted information in an increasingly confusing and overloaded information ecosystem. While less tangible and indirect, they play a pivotal part long term in maintaining and further fueling demand and consumption.	Audience Sentiment Survey

Monitoring and evaluation

Table 5. Key Evaluation Questions

Key Evaluation Question	Project performance	Continuous improvement opportunities
To what extent has the project: - translated new science quantifying the nutritional and bioactive profile of Australian melons in HP resources? - increased HP knowledge and awareness of the unique colour-associated nutritional/bioactive properties and health benefits of Australian melons in HPs? - increased the focus, confidence and proficiency of HPs in recommending Australian melons as a way to improve colour variety and achieve optimal health and wellbeing?	The umbrella review publication was the underpinning to key messages used to support education around melon's health benefits indirectly via its bioactive composition. The umbrella review was hugely successful as a translation piece to provide melons attention due to its newsworthiness. As a publication it has 16803 views to date, 21 citations and an Alt metric score 261 putting it in top 5% of researched article scores. It was shared by 294 social media users, ten news outlets and was key driver of Leanne Ward Podcast episode undertaken for the melons project with >13,770 downloads to date, putting it in the top 3% of podcasts. The resources were deemed 100% useful by those who had accessed them, with 44% saying they would like more. Some of the anonymous open-ended feedback in the final project ASR include: *"It provided a great summary of the research on melons for both health professionals and the general public, and it was presented in an aesthetically pleasing way."* *"They provide detailed nutritional information, highlight health benefits, support dietary variety, offer practical tips for selection and preparation, and enhance client education on the benefit."* *"They are practitioner-friendly and provide just the right level of info to allow us to convey the key points to the general public."* *"Evidence-based info I can trust."* 97% HP who accessed the resources reported being familiar with the nutritional benefits of melons versus only 82% of those who had not. Nearly half (44%) of those accessing the resources stated they were both	• The project has demonstrated that raising awareness and education of HP increases their familiarity and knowledge, and ultimately intent to actively recommend. Key reason for not recommending melons from the audience survey is not thinking about melons. Maintaining an ongoing conversation with HP to keep melons top of mind will be paramount to maintain their active recommendation. Development and execution of an ongoing integrated dedicated Melons HP website/digital activation strategy should be high priority.

	familiar and can specify. This was 76% increase on baseline (KPI: 50% increase). Unfamiliarity with nutrition benefits significantly decreased (64%) in those who had accessed resources compared to baseline. The number of HP able to correctly identify melon's key nutrients bioactive components other than vitamin C, dietary fibre and water was significantly higher in those who had accessed the resources and increased by ~30-40 percentage points from baseline. See **Appendix 2** for further details. At project end, 89% HP believe that melons can play a key role in improving colour variety in the diet. Of those seeing clients, there was higher likelihood to recommend with 84% recommending melons to clients vs only 55% in those who had not accessed. Further consolidation of the value of education on recommendation is supported from survey measures at events. Attendees at the webinar were asked to also indicate their intent to recommend post event with 100% indicating they would recommend melons.	
To what extent - have the educational resources been disseminated to HCPs? - Has the project team successfully engaged with HCPs? - Have regular project updates been provided through linkage with the industry communication project?	All nine developed project resources have been housed on the melons HP repository – FOODiQ Melon Hub as well as the Melons Australia HP and consumer webpages. They have been disseminated via EDMs sent to the Melons HP database which had good performance with open rates ranging from 2.9-52%. The resources were also distributed to 289 registrants of the webinar (KPI: 200) and via advertisement in the digital outreach campaign that reached 49,940 people (KPI: 20,000). The webinar and resources have consistently been rated by HP as engaging and exceeding KPI >80% and no-one rating bottom 2 box of not engaging. 100% indicated they found the webinar 'extremely or very engaging'. Unprompted survey feedback was	• Improvement opportunities exist in leveraging additional opportunities to distribute the resources to HPs via additional targeted social media posts and events. Ongoing investment in dissemination could leverage the investment already made in the creation of the resources.

	extremely complimentary of the format of the events with engagement driving overall positive ratings. The project team has provided regular updates to key industry stakeholders via 6 PRG meetings and 6 news articles for the grower's magazine.	
Did the project identify barriers to melon recommendation and provide practical ways to solve them, using Australian melons? How accessible were campaign communications to HCPs?	No barriers were identified during the project but at project end the ASR identified that key drivers for not recommending were melons not being 'top of mind' and not familiar with their benefits. Project has identified that when HP are aware of the resources, their knowledge increases and their intent to recommend. It will be key to maintain ongoing communication with HP to keep melons top of mind. An opportunity exists to drive the 'Goodness in every colour' messaging through to grassroot consumer communications and even point of sale as a 'top of mind' strategy. The audience sentiment survey at project end, showed while 100% those accessing resources rated them to be useful, only 25% had accessed the hub and seen the resources.	• There is opportunity for ongoing investment to further drive awareness to capitalise on the finding that when HP are aware of the resources, they are likely to find them useful and to increase their active recommendation to clients/followers.
Have project outputs been delivered within timelines, to budget and quality?	All project outputs have been delivered within the required timelines within budget and to high quality as exemplified by feedback at events and from PRG members. The project team operated with an efficiency and continuous improvement mindset. This is evidenced by our strategic review process throughout the project leading to recommendations by the team to re-funnel budget into digital activation to drive greater reach.	• Going forward it is recommended that if operating within same budget that targets for awareness of hub and resources are reduced as it is difficult with limited budget to both create resources whilst also striving to drive HCP awareness of resources and hub. It is recommended that HP education projects should have longer term perspectives to include a 5 year rather than 3 year plan. The first 2-3 year project focused on the development of the baseline 'infrastructure', science collation, resource development and education and the following 2 year project focused on driving database growth and resource awareness and dissemination.

Recommendations

Overall, this project successfully achieved the stated aim of increasing HP knowledge about the nutrition benefits of melons and thereby increasing the frequency with which HPs recommend melons to their clients or followers. This was evidenced at project end by an increase in HP correctly identifying key melon nutrition benefits who accessed resources versus those that had not. Similarly there was 1.5 times greater likelihood of those accessing resources and who saw clients to recommend melons (85%) versus those who had not accessed (55%). It is well regarded that HPs are a key influence on the nutrition and health landscape and consumer food choices and consumption, which is increasingly a confusing and information-overloaded ecosystem. This project validates that efforts to drive awareness of melon benefits with HP is a valuable strategy to unlocking and driving industry growth.

While this project has started to make an important and successful first step into educating and influencing this important stakeholder influencer group, it is recommended that further investment be continued. Success in any behaviour change lies in consistent and long-term focused investment. Further investment will maximise the return on the current investment and help secure melons as an active specific recommendation.

It is recommended that any future investment should have both short-, medium- and long-term strategies. While in the short to medium term, maintaining top-of-mind awareness with the established highly engaged HCP database is paramount, there is opportunity to drive further penetration of the communication messages to reach more HCPs. Medium to longer-term strategies include investment in research to further build the science for melons and new news to keep melons top of mind with HP.

The following recommendations are made:

Short term:

- Continue to **maintain and build on the currently highly engaged HP database** by **c**reating & implementing an ongoing integrated website-digital HP engagement strategy. Recommend that this needs to be evidenced based and contain engaging and relevant content. At a minimum, communicate quarterly e-news on latest science summaries.
- Extend HP key messaging through to consumer communications to amplify and strengthen uptake of messages and cut through.

Communication considerations:

- **Recommend to continue with 'Goodness in every colour' message** across HP and look to extend this to consumer communication to build a powerful position for melons. The simplicity of the message "Goodness in Every Color" paired with the melon rainbow icon conveys a clear and memorable idea. It succinctly communicates the idea that each colour of melon offers unique health-promoting benefits, leveraging the concept of "eating the rainbow" for optimal nutrition. In a crowded marketplace inundated with health messages, the "Melons - Goodness in Every Color" concept stands out as distinctive and memorable. It offers a fresh perspective on melons, positioning them not just as fruits but as colorful sources of vital nutrients and bioactive compounds that contribute to overall wellness. By associating melons with the imagery of a rainbow, the concept taps into emotional responses related to joy, health, and well-being that aside from the rationale nutritional benefits also fosters positive perception of melons as not only delicious fruits but also essential components of a healthy diet.

Medium-term:

- **Build further HP awareness and database** through further strategic planning leveraging FOODiQ iQ³ strategy process. This could include digital lead generation strategies and bespoke face-to-face melon events dependent on budget funding.
    - Develop HP endorsed therapeutic recipe book development & leverage in digital comms
    - Undertake FOODiQ 'Bring science to kitchen™' - melons roadshow in key states.

Medium/longer term:

- Recommend undertaking **strategic planning to help identify and prioritise innovative research opportunities** that could be leveraged. Research is paramount to future-proof future communications. It provides the necessary underpinnings to support unique and credible messaging and positionings that allow melons to stand apart from other produce and maximise future long-term demand and industry growth. There are countless examples of food products (e.g. blueberries, mushrooms, extra virgin olive oil, nuts) where industry have invested in research over many years and reaped positive long-term impacts. There are 3 key broad territories that could be explored and offer different yet complementary lens for research.

- **Practical Usage of melons**
  - Research on the occasions and style of consumption to inform future education and marketing around the diverse culinary uses of melons.
  - Research on home uses of melon rind and seed investigating facilitators and barriers to use of all parts of the melons, contribution to nutrition/bioactives if used. It could take a culinary nutrition perspective.
- **The contribution of melons to nutrients, bioactives & diet quality**
  - Secondary analysis of national data, when updated National Nutrition Survey data is available to perform secondary analysis on melons looking at
    - Contribution of melons to key bioactive intake
    - Australian melon consumption and impact on nutrient intake and health biomarkers where relevant - do people who eat melons eat better, what nutrients are melons key in providing?
    - Analysis of melons bioactive content compared to other foods and impact of seasonality
  - Secondary analyses/reviews of available food composition data on bioactive contents of melons compared to other foods that contribute the same bioactives – this could create a hero story for melons. This could also be approached with target bioactives or colours in mind e.g. chlorophyll. E.g. Review of food source of X and impact on Y health outcome x.
- **Melons & Health knowledge**
  - Publish a scoping review on the research on the relationships between melons and health. This would be an opportunity to highlight the data that do exist and to highlight the gaps in direct evidence with a call to action for the needs in the future. A review of the key nutrients in melons and their associated health benefits could be included to demonstrate the potential benefits and likely mechanisms (e.g. because 'X' melon is high in 'Y' nutrients/bioactives) it is likely to benefit 'Z' health outcome), and a reference to the bioactives eat the rainbow work.
  - Melon interventions in different demographic groups to extend on or complement previous findings in the Eat the Rainbow Umbrella review and other research e.g.
    - Watermelon intervention - measuring cardiovascular outcomes and nitric oxide levels.
    - Mixed melons intervention - measuring cognition, satiety etc.
    - Rockmelon/watermelon intervention – measuring blood sugar markers
    - Honeydew intervention - measuring inflammation

Refereed scientific publications

Blumfield, M., Mayr, H., De Vlieger, N., Abbott, K., Starck, C., Fayet-Moore, F., Marshall, S. 2022. Should We ‘Eat a Rainbow’? An Umbrella Review of the Health Effects of Colorful Bioactive Pigments in Fruits and Vegetables. Molecules 27 (13), 4061; https://doi.org/10.3390/molecules27134061

References

Nil

Intellectual property

No project IP or commercialisation to report

Appendices

Appendix 1 – Audience Sentiment Research (Baseline)

Appendix 2 – Audience Sentiment Research (Project end)

Appendix 3 – Umbrella review publication

Appendix 4 – Technical report

Appendix 5 – Gaps Analysis

Appendix 6 – Website copy

Appendix 7 – Factsheets

Appendix 8 – FOODiQ Global Webinar Evaluation

Appendix 9 – Digital Activation Campaign Evaluation

Appendix 10 – EDMs

Appendix 11 – HCP Database (Confidential) – sent separately

Appendix 12 – PRG Meetings

Appendix 13 – Melon Journal News

Appendix 14 – NiQ Science Summary Updates

APPENDIX 1

Melons Market Research:
Baseline Report

Prepared for Hort Innovation

January 2022

Background

Project code: VM20003

Project name: Educating health professionals on Australian melons

Project leader: Dr Flavia Fayet-Moore

Delivery partner: Nutrition Research Australia Pty Ltd (NRAUS)

Report author: NRAUS

Contact: Flavia Fayet-Moore

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Contents

Objectives & Outcomes

Objectives

1. Gain market insights to help tailor key message development and adjust the communication plan.

2. Obtain baseline data to be used for project evaluation.

This report describes the findings from the baseline market research survey among health-care professionals (HCPs).

It is the first of two market research reports, with the second due to be conducted at the conclusion of the 3-year project, in 2024.

Outcomes

The 3-year project has the following outcomes:

Improve awareness of the **unique colour-associated nutritional and bioactive properties** of Australian melons.

Improve awareness of the **health benefits** of Australian melons.

Increase practising health care professional's **focus**, **confidence** and **proficiency** in using melons to improve the fruit variety of their client's diet in order to achieve optimal health and wellbeing across all life stages.

Methods

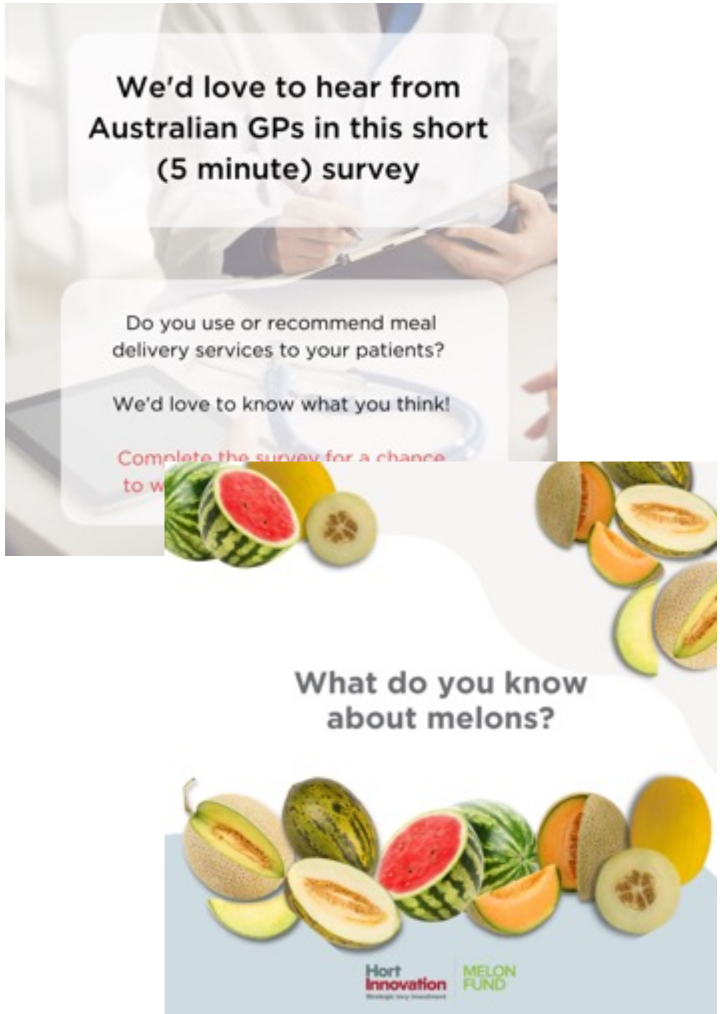
Approach

A social media campaign was run to recruit a minimum of 200 health care professionals:

- over 4 weeks (Oct 1st to Oct 29th, 2020).
- across Facebook, Instagram and LinkedIn.
- promoted with the chance to win 1 of 5 $100 major supermarket vouchers.
- complemented with organic strategies (e.g., sharing via NRAUS employee social media accounts to professional networks).

To be eligible, participants had to reside in Australia, and either be a health-care professional or studying to become one.

Seven separate social media tiles were designed, which allowed us to test and refine the recruitment strategy.



Spend & assets

Platform	Spend	Impressions	Clicks	Cost per click
LinkedIn	$299.63	14,454	79	$3.79
Facebook	$190.99	16,747	118	$1.62
Instagram	$20.84	2,886	17	$1.23
Total	**$511.46**	**34,087**	**214**	**$2.39**

A further 409 clicks were achieved through organic, non-paid strategies.

Results

Audience demographics

Survey stats

Participant flow:

623 Total views	420 Starts	358 Submissions	339 Eligible
54% of all viewers completed the survey	80.7% of all starters completed the survey	19 excluded as were not HCPs living in Australia	Exceeded target of 200

Average time to complete:

4:52 mins

Audience Segmentation

Age: 74% were 25-44

- 43% 25-34yrs
- 31% 35-44yrs
- 11% 45-54yrs
- 8% 24yrs or younger
- 7% 55+yrs

Sex: 61% female

- 61% Female
- 35% Male
- 3% Other

State: QLD most popular

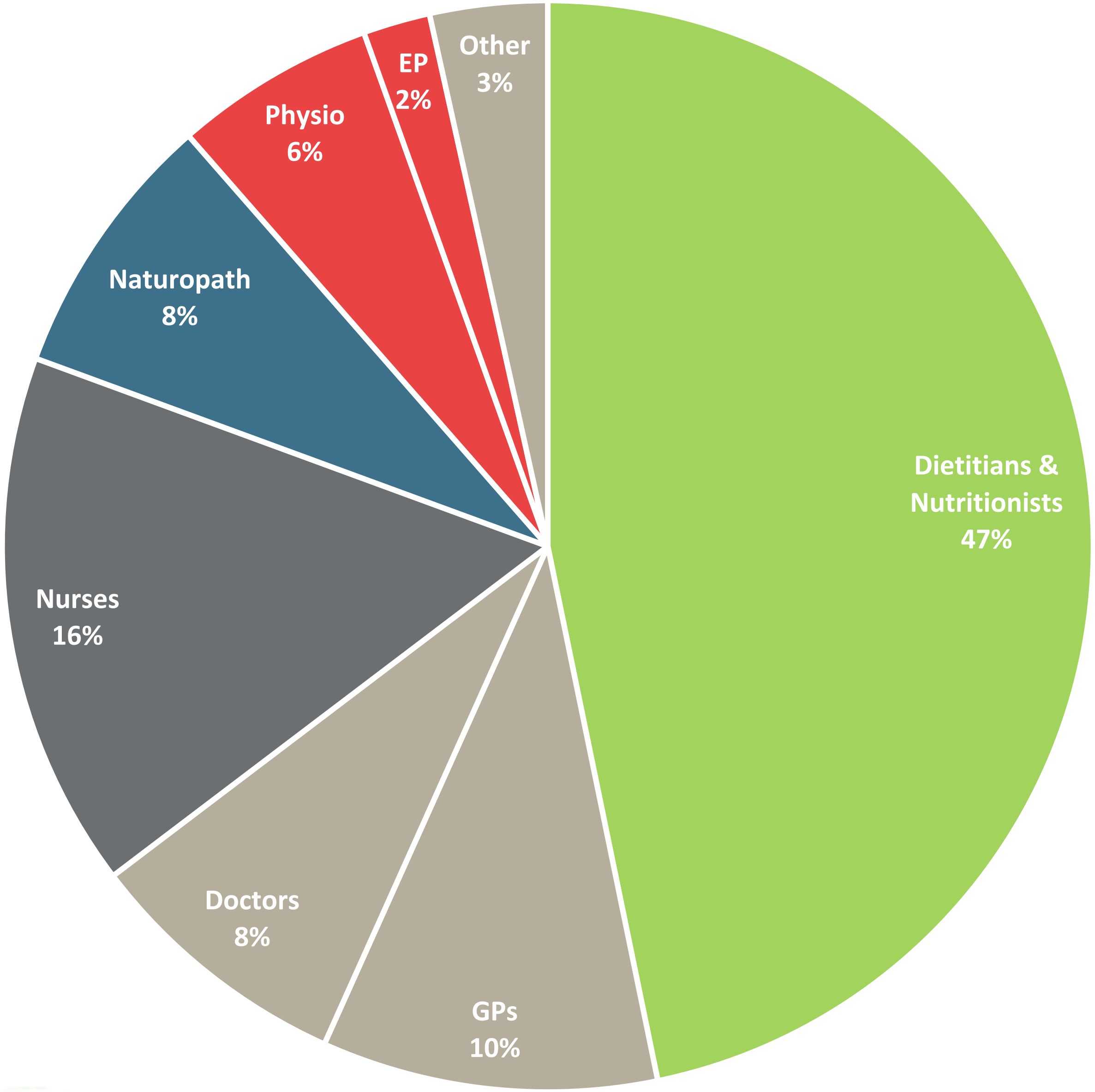
- 29% QLD
- 20% NSW
- 17% VIC
- 15% WA
- 8% SA
- 9% ACT, NT, TAS

Students: 2 in 5

- 59% HCPs
- 41% studying

n = 339

Almost half were dietitians or nutritionists, with many (55%) in clinical or private practice



Setting of current practice:

- 31% in clinical
- 24% in private practice
- 18% in public health
- 14% in education/tertiary
- 11% in research
- 3.5% management or other

n = 339

Results

Colour-associated fruit variety

High agreement (81%) that colour-associated fruit variety is important for health and wellbeing

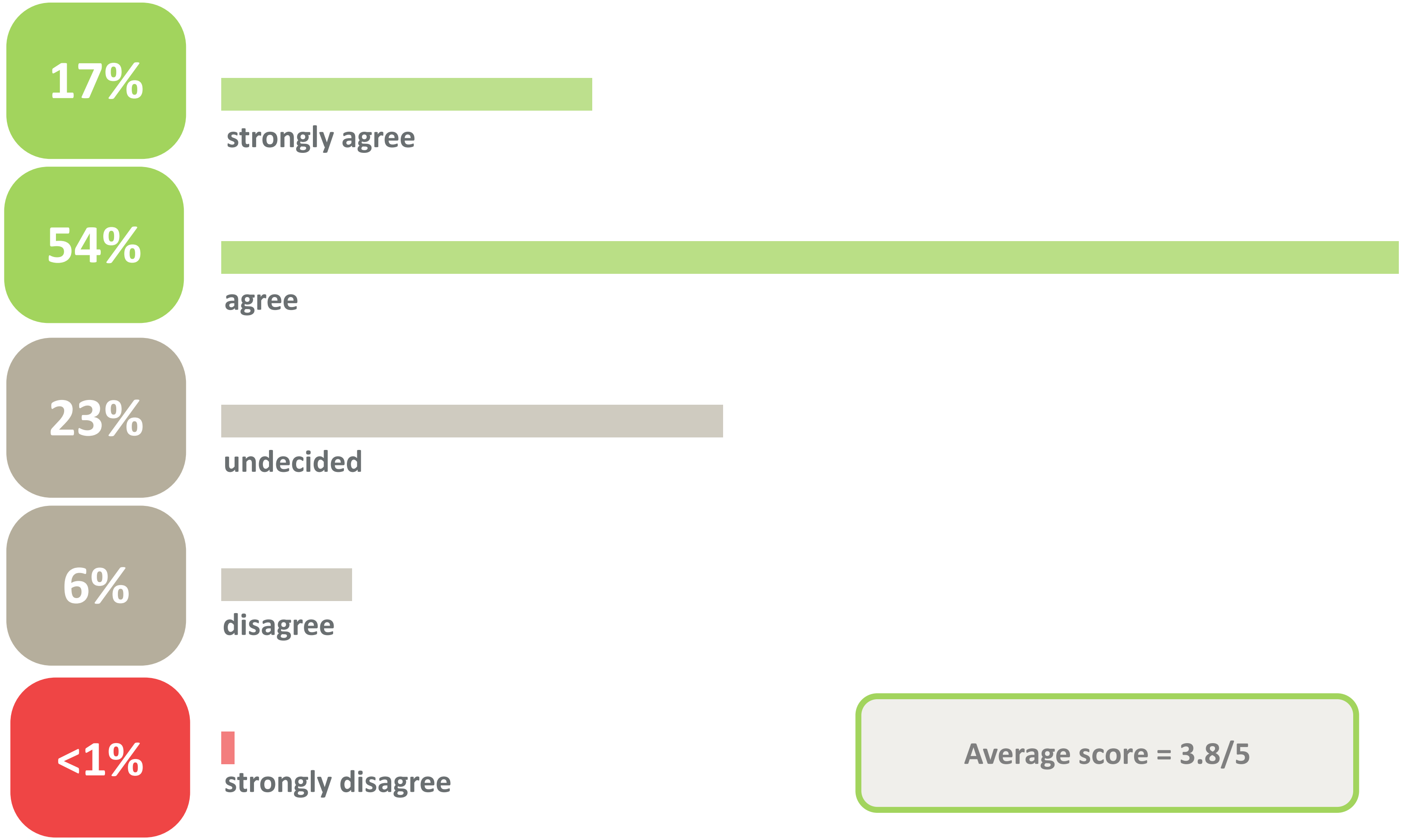
Q. How strongly do you agree: “choosing fruit in a variety of colours is important for overall health and wellbeing”.

Average score = 4.1/5

n = 339

Nearly 3 in 4 HCPs agreed that Australian's fruit intake lacks colour variety

Q. How strongly do you agree with the following: “fruit intake in the current Australian diet is lacking colour variety (i.e.. inclusion of different coloured fruit)?”

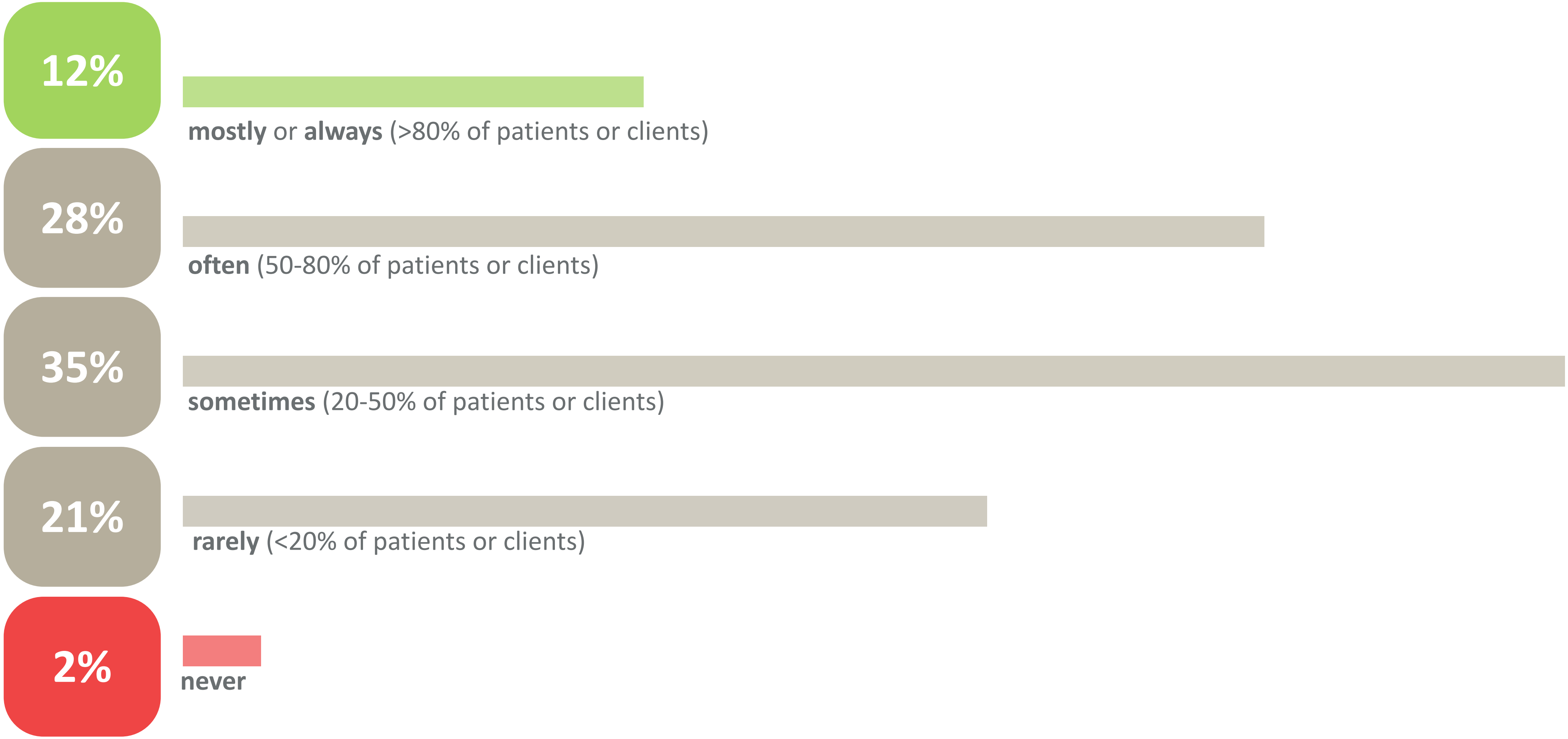


Average score = 3.8/5

n = 339

The majority (58%) of HCPs assess fruit variety for half their patients/clients or less, with only 12% assessing it mostly or always

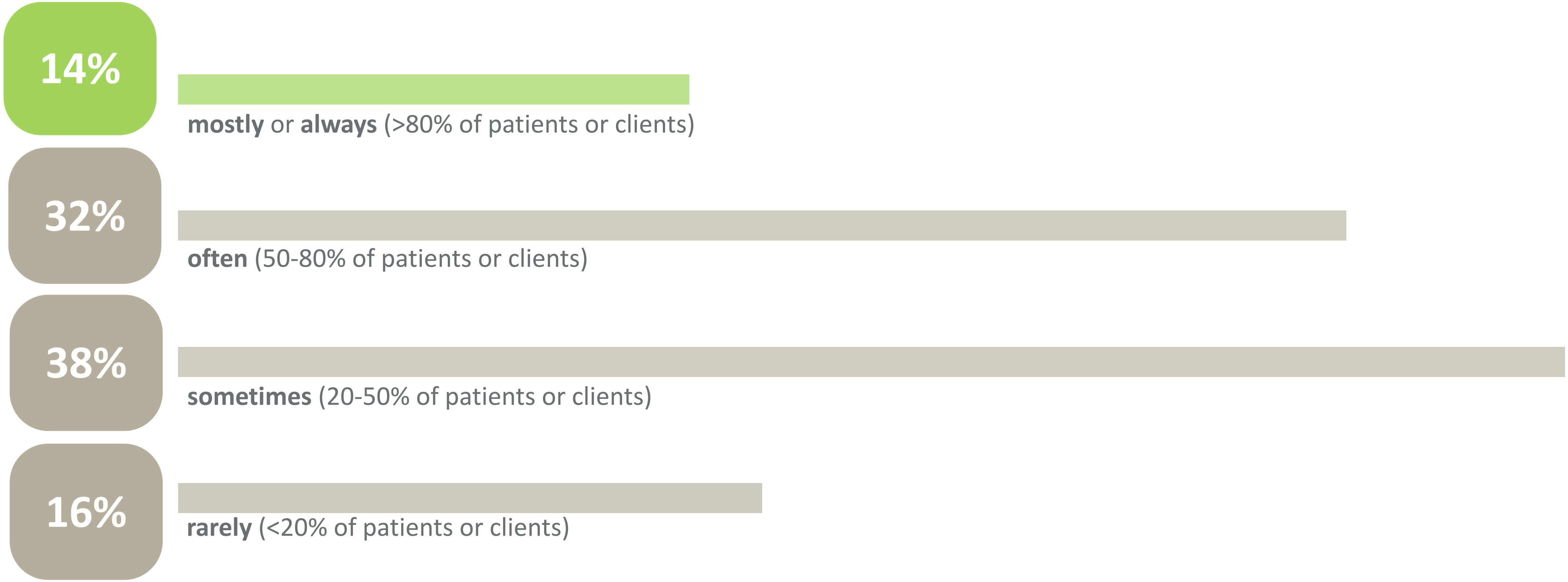
Q. When assessing a patient or client's dietary intake, how often do you specifically assess or consider fruit variety?



n = 339

Less than half (46%) of HCPs are recommending improved fruit variety for 50% or more of their patients/clients

Q. How often do you specifically recommend to your clients or patients to improve their fruit variety?



Surprisingly, dietitians were more likely to 'rarely' assess (30%) fruit variety, compared to other groups

n = 324

There were a range of reasons for recommending increased fruit variety, with no clear standout

Q. When you recommend improved fruit variety to your clients and patients, what is the reason for doing so?

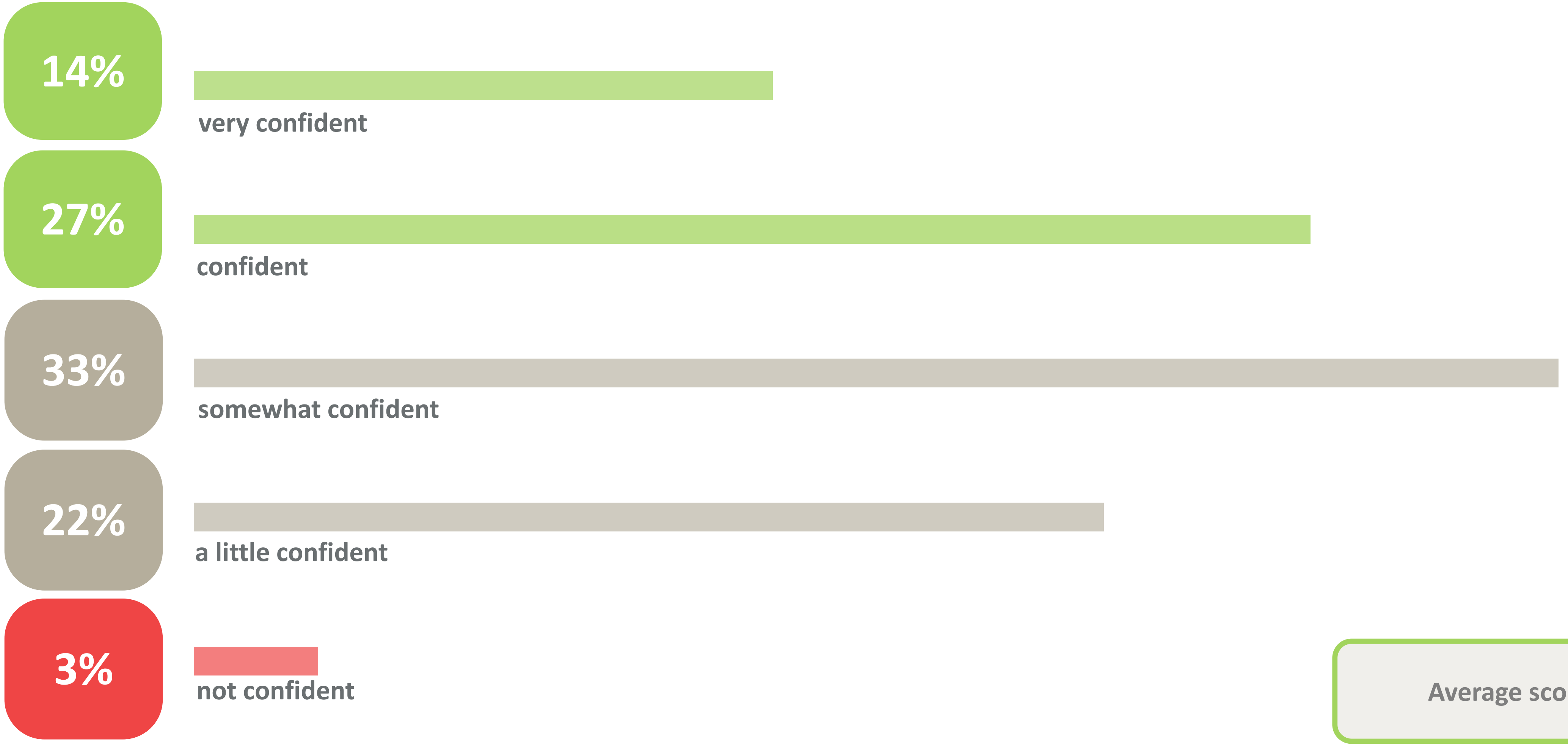
- **54%** to provide a greater variety of **vitamins and minerals**
- **52%** to improve **diet quality** generally
- **42%** to improve a specific **health condition**
- **41%** to provide a greater variety of **bioactives** (e.g. antioxidants)
- **33%** to improve **health** or **wellbeing** generally
- **18%** to help increase the **quantity of fruit** consumption

The top reasons for recommending increased fruit variety were to achieve greater nutrients and dietary quality, rather than for general health benefit or meeting a specific quantity of daily fruit.

n = 324

1 in 2 HCPs were uncertain in their ability to improve patient or client fruit variety in the diet, with few (14%) very confident

Q. How confident are you in your ability to improve the colour-associated fruit variety of your clients or patients?

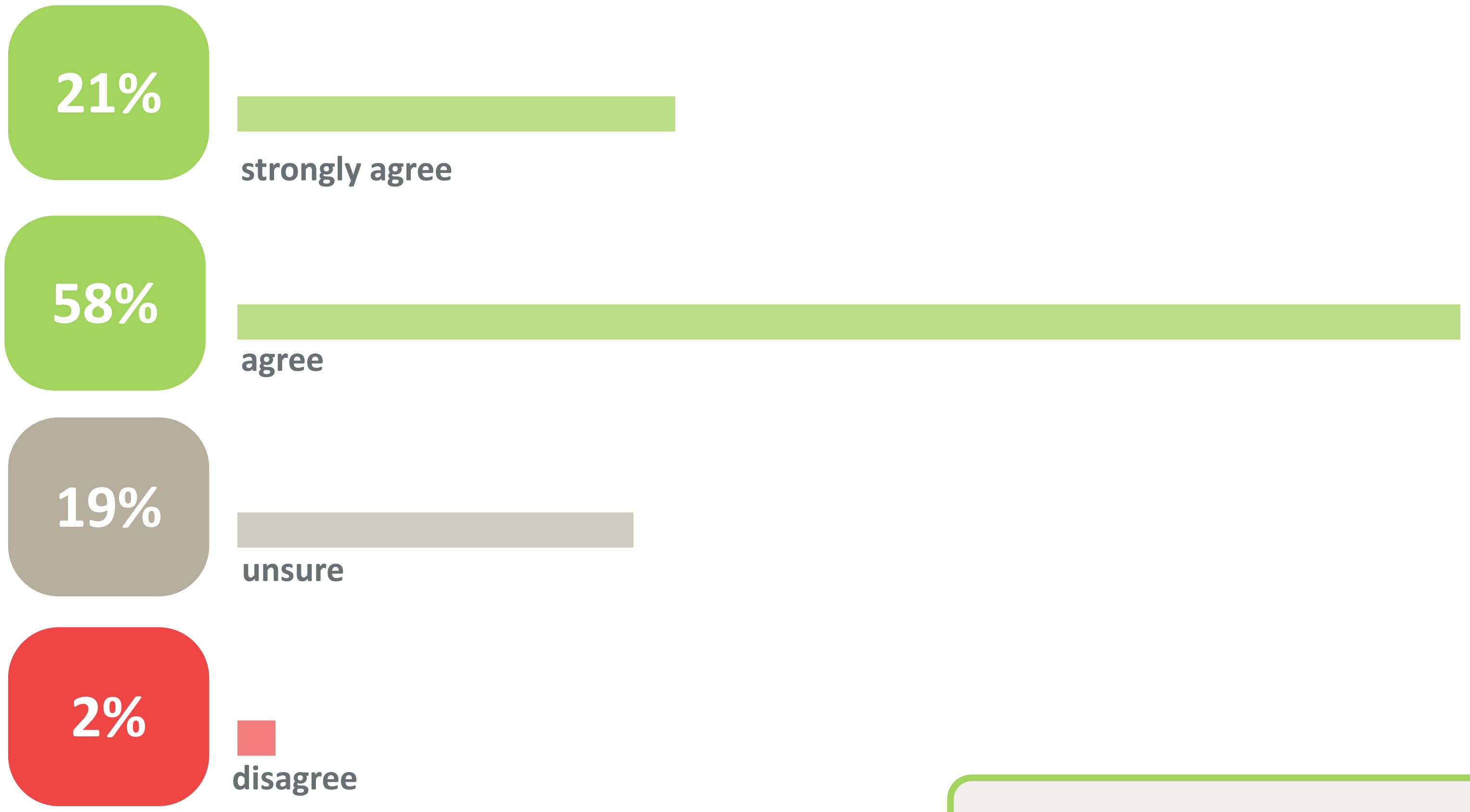


Average score = 3.2/5

n = 339

79% of HPCs believed that melons play a key role in improving fruit variety in the diet

Q. How strongly do you agree: “melons can play a key role in improving colour-associated fruit variety in the diet”.



Average score = 4.0/5

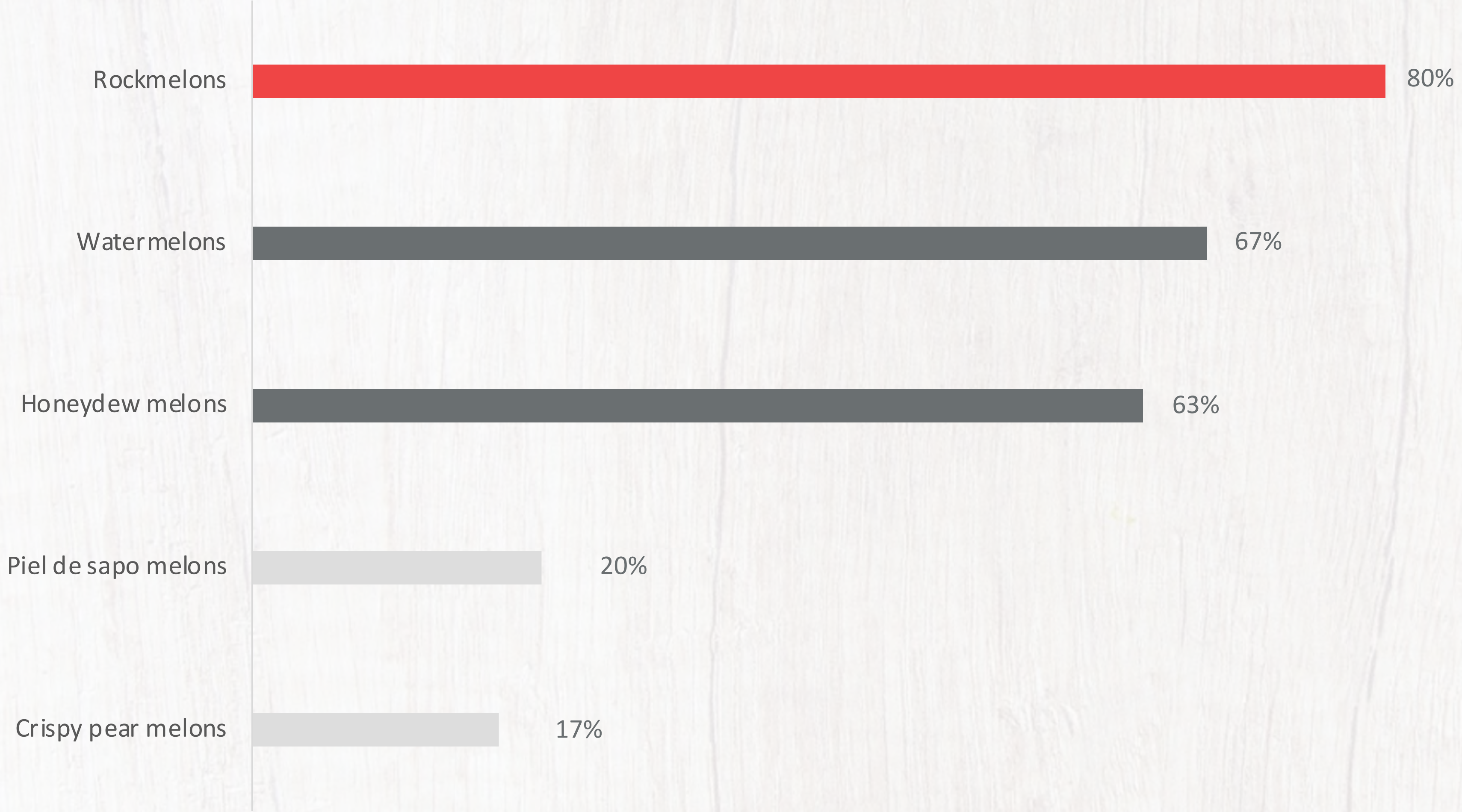
n = 339

Results

Melon nutritional and health properties

Majority of HCPs are familiar with rockmelons, watermelon and honeydew, but only 1 in 5 were familiar with Piel de sapo or Crispy pear melons

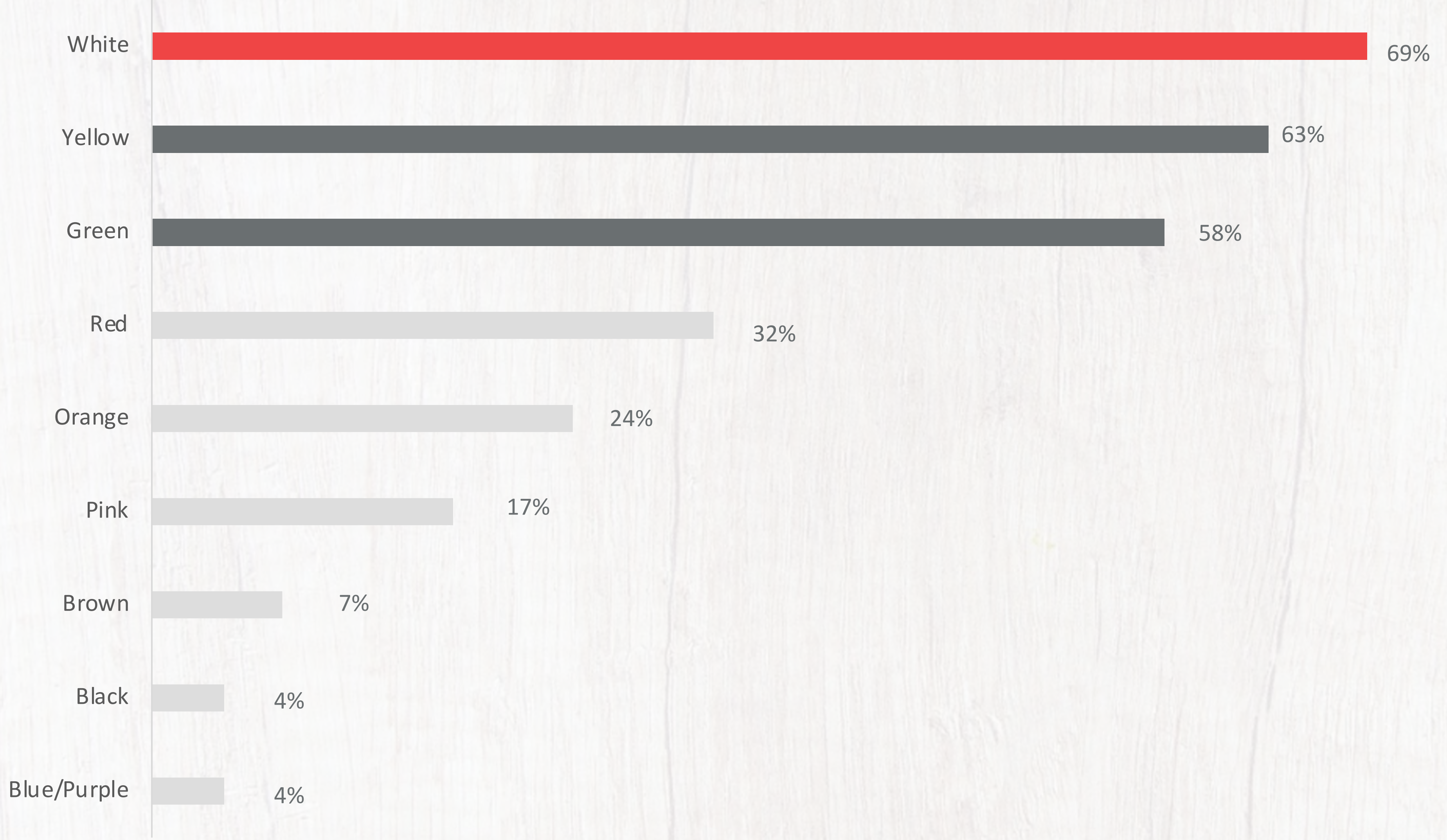
Q. Which of the following melons are you familiar with?



n = 339

Surprisingly, most HCPs were familiar with white, yellow and green coloured melons, but not red or orange melons, despite rockmelons, watermelons and honeydew being amongst the most familiar melon types

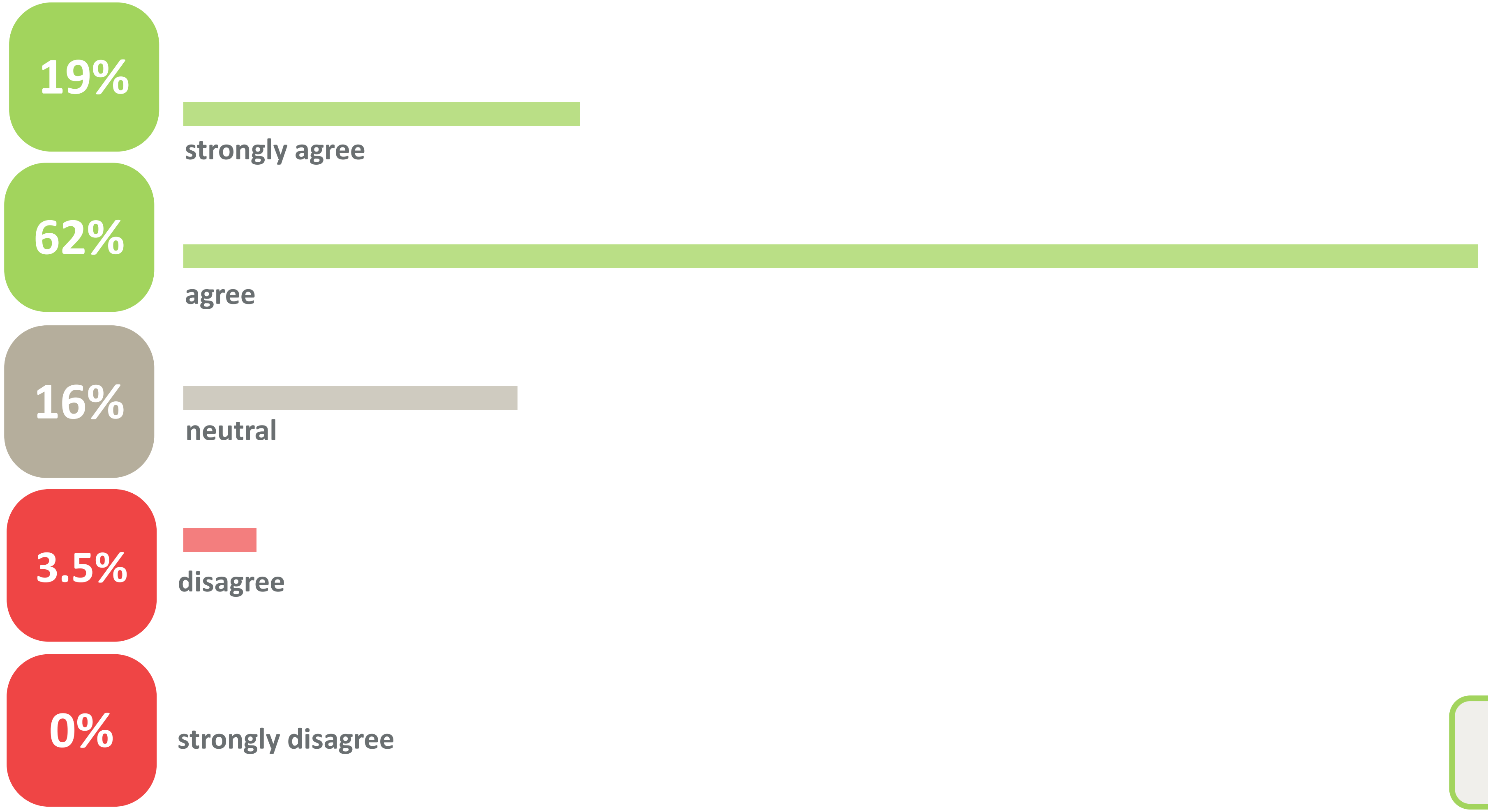
Q. What colours are Australian melons available in?



n = 339

4 in 5 HPCs agreed that melons provide nutrients and bioactives for optimal health

Q. How strongly do you agree: “melons can provide a range of colour-associated nutrients and bioactives required to achieve optimal health”.



Average score = 4.0/5

n = 339

While 2 in 3 agreed melons contain nutritional properties, 1 in 4 didn't know what these were

Q. How familiar are you with the different nutritional properties (nutrient content and bioactive properties) of melons?

3% had **academic knowledge** of their nutritional properties

25% were **familiar** and **can specify** their nutritional properties

61% were **familiar** with some of the nutritional properties but **cannot specify them**

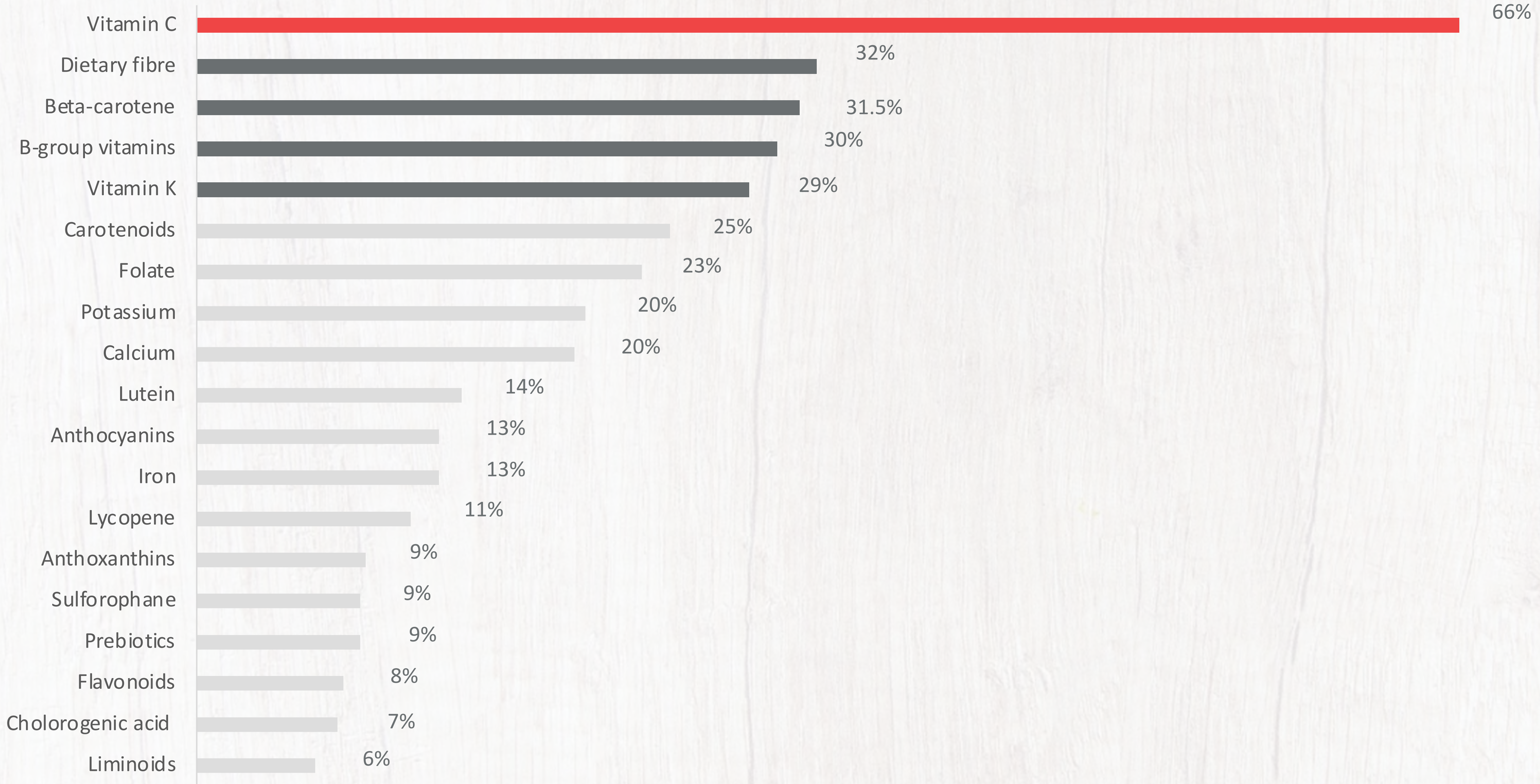
11% were **not at all** familiar

Average score = 2.2/5

n = 339

Overall, HCPs struggle to identify key nutritional components beyond vitamin C, with little knowledge of their bioactive composition

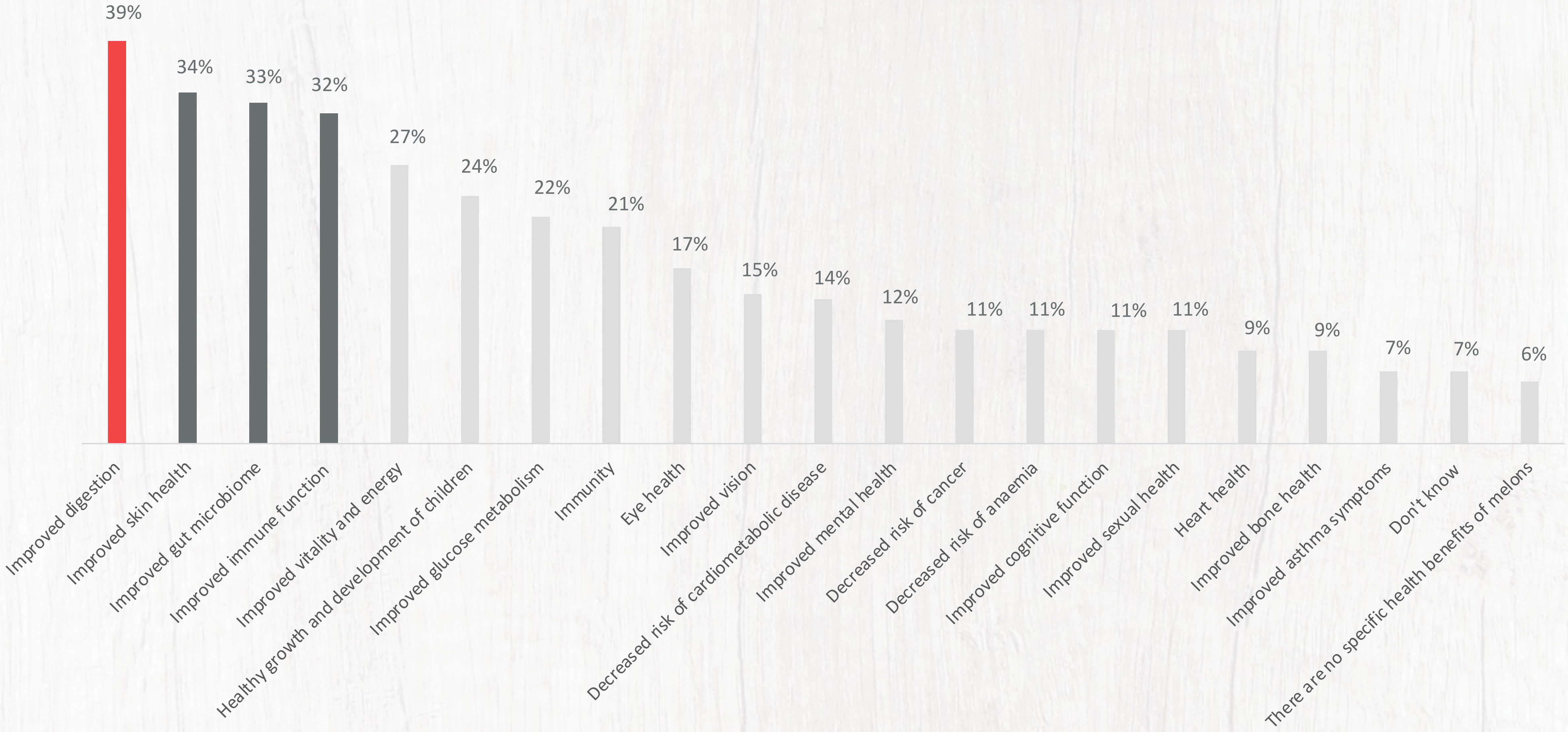
Q. In your opinion what are the key nutritional and bioactive properties of melons?



n = 339

The health benefits for melons were not well understood, with improved digestion the most identified health benefit

Q. In your opinion what are the key health properties of melons?



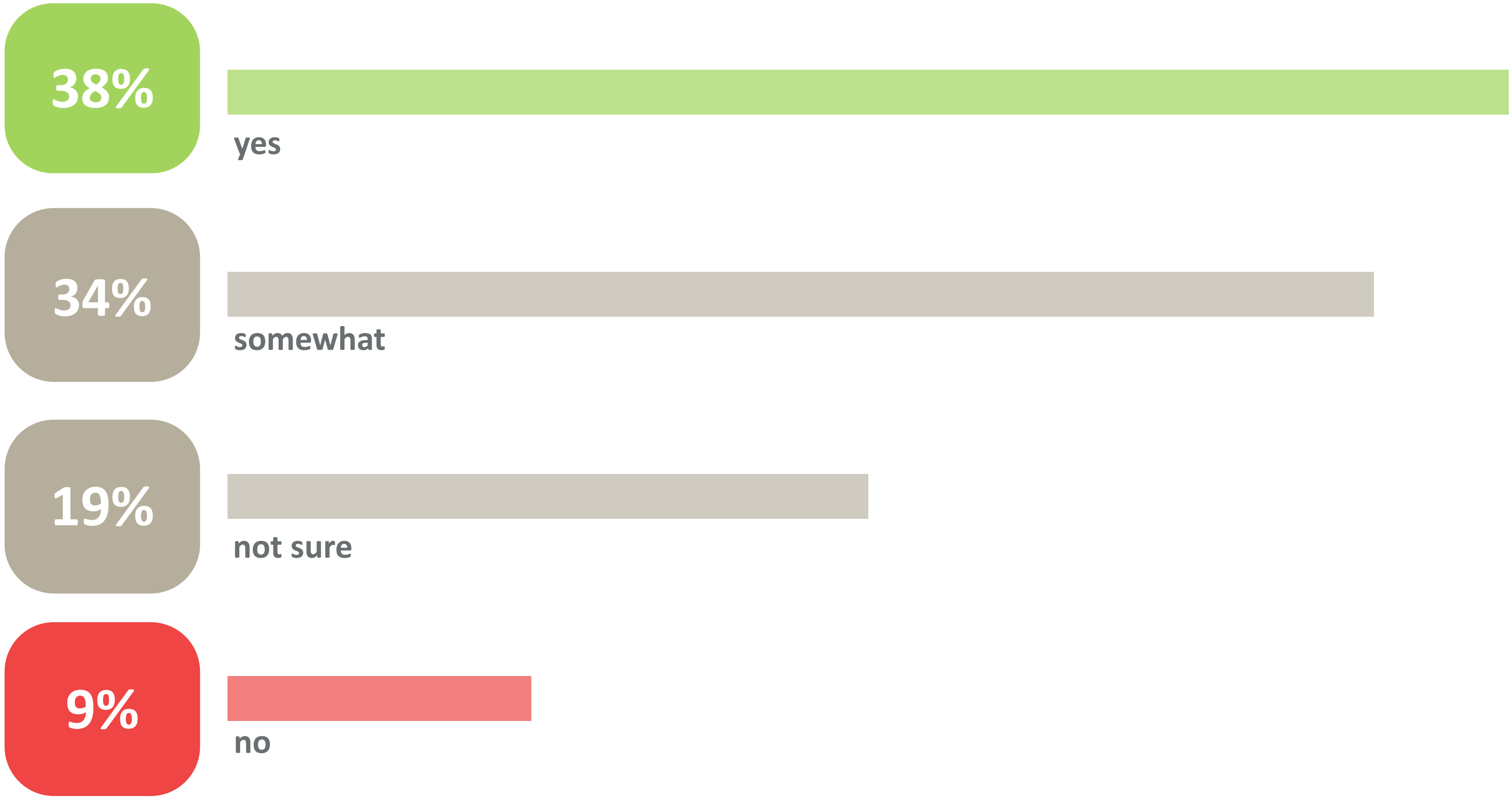
n = 339

Results

Other considerations

2 in 5 were aware of food-borne illness risks with melons, but over half were uncertain and nearly 1 in 10 unaware

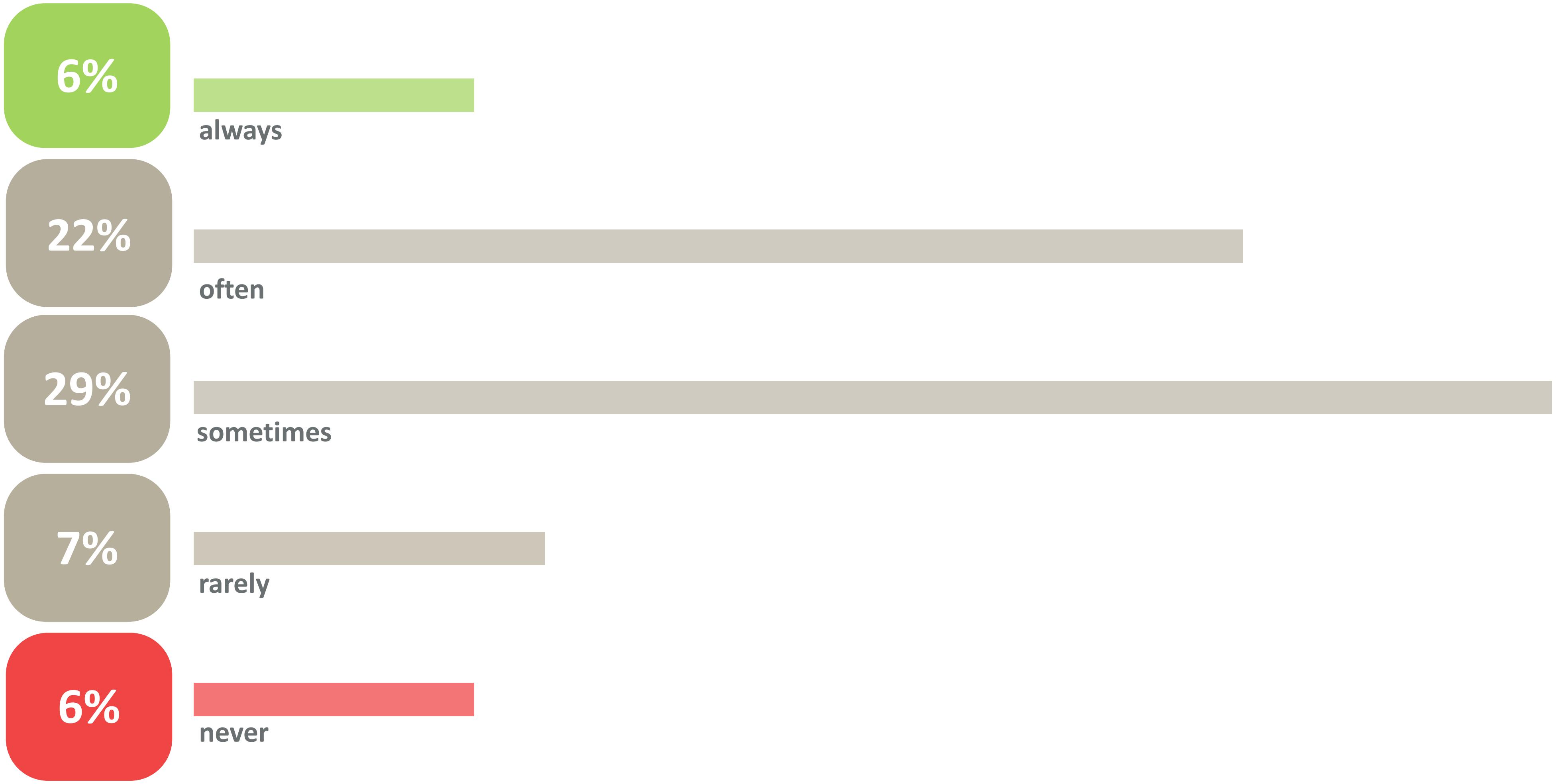
Q. Are you aware of the food borne-illness risks associated with melons?



n = 339

The food-borne illness risks of melons affects 1 in 4 HCPs willingness to recommend melons to certain population groups often or always

Q. Does the risk of food borne-illness in melons currently affect your willingness to recommend certain population groups, eg. elderly, pregnant women, or people undergoing chemotherapy?



n = 237

HCPs were most interested in learning more about fruit variety and melons from a range of educational resources, with technical scientific brochures the most popular

Q. If you were to receive new information about fruit variety and the role of melons, which type of educational resources would you find most useful?

55%
technical scientific brochures

43%
simple, infographic style brochures

48%
short videos

34%
podcast

47%
webinars

27%
animations

97% of HCPs indicated that they would be interested in receiving information about melons

n = 339

HCPs wanted to know more about what's in melons, their health benefits and therapeutic uses, and safety considerations

Q. What else would you like to know about melons?

General nutritional info

"tell us more about the **nutrition** of this fruit"

"**nutrition** of melons vs other fruits"

"recommended serving size"

Health benefits & therapeutic uses

"**specific** relevance to macula function would be good to know like carotene etc."

"can melon help soften blood vessels?"

Safety concerns and contraindications

"proper publicity of which groups should not eat melon and the negative effects it will bring"

"edible contraindications of melons"

"is melon suitable for **diabetics**?"

"whether **everyone** can eat it"

Learnings & Recommendations

Survey Q's and promotion

Learnings	Recommendations
• 339 eligible respondents, exceeding the target of 200. • Facebook had a lower cost/click vs. LinkedIn. • Average time to complete was 4:52 minutes and 86% of starters completed the survey.	• Repeat the same social media promotional strategy for the final survey. • Social media spend to be upweighted for Facebook vs. LinkedIn. • Keep the survey to a similar length.

HCP knowledge and understanding

Learnings	Recommendations
• HCPs agree that colour-associated fruit variety is important and lacking in the Australian diet, yet it is not always assessed or recommended with patients/clients. This was particularly evident with dietitians. • HCPs were uncertain in their ability to improve fruit variety of their patients/clients. • It was evident that they did not have a clear understanding of their nutritional and particularly bioactive composition, nor what health benefits melons have. • HCPs also lack familiarity with the diversity of melons available and are unable to clearly associate even the common melon types to their colours. • Positively there is already strong agreement that in general melons can play a key role in improving colour-associated fruit variety in the diet and this perceived value currently lies in driving general dietary quality and vitamin and mineral intake. • If we can increase their confidence and knowledge, we can likely shift them to more frequently assess and recommend increased coloured fruit variety, and use melons as the example.	• Focus on creating awareness and relevancy of the colour-associated fruit variety messaging by providing practical tips on how to assess and improve, to make it top-of mind to support HCPs to more regularly assess with their clients. • Provide HCPs with a clear and compelling reason why increasing colour-associated fruit variety is important. • Increase HCPs confidence in recommending melons to achieve greater colour-associated fruit variety via education of their nutritional and bioactive composition. Include all melons in the messaging and do not assume that HCPs are across the more familiar ones, e.g., water and rock melons. • Consider finding 1 or 2 key unique health benefits for melons to be linked with to drive even greater relevancy and top of mind awareness. • Educating dietitians is particularly important.

Other considerations

Learnings	Recommendations
• 97% of HCPs want information about melons and are open to a range of different resource types. • While technical scientific brochures was the most desired education resource, a variety of different resource types are required to meet the audiences needs. • HCPs lacked specific knowledge about the food-borne illness risks associated with melons, and the implications of these.	• Repeat key information to HCPs through a range of different educational resources. • Provide transparent information and guidelines on the risks of food borne illness with melons and any contraindications.

Limitations

Key Limitations

- 41% of respondents were students, who may have different attitudes and behaviours from working HCPs.
- The number of respondents from any singular health profession, with the exception of dietitian/nutritionist, was small (<60), limiting conclusions by type of HCP.

Conclusions

The key findings

- While HCPs are aware that colour-associated fruit variety is important and that melons play a key role in improving it, this message is not top-of-mind and is not currently being translated into dietary recommendations.
- There is also a lack of specific knowledge about the nutritional and health properties of melons, in particular their bioactive properties.

The key recommendations

- Develop a relevant nutrition story to HCPs that portrays the urgency needed to address colour-associated fruit variety in the Australian diet.
- Supplement this story with specific education and practical tips that increase understanding on melon diversity and improve the confidence and knowledge of HCPs to address this nutrition problem.

Next Steps

- NRAUS to update the comms plan and key messaging based on these findings, upon completion of the systematic literature review.
- NRAUS to update the monitoring and evaluation plan with specific targets, based on these findings.

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Thank you

APPENDIX 2

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VM20003: Educating healthcare professionals on Australian Melons

End of project ASR

June 2024

Background

- **Project code**: VM20003
- **Project name**: **Project leader**: Dr Flavia Fayet-Moore
- **Delivery partner**: FOODiQ Global (formerly Nutrition Research Australia)
- **Report author**: FOODiQ Global

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Objectives

1. Help measure the impact of the project on changes in knowledge and recommendations in those who accessed the project resources, compared to those who did not, with reference to baseline data, where appropriate
2. Gather insights on the current level of knowledge and recommendations to inform future research.

This report describes the findings from the 2nd market research survey among health professionals (HPs). It is the 2nd of two market research reports, following on from the baseline data report in January 2022.

Project outcomes

- **50% of Health professionals (HPs)** will be aware of resources
- **50% increase** in HPs reporting they are familiar and can specify the nutritional properties of melons
- **80% of HPs** recommend Australian melons to help improve colour variety in the diet.

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Methods

Approach

A digital recruitment campaign to recruit a minimum of 200 health professionals (HPs)

- 4 weeks (26th March – 4th May 2024)
- across paid Meta social media channels, complemented with organic strategies
- dedicated EDM to Melons and FOODiQ Global databases
- promoted with the chance to win 1 of 5 $100 Visa gift cards.

- To be eligible, participants had to reside in Australia, and either be a health professional or studying to become one.

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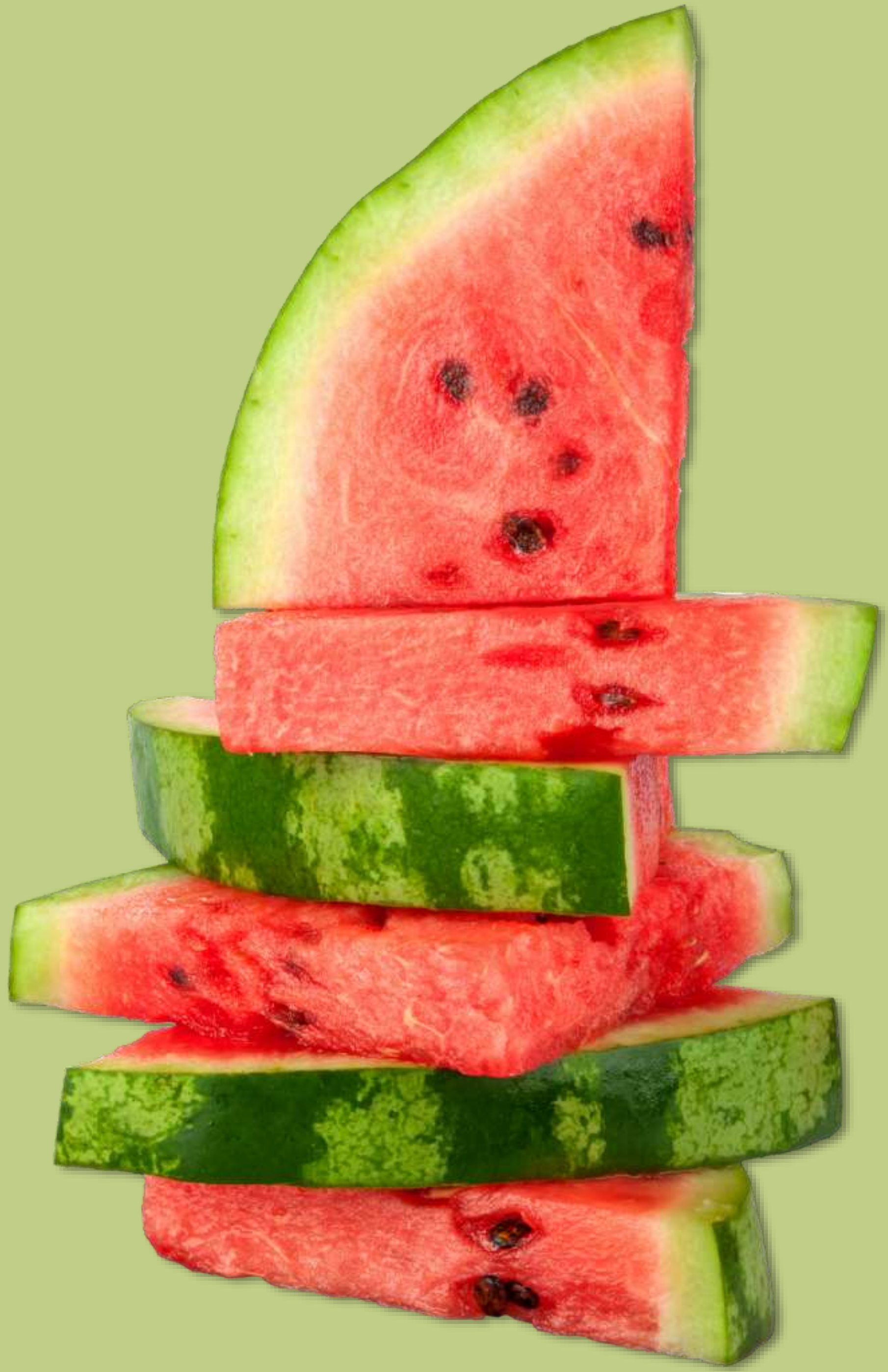
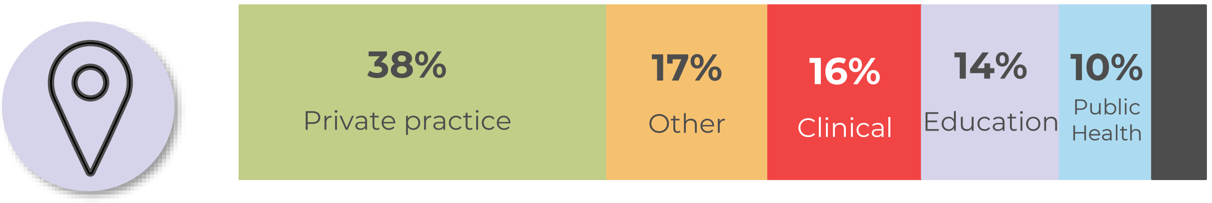
Results

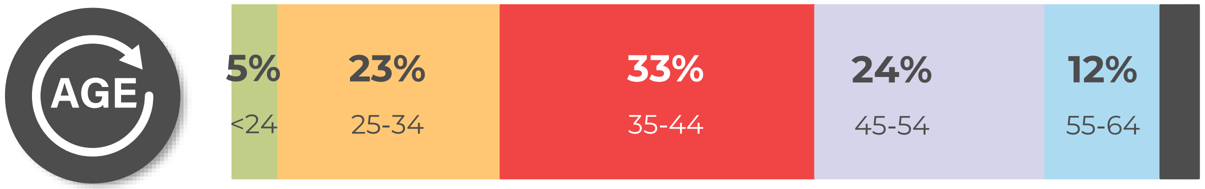


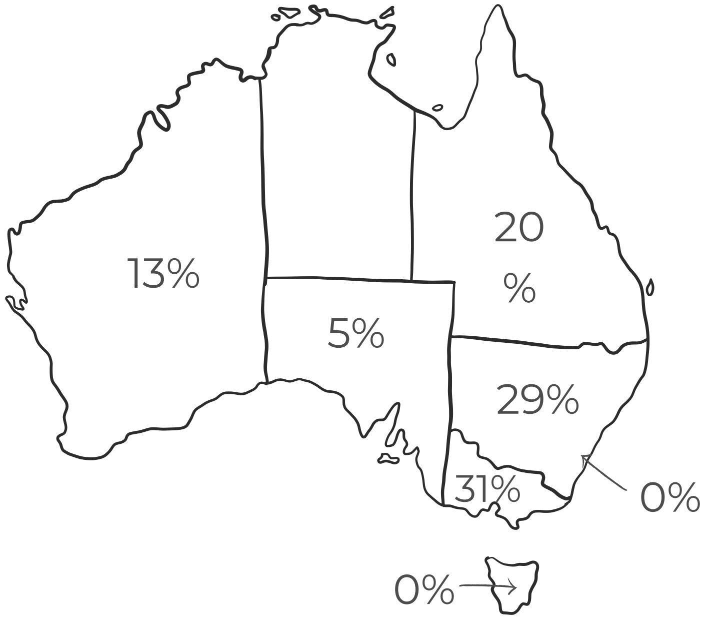
Survey statistics

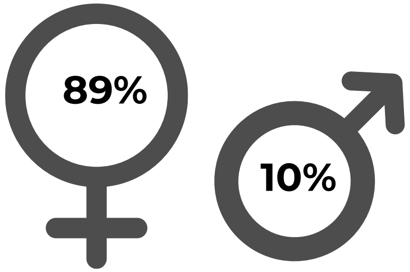
175 surveys completed → 127 eligible

81% HPs; 19% students









Resource Access & usefulness

27% of participants had accessed the Melons Hub resources. **Target: 50%**

100% of participants that accessed the FOODiQ Melons Hub resources found them useful. **Target: 80%**

- 44% very useful and I would like more
- 29% very useful
- 24% useful
- 3% somewhat useful

of those who accessed resources would like more.

What do health professionals think of resources?

It provided a great summary of the research on berries for both health professionals and the general public, and it was presented in an aesthetically pleasing way.

A brief but clear information to discover the properties and understand melons in nutrition

they provide detailed nutritional information, highlight health benefits, support dietary variety, offer practical tips for selection and preparation, and enhance client education on the benefits

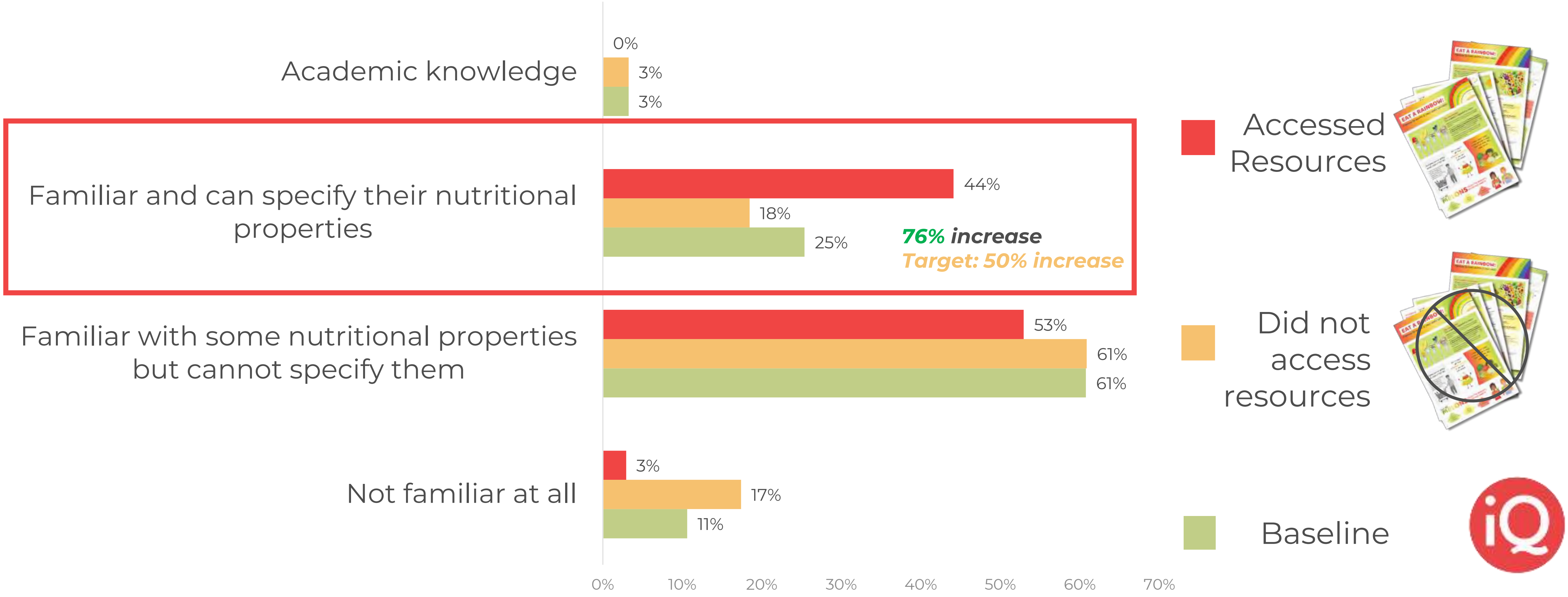
Simple, clear, visual, colourful, informative

They are practitioner-friendly and provide just the right level of info to allow us to convey the key points to the general public.

Evidence based info I can trust

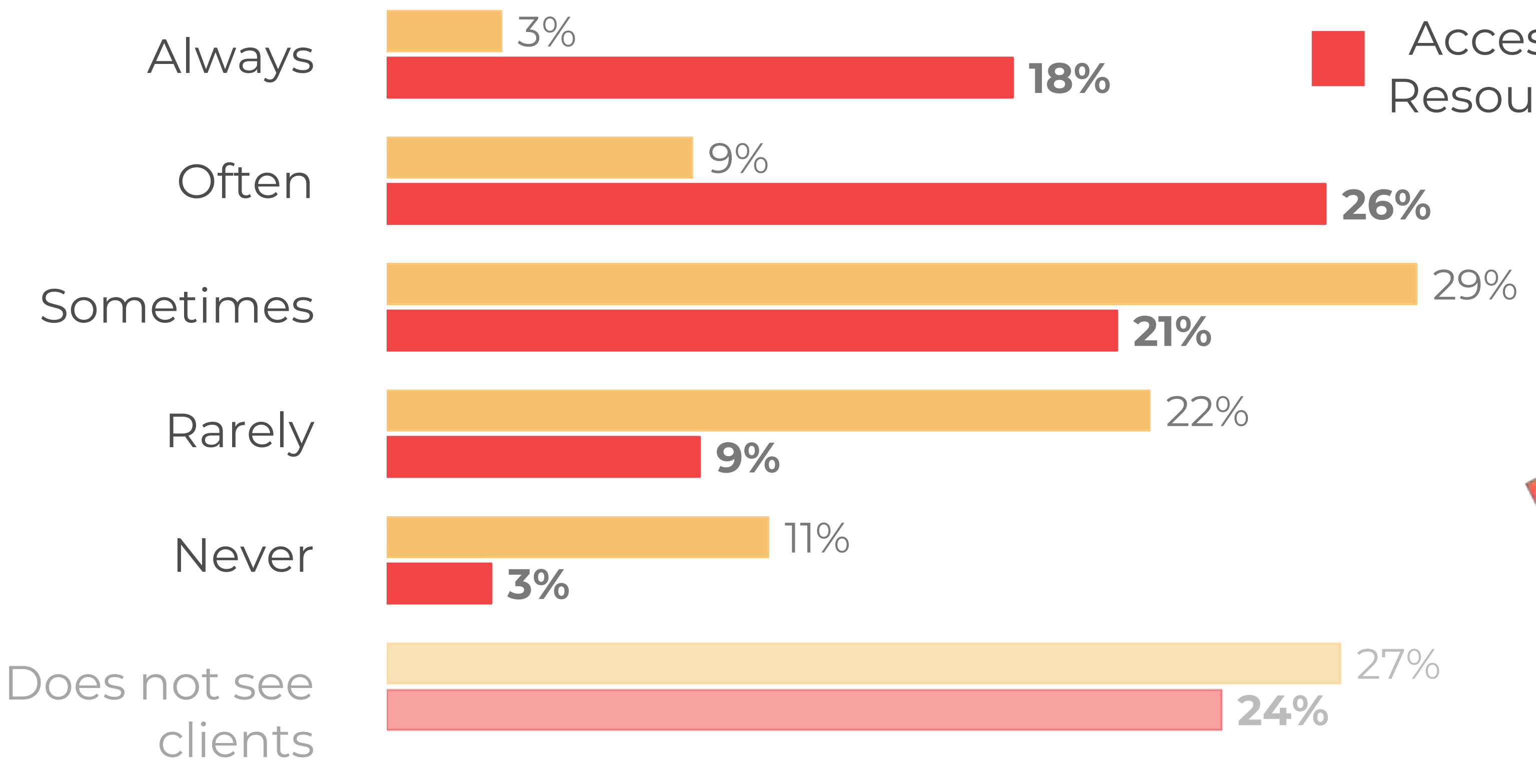
The broader message around eating the rainbow is very useful for connecting with people

Those who accessed resources increased their self-reported familiarity with the nutritional and bioactive properties of melons.



Recommendations to clients increased

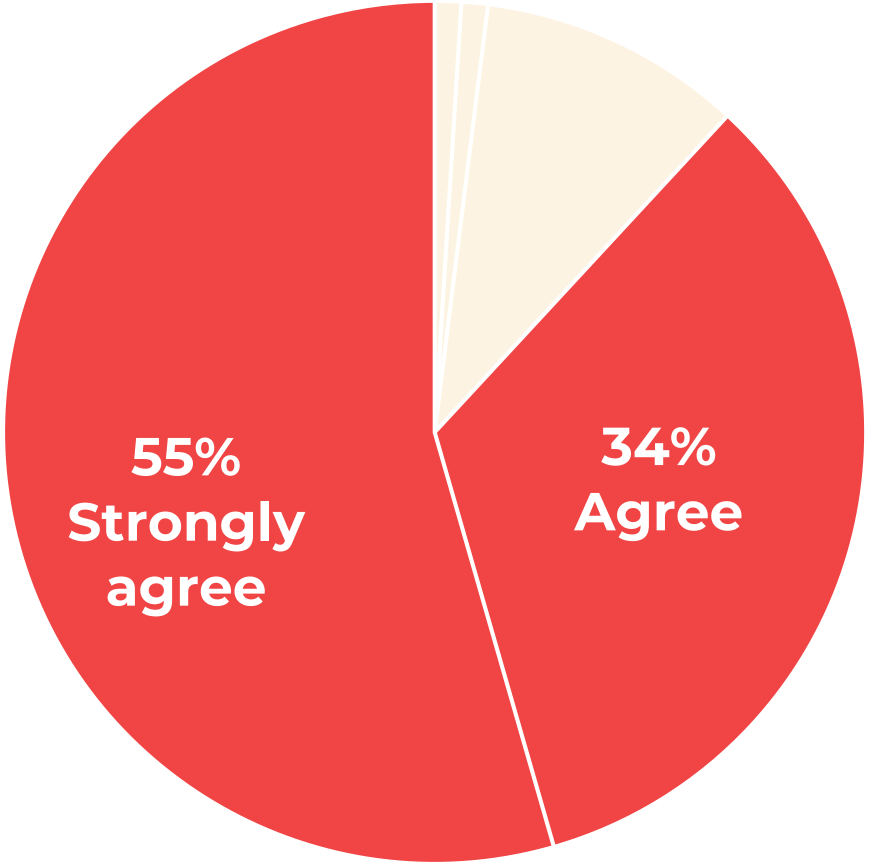
Which statement **best describes** how often you **specifically recommend melons** to your clients or patients?



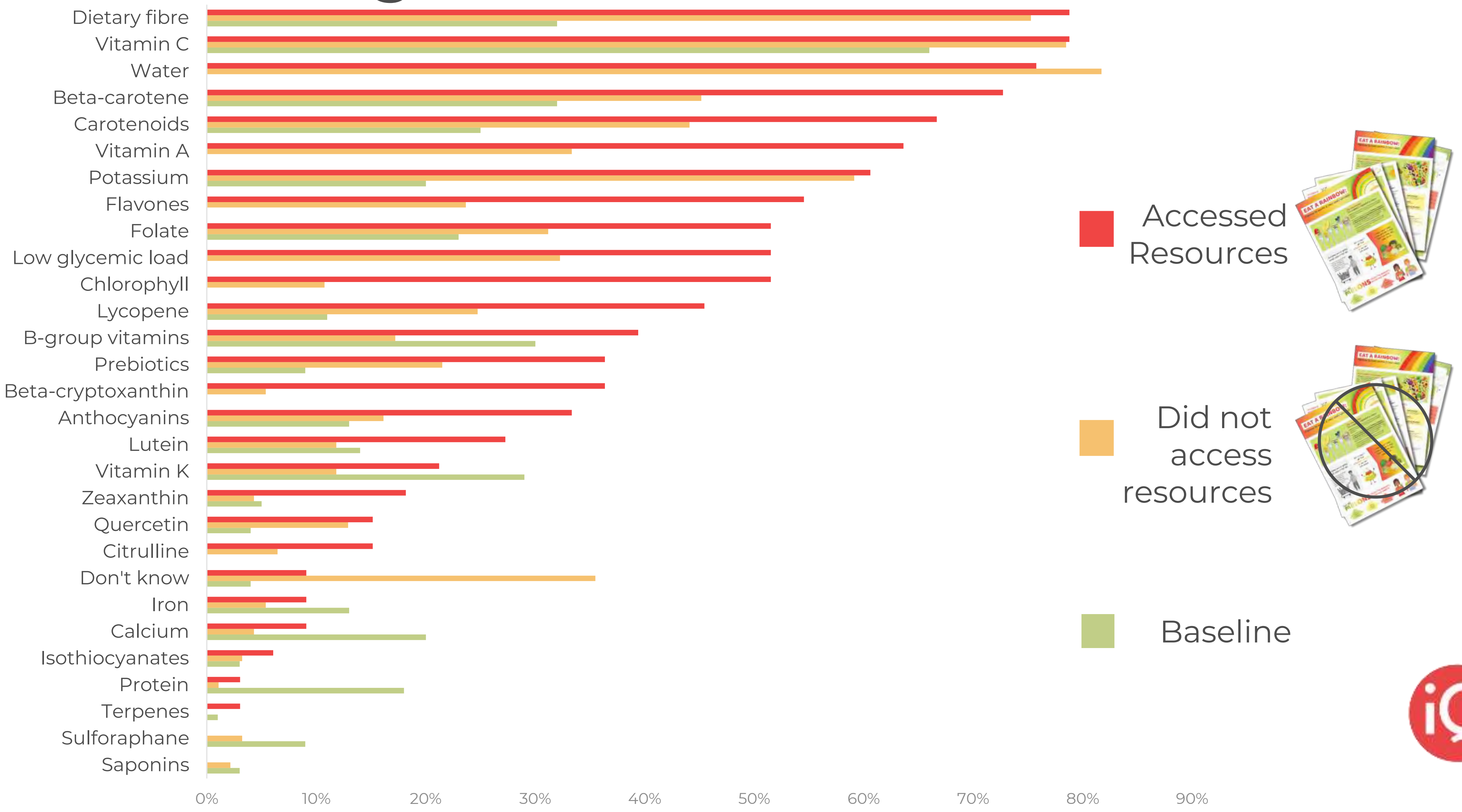
Of those who saw clients, 84% of those that accessed resources reported recommending melons to clients, compared to 55% of those who did not access resources

89% ‘strongly agree’ or ‘agree’ that melons can play a key role in improving colour variety in the diet’

Target: 80%

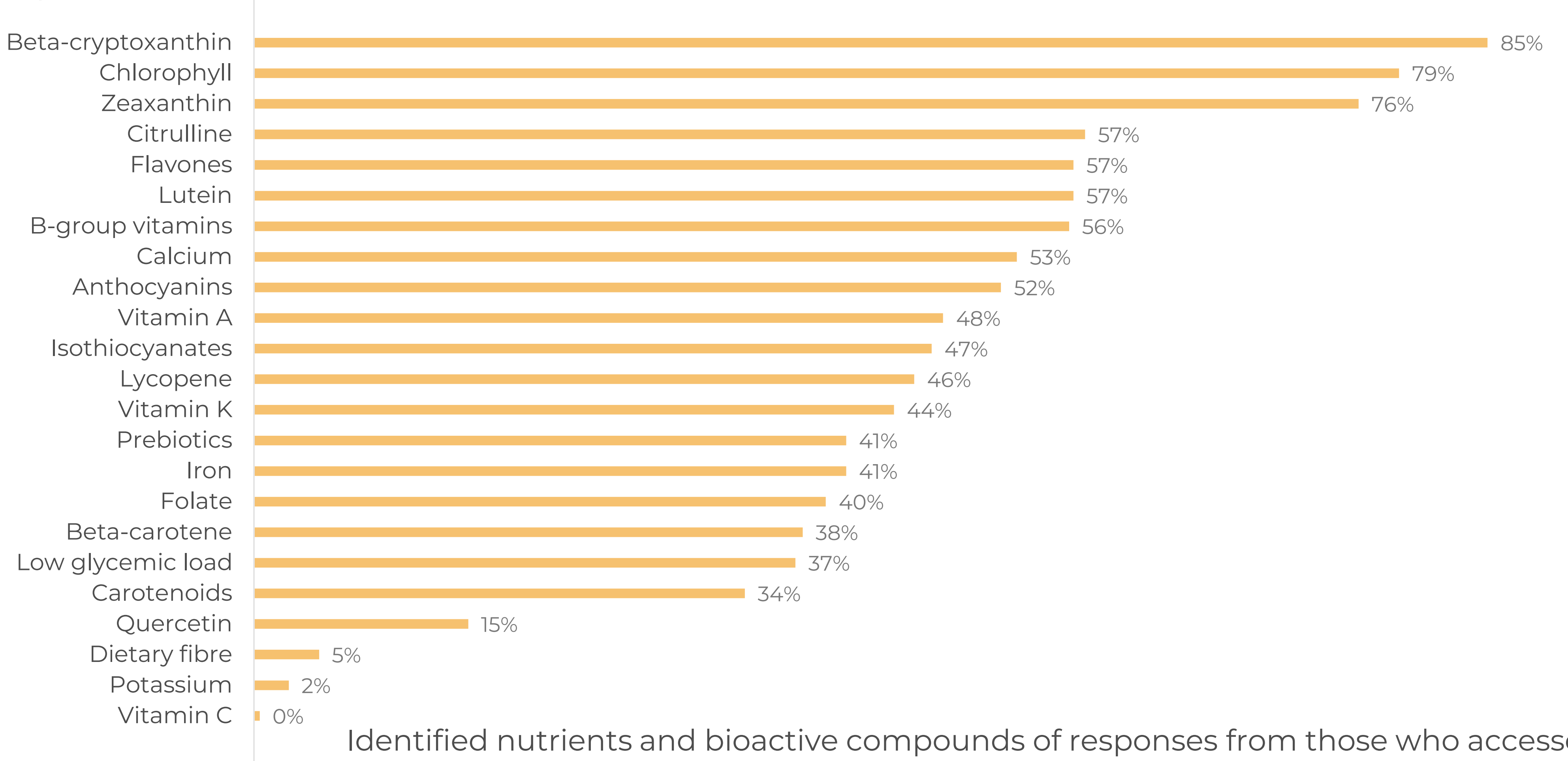


Knowledge increased



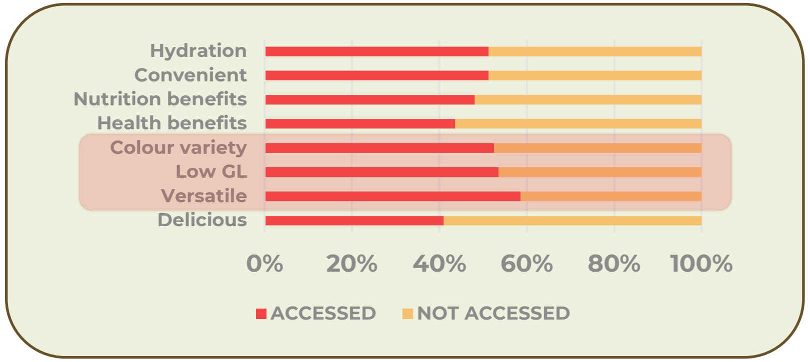
Bioactive knowledge was significantly higher in those who accessed resources*

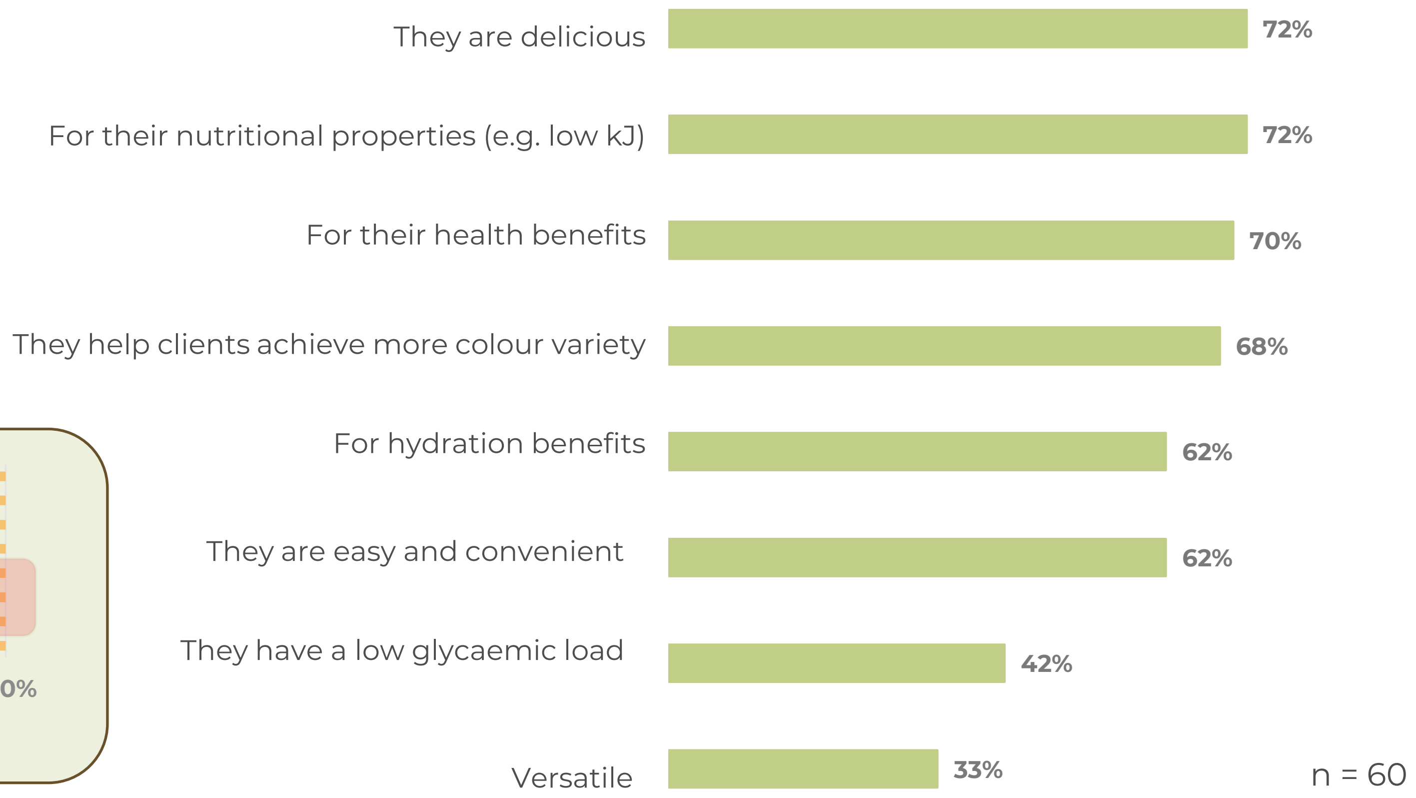
*Compared with those who did not access resources



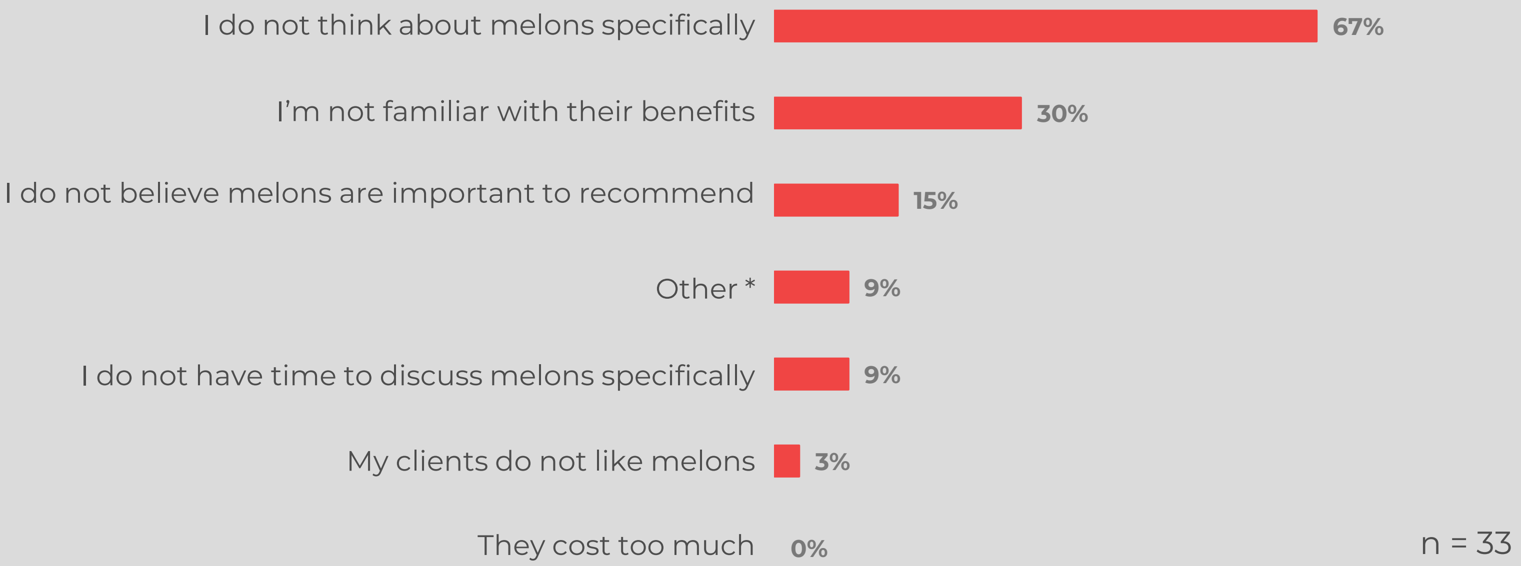
Identified nutrients and bioactive compounds of responses from those who accessed resources as a percent increase of those who did not access resources (%)

DRIVERS FOR RECOMMENDING MELONS





BARRIERS FOR RECOMMENDING MELONS



What else would HP like to see?

Recipe & culinary usage inspiration

Seasonality and impacts on nutrition

Health benefits any science including acceptability in diabetes

> I'd love to see some more novel recipes included.

> About the seasons and the best way to use them and maintain or enhance their nutritional values

> I'll be interested to hear what you have to say other benefits
> Would like information on melons and diabetes.

> Would love to learn more about the bioactives of melons

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Learnings & recommendations

Survey learnings and recommendations

Learning

- ✓ Participants tended to be older and female than baseline survey.
- ✓ Similar professional profile with nearly half dietitians. More likely to work in private practice versus baseline. Baseline survey had significant skew towards students, double the current.
- ✓ Missed 200 respondent target. May have been influenced by reduced activity on meta and/or fatigue with other surveys taking place.
- ✓ Percentage of respondents having accessed the resources was lower than anticipated, limiting opportunities to stratify by profession.

Recommendation

- ✓ Increase recruitment target in follow-up (end of project) relative to baseline recruitment to account for diversity and stratification by accessed vs. did not access.
- ✓ Maintain diverse recruitment techniques for future surveys.
- ✓ Additional survey touch-points at point and time of access may yield additional results. Participants may have accessed the resources, but not recently.

HCP Knowledge & behaviour learnings and recommendations

Learning

- ✓ Resource access appears to have been powerful for changing knowledge, recommendation and confidence, but awareness of the resources was lower than hoped.
- ✓ HP knowledge on the key project education messages increased the most supporting that focused messaging strategy had intended outcome.
- ✓ HPs were 1.5 times more likely to recommend melons to clients if they accessed resources.

Recommendation

- ✓ HP communications benefit from using focused messaging
- ✓ Ongoing continuous HP communication to be maintained to increase reach

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Limitations & Considerations

Limitations & Considerations

1. Rebrand (NRAUS to FOODiQ) may have impacted brand recognition of resources in follow-up survey.
2. The number of respondents from singular professions, combined with the lower-than-projected number of participants who had accessed the resources, limited the analysis by type of health profession.

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APPENDIX 3

molecules

MDPI

Review

Should We 'Eat a Rainbow'? An Umbrella Review of the Health Effects of Colorful Bioactive Pigments in Fruits and Vegetables

Michelle Blumfield [1], Hannah Mayr [1,2,3,4], Nienke De Vlieger [1,5], Kylie Abbott [1], Carlene Starck [1], Flavia Fayet-Moore [1,*] and Skye Marshall [1,2,6]

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Abstract: Health promotion campaigns have advocated for individuals to 'eat a rainbow' of fruits and vegetables (FV). However, the literature has only focused on individual color pigments or individual health outcomes. This umbrella review synthesized the evidence on the health effects of a variety of color-associated bioactive pigments found in FV (carotenoids, flavonoids, betalains and chlorophylls), compared to placebo or low intakes. A systematic search of PubMed, EMBASE, CINAHL and CENTRAL was conducted on 20 October 2021, without date limits. Meta-analyzed outcomes were evaluated for certainty via the GRADE system. Risk of bias was assessed using the Centre for Evidence-Based Medicine critical appraisal tools. A total of 86 studies were included, 449 meta-analyzed health outcomes, and data from over 37 million participants were identified. A total of 42% of health outcomes were improved by color-associated pigments (91% GRADE rating very low to low). Unique health effects were identified: n = 6 red, n = 10 orange, n = 3 yellow, n = 6 pale yellow, n = 3 white, n = 8 purple/blue and n = 1 green. Health outcomes associated with multiple color pigments were body weight, lipid profile, inflammation, cardiovascular disease, mortality, type 2 diabetes and cancer. Findings show that color-associated FV variety may confer additional benefits to population health beyond total FV intake.

Keywords: fruit; vegetables; color; health; phytochemicals; carotenoids; flavonoids; chlorophyll; systematic review

Citation: Blumfield, M.; Mayr, H.; De Vlieger, N.; Abbott, K.; Starck, C.; Fayet-Moore, F.; Marshall, S. Should We 'Eat a Rainbow'? An Umbrella Review of the Health Effects of Colorful Bioactive Pigments in Fruits and Vegetables. *Molecules* **2022**, *27*, 4061. https://doi.org/10.3390/molecules27134061

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1. Introduction

Inadequate intake of fruits and vegetables (FV) is a leading modifiable dietary risk factor for mortality and contributes to the increasing burden of both communicable and non-communicable diseases [1,2]. In 2017, poor FV intake was responsible for 3.9 million deaths [3] and was among the top dietary risk factors affecting disability-adjusted life years worldwide [1]. Not only is meeting recommended servings of FV important, but a greater variety in the types of FV consumed has been independently associated with a lower risk of diabetes [4], cancer [5–7] and mortality [8,9], and improved cognitive function [10,11]. Increasing variety of FV is particularly critical during childhood to support growth and development, and to establish healthy eating habits that track into adulthood [12].

FV contain an abundance of nutrients, including vitamins, minerals and bioactive compounds known as phytonutrients. Phytonutrients improve health through their antioxidant, anti-inflammatory, antibacterial, antifungal, antiallergic, chemoprotective, neuroprotective, hypolipidemic and/or hypotensive properties [13]. Despite the unequivocal health benefits of eating FV, 78% of adults worldwide do not consume the daily recommended servings [14], leading to a 'phytonutrient gap'. Naturally occurring and pigmented phytonutrients (herein referred to as bioactive pigments) give FV their vibrant colors and correspond to one or more phytonutrient categories; e.g., red corresponds to lycopene, yellow to alpha-carotene, orange to beta-carotene, green to chlorophyll, purple and blue to anthocyanins, and white to flavones (Table 1) [15]. Given the range of colors and bioactive pigments in FV, both the nutrient profile and physiological functions of FV may differ in part due to their variations in color, and those of the same color are likely to have similar health benefits.

Table 1. Natural bioactive pigment classes and subclasses and the typical colors they produce in fruits and vegetables [16].

Pigment Class	Pigment Subclass	Pigment Minor Subclass	Typical Colors
Carotenoids	Lycopene Beta-cryptoxanthin Capsorubin Capsanthin	-	Red
	Beta-carotene Alpha-carotene Lutein Zeaxanthin Violaxanthin	- -	Orange Yellow
Flavonoids	Anthocyanins/ anthocyanidins	Cyanidin Malvidin Peonidin Delphinidin Pelargonidin Petunidin	Red, purple, blue
	Aurones Chalcones Flavonols	Kaempferol Quercetin Myricetin	Pale yellow
	Flavones	Apigenin Luteolin Isoetin	White
	Tannins	Proanthocyanidins Proanthocyanins	Red, purple, blue, brown
Betalains	Betacyanins Betaxanthin	Betanin Indicaxanthan Vulgaxanthin	Red, violet, orange, yellow
Chlorophylls	Chlorophyll a and b	-	Green

Population-based data have shown that the diets of eight out of ten American adults fall short in every color of phytonutrient (i.e., have a phytonutrient gap), when compared to the median phytonutrient intake in adults who meet the recommended daily intake of FV, with the proportion of insufficient intakes per color category reported as 88% for the color purple/blue, 86% for white, 79% for yellow/orange, 78% for red and 69% for green [17]. In an attempt to improve health, dietary guidelines and health promotion campaigns have advocated for individuals to 'eat by color' or 'eat a rainbow' of FV [15]. Associating each color with a health benefit is a simplified strategy designed to: (1) help individuals relate to the health properties of FV, (2) promote greater recognition of their importance, and (3) increase the diversity of FV colors consumed across all life stages [15].

Despite these campaigns, assessment of FV variety in both clinical practice and research has been typically based on the number of individual types of FV a person consumes rather than assessing variety of bioactive pigments [18,19]. Observational studies have shown that FV intakes, grouped by their color, are associated with improvement in a range of health outcomes including cognitive decline, cardiovascular disease (CVD) and colorectal cancer [20–23]. The body of evidence linking bioactive pigments in FV to beneficial health effects is growing, but the reviews and syntheses of the evidence have focused either on individual pigments or on individual health outcomes [24–32]. There is a gap in practice and in research whereby the evidence for consuming a variety of color and bioactive pigments from FV for human health and wellbeing is summarized and synthesized.

Collating the evidence will support recommendations for improving health related to the types of bioactive pigments found in FV and highlight important research opportunities. Findings for each bioactive pigment color are relevant to all FV which contain them, and are not limited to a specific FV, thereby increasing the translational impact of existing messaging around eating a variety of FV. The aim of this umbrella review was to synthesize the evidence on the effects of a variety of color-associated bioactive pigments found in FV (carotenoids, flavonoids, betalains and chlorophylls), as compared to placebo or low intakes, on human health outcomes relevant to population health.

2. Results

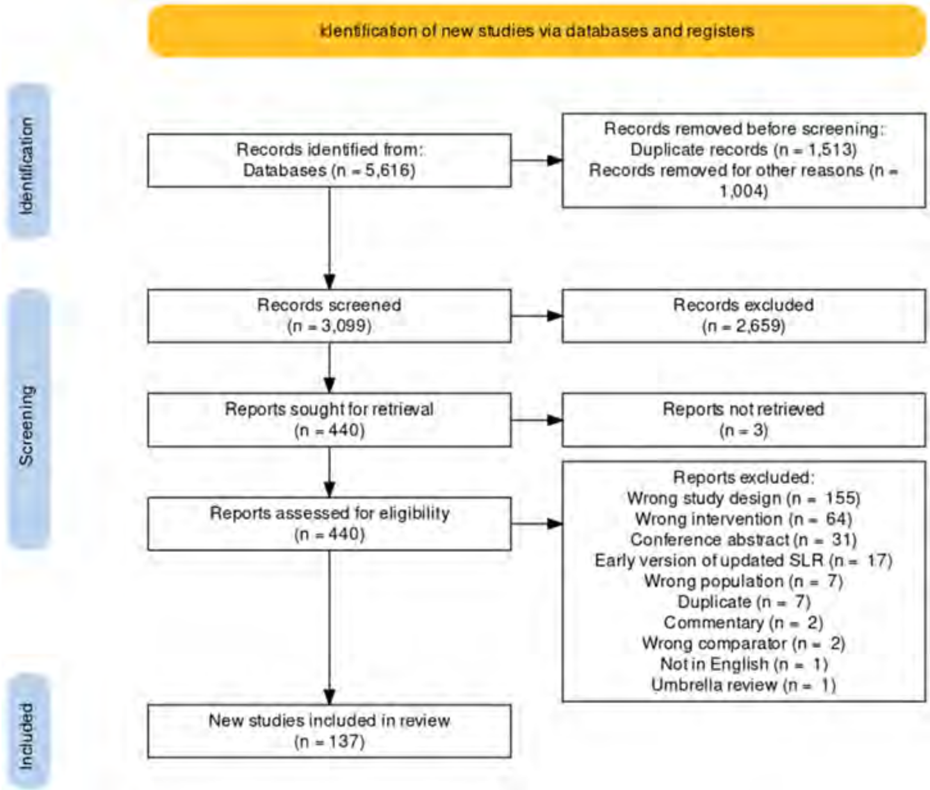
The systematic search strategy identified 5616 records, of which 137 systematic literature reviews (SLRs) containing 449 meta-analyses (MAs) were eligible for inclusion (Figure 1a). Fifty-four SLRs were excluded due to a very high degree of overlapping of studies included in MAs of the same pigment and health outcome, resulting in 83 SLRs included in this umbrella review. When the search was extended to include single randomized controlled trials (RCTs) or cohort studies for chlorophyll, three additional studies were included: two RCTs and one cohort (Figure 1b).

2.1. Characteristics of Included Studies

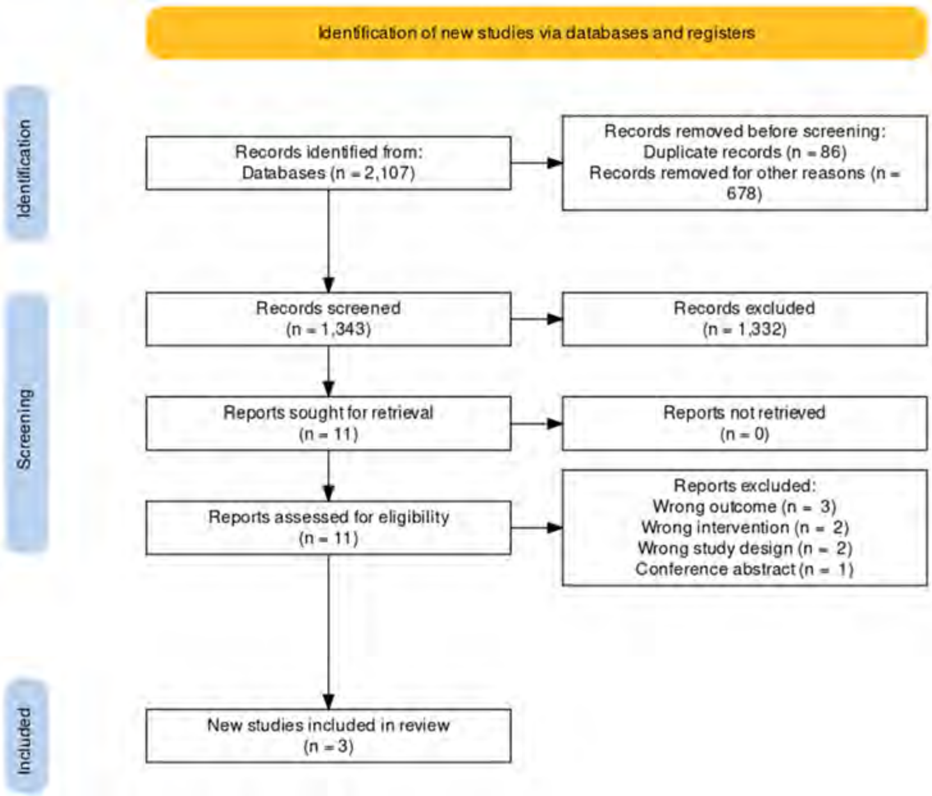
Characteristics of included studies are presented in the data extraction spreadsheet published elsewhere [33]. The included SLRs were published between 1998 and 2021 and were conducted in adults. The number of primary studies within the included SLRs ranged from 2 to 38. Of the 83 included SLRs, n = 33 included only RCTs, n = 12 only cohort studies, n = 6 only case–control studies and n = 32 both cohort and case–control studies. The number of SLRs and MAs included in this umbrella review, by pigment and health outcome are summarized in Table S1.

MAs included participants of both sexes, except for outcomes relating to pregnancy health (females only), breast or ovarian cancer (females only), prostate cancer (males only) and a single MA of osteoporosis (males only [34]). None of the included MAs reported on health effects in children or adolescents, and only n = 7 MAs (0.02%) were reported exclusively in older adults. The countries of the original research were rarely and poorly reported by the included SLRs, and therefore were not extracted.

For chlorophyll, included RCT (n = 2) and cohort (n = 1) studies were published between 2006 and 2016, and were conducted in adults of both sexes from the Netherlands, Sweden and Japan.



(**a**)



(**b**)

Figure 1. PRISMA flow diagram of the literature search and selection. (**a**) Flow chart for the search for systematic literature reviews with meta-analyses for all color pigments. (**b**) Flow chart for the search for randomized controlled trials and cohort studies for the green pigment chlorophyll.

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2.2. Bioactive Pigment Interventions

2.2.1. SLRs and MAs

The review of SLRs identified MAs on 17 different bioactive pigments which included all colors of fruits and vegetables except green (i.e., chlorophyll) (Table S1). No MAs were found for betalains or it's sub-classes; however, the betalains colors of red, violet, orange, and yellow were represented by the included carotenoids and flavonoids.

The only major class of bioactive pigment included for data extraction was carotenoids (n = 4 SLRs reporting n = 12 MAs), as all other health outcomes identified were reported at the bioactive pigment subclass. The bioactive pigment sub-classes which reported unique health outcomes were flavonols, and they were all pale yellow in color (kaempferol n = 1 SLR reporting n = 1 MA, myricetin n = 1 SLR reporting n = 1 MA, quercetin n = 10 SLRs reporting n = 25 MAs) and tannins (proanthocyanidins n = 5 SLRs reporting n = 11 MAs, proanthocyanins n = 2 SLRs reporting n = 2 MAs), which can be red, blue, purple or brown (Table S1).

Anthocyanin (red/blue/purple) was the most extensively researched bioactive pigment (n = 18 SLRs reporting n = 81 MAs, representing n = 729 original research studies), followed by beta-carotene (orange; n = 34 SLRs reporting n = 74 MAs) and lycopene (red; n = 25 SLRs reporting n = 65 MAs). Of the bioactive pigment subclasses included, zeaxanthin (yellow; n = 2 SLRs reporting n = 3 MAs) was the least explored (Table S1); and no MAs were identified for the sub-classes capsorubin, capsanthin, violaxanthin, aurones and chalcones.

Bioactive pigments were primarily investigated via dietary intake (n = 20 MAs of RCTs, n = 186 MAs of cohort studies), followed by natural supplements or a mix of natural and synthetic supplements (n = 74 MAs of RCTs, n = 1 MA of observational research), and serum levels (n = 47 MAs of observational studies). However, a large number of MAs included bioactive pigments measured from a variety of sources including diet, supplement and/or serum levels (n = 68 MAs of observational research, n = 53 MAs of RCTs).

Intervention duration varied widely, from 4 h to 18 years in RCTs, and from 3 months to 41 years in observational studies. Comparator groups were either placebo or non-specified controls for RCTs, and the lowest category of intake for cohort studies.

2.2.2. Single RCTs and Cohort Studies

Two RCTs delivered chlorophyll as a supplement containing 3000 mg extracted from green spinach leaves; and another as 0.7 mg of chlorophyll c2. A cohort study examined chlorophyll intake from the usual diet.

2.3. Health Outcomes and Confidence in the Body of Evidence

2.3.1. SLRs and MAs

This umbrella review of SLRs identified many unique meta-analyzed outcomes (n = 98), which were grouped as cancer (n = 192 MAs), CVD (n = 135 MAs), exercise (n = 28 MAs), mortality (n = 27 MAs), type 2 diabetes mellitus (T2DM; n = 24 MAs), obesity (n = 13 MAs), bone health (n = 9 MAs), eye health (n = 9 MAs), the nervous system (n = 5 MAs), pregnancy health (n = 4 MAs), cognitive function (n = 2 MAs) and the respiratory system (n = 1 MA) (Table S1).

Of the 449 MAs included, 42% (n = 89 MAs) reported at least one significant improvement in a pooled health outcome, with n = 35 (19%) having a significant dose–response. There was also n = 4 MAs (0.009% of included MAs) which reported a significant negative effect from having the bioactive pigment (Tables S2–S8).

Using GRADE, confidence in the body of evidence ranged from very low (n = 349 MAs), low (n = 61 MAs), medium (n = 28 MAs), and high (n = 11 MAs). Of the 28 included SLRs that reported their own GRADE level, the current investigators allocated a higher GRADE rating for seven MAs, agreed with the GRADE rating for six MAs, and allocated a lower GRADE rating for 15 MAs. The most common reason for downgrading the confidence in the body evidence was that most (67%) MAs were based on observational data, which downgraded all GRADE ratings to at least "low" confidence. Other common reasons for downgrading were moderate to high risk of bias in the original studies included in the SLRs, wide confidence intervals, or substantial statistical heterogeneity.

2.3.2. Single RCTs and COHORT STUDIES

Each included RCT and cohort study for chlorophyll examined a unique health outcome: cancer (n = 1 case–cohort study), CVD (n = 1 RCT) and allergy (n = 1 RCT) (Table S9). Of the 16 included health variables extracted from these three studies, only one was significant, with a second variable with borderline significance and likely underpowered by a small sample size (n = 36 participants; p = 0.06). As no two included original research studies on chlorophyll examined the same health outcome, meta-analysis and GRADE assessment were not performed.

2.4. Health Effects of Total Carotenoid Pigments in Fruits and Vegetables

Total carotenoids represent red, orange, and yellow pigments (Table 1, Figure 2). There was n = 12 unique MAs (n = 10 MAs of RCTs, n = 2 MAs of cohort studies) which were reported by the bioactive pigment class carotenoids. Carotenoid intervention was measured via dietary intake (n = 1 MA with 4–24 years follow-up), serum (n = 1 MA with 12–14 years follow-up), supplement (n = 8 MAs with 12–16 weeks intervention duration) or mixed (n = 2 MAs with 2-months to 18-years intervention duration) (Tables S1 and S2). The intervention doses in RCTs were not reported (n = 5 MAs) or were 0.5 mg to 60 mg/day, and cohort studies compared the highest categories of intake or serum levels with the lowest.

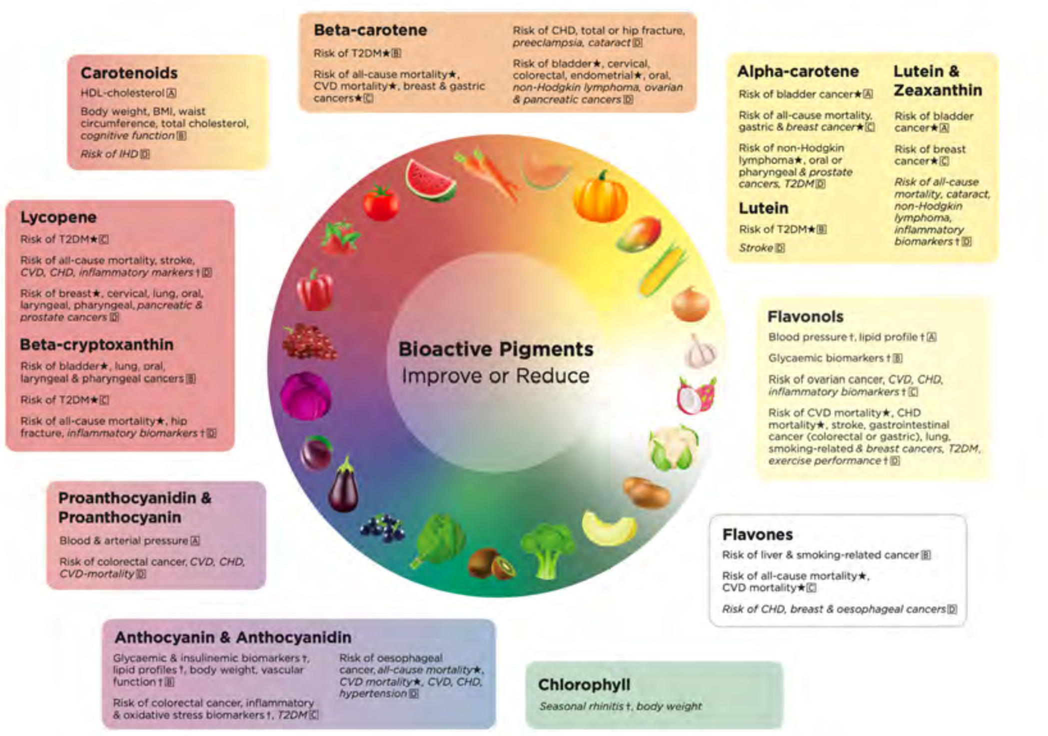

Figure 2. The health promoting effects of bioactive pigments by color in fruits and vegetables. GRADE working groups of evidence: A = high quality, further research is unlikely to change our confidence in the estimated effect; B = medium quality, further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate; C = low quality, further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate; and D = very low quality, we are very uncertain about the estimate. ⋆ = dose–response established. † = cause and effect established. Health effects in italics are those with small effect sizes. BMI, body mass index. CVD, cardiovascular disease. CHD, coronary heart disease. IHD, ischemic heart disease. T2DM, type 2 diabetes.

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Carotenoid supplementation had a large effect on risk factors for obesity and CVD, including reductions in body weight (SMD −2.54 kg; 95% CI −3.80, −0.87), BMI (SMD −0.95 kg/m²; 95% CI −1.88, −0.01), waist circumference (SMD −1.84 cm; 95% CI −3.14, −0.54), total cholesterol (SMD −2.10 mg/dL; 95% CI −3.20, −0.99), and increased HDL cholesterol (SMD 0.76 mg/dL; 95% CI 0.10, 1.41) when consumed for up to 16 weeks [35] (Table S2).

The highest category of dietary carotenoid intake was associated with a 15% decreased risk of ischemic heart disease (RR 0.85; 95% CI 0.77, 0.93), compared to the lowest category of intake [36]. High carotenoid levels (0.5–50 mg) modestly improved cognitive

Carotenoid supplementation had a large effect on risk factors for obesity and CVD, including reductions in body weight (SMD −2.34 kg; 95% CI −3.80, −0.87), BMI (SMD −0.95 kg/m^2; 95% CI −1.88, −0.01), waist circumference (SMD −1.84 cm; 95% CI −3.14, −0.54), total cholesterol (SMD −2.10 mg/dL; 95% CI −3.20, −0.99), and increased HDL cholesterol (SMD 0.76 mg/dL; 95% CI 0.10, 1.41) when consumed for up to 16 weeks [35] (Table S2).

The highest category of dietary carotenoid intake was associated with a 15% decreased risk of ischemic heart disease (RR 0.85; 95% CI 0.77, 0.93), compared to the lowest category of intake [36]. High carotenoid levels (0.5–50 mg) modestly improved cognitive outcomes (SMD 0.14, 95% CI, 0.08, 0.20) [28] (Table S2). Total carotenoid intake was found to have no effect on tumor necrosis factor alpha (TNF-alpha), triglycerides, low density lipoprotein (LDL) cholesterol or change in fat ratio [35,37] (Table S2). No dose–response MAs were included for total carotenoids.

The strongest evidence for the health effect of carotenoids was for improved adiposity (very large effect sizes, GRADE: low to medium) and lipid profiles (large to very large effect sizes, GRADE: medium to high) (Figure 2).

2.5. Health Effects of Red Pigments in Fruits and Vegetables

Data on the effect of red bioactive pigments were from beta-cryptoxanthin (*n* = 15 SLRs reporting *n* = 33 MAs) and lycopene (*n* = 25 SLRs of *n* = 65 MAs) (Tables S1 and S3). Anthocyanins may also be red in an acidic environment, but were reported with the blue/purple bioactive pigments [38].

2.5.1. Beta-Cryptoxanthin

Only two of the included MAs on beta-cryptoxanthin were based on RCT data (12-weeks; 6 mg/day; mixed sources of beta-cryptoxanthin), and the remaining 31 MAs were based on cohort data (1–26 years). Most cohort MAs compared an unspecified highest category with the lowest; however, where the highest categories were specified, they provided 56–200 µg/day compared with the lowest at <1.8 to 20 µg/day. Cohort data were derived from diet (*n* = 21 MAs), mixed sources (*n* = 3 MAs), or serum levels (*n* = 7 MAs); and included seven dose–response MAs.

The highest category of beta-cryptoxanthin intake was associated with a 28% decreased risk of hip fracture (OR 0.72; 95% CI 0.60, 0.87) [39] and up to a 27% decreased risk of all-cause mortality (RR 0.73; 95% CI, 0.58, 0.88) [40], compared to the lowest category of intake. A small effect was also found for the inflammatory biomarker C-reactive protein (CRP; MD −0.35 mg/L; 95% CI −0.54, −0.15), after individuals consumed 6 mg beta-cryptoxanthin over 12-weeks [37] (Table S3).

In relation to cancer, the highest category of dietary beta-cryptoxanthin intake was associated with a 69% decreased risk of larynx cancer (OR 0.41; 95% CI 0.33, 0.51) [41], 64% decreased risk of oral cavity and pharynx cancer (OR 0.46; 95% CI 0.29, 0.74) [41], 42% decreased risk of bladder cancer (RR 0.58; 95% CI 0.36, 0.94) [42], and 20% decreased risk of lung cancer (RR 0.80; 95% CI 0.72, 0.89) [43], compared to the lowest category of intake (Table S3).

In dose–response MAs of serum levels, each 0.1 mg/day increase in beta-cryptoxanthin, decreased the risk of all-cause mortality by 6% (RR 0.94; 95% CI 0.89, 0.99) [40], whereas for every daily increase of 0.5 µmol/L, the risk of T2DM decreased by 15% (RR 0.85; 95% CI 0.76, 0.94) [44] (Table S3).

No differences were found for beta-cryptoxanthin and risk of: cataracts [45], early age-related macular degeneration [46], osteoporosis [39], Parkinson's disease [47], non-Hodgkin lymphoma [48], breast cancer [29], colorectal cancer [49], pancreatic cancer [50] or lung cancer mortality [43] (Table S3).

The strongest evidence for the health effect of beta-cryptoxanthin was for a decreased risk of all-cause mortality (dose–response relationship, moderate to large effect size, GRADE: very low), bladder cancer (dose–response relationship, very large effect size, GRADE: medium), oral, laryngeal, or pharyngeal cancer (very large effect size, GRADE: very low to medium), and T2DM (dose–response relationship, large effect size, GRADE: low) (Figure 2).

2.5.2. Lycopene

There was n = 14 MAs included based on RCT data (1-day to 6-months duration; 2–50 mg/day); with the remaining n = 51 MAs based on observational cohort data (3-months to 26-years duration; 2035–10,000 µg/day), n = 11 of which were dose–response MAs (per 1000 µg/day or incremental serum levels) (Table S3). Most MAs analyzed dietary intake data (n = 32 MAs), followed by mixed sources (n = 22 MAs), serum values (n = 10 MAs), and one MA measured supplemental intake.

The highest category of dietary lycopene intake was associated with reductions in the risk of cervical (OR 0.54; 95% CI, 0.39, 0.75) [51], larynx (OR 0.50; 95% CI, 0.28, 0.89) [41], lung (RR 0.71; 95% CI, 0.51, 0.98) [43], oral cavity and pharynx (OR 0.74; 95% CI, 0.56, 0.98) [41] and prostate (RR 0.88; 95% CI, 0.79, 0.99) [34] cancers, compared to the lowest category of dietary lycopene intake. Reductions in the risk of breast cancer were only reported in case control studies, where greater reductions in risk up to 29% (OR 0.71; 95% CI, 0.56, 0.92) [29] were found with greater dietary lycopene intake (Table S3).

Higher lycopene intake was also associated with cardiovascular improvements with small to moderate clinical significance, including a lower risk of CHD (RR 0.87; 95% CI, 0.76, 0.98) [52], CVD (HR 0.86; 95% CI 0.77, 0.95) [53], stroke (HR 0.74; 95% CI 0.62, 0.89) [53], T2DM (RR 0.85; 95% CI 0.76, 0.96) [44], mortality (HR 0.63; 95% CI 0.49, 0.81) [53] and all-cause mortality (RR 0.72; 95% CI 0.49, 0.95) [40] (Table S3). In dose–response MAs of serum levels, each 0.5 µmol/L increase in serum lycopene decreased the risk of T2DM by 17% (RR 0.83; 95% CI 0.74, 0.92) [44].

Lycopene status had no effect on preeclampsia [54], early age-related macular degeneration [46], risk of hip fracture [55], advanced prostate cancer [34,56], colon/colorectal/rectal cancer [49], bladder cancer [42], gastric cancer [57], non-Hodgkin lymphoma [48], ovarian cancer [58], Parkinson's disease [47], inflammatory biomarkers (except a small effect in interleukin-6 (MD −1.08 pg/mL; 95% CI −2.03, −0.12) [37], lipid profiles [59,60], blood pressure [60] and prostate specific antigen (PSA) levels [61] (Table S3).

The strongest evidence for the health effects of lycopene were decreased risk of breast cancer (dose–response relationship, large to very large effect size, GRADE: very low) and T2DM (dose–response relationship, moderate to large effect size, GRADE: very low to low) (Figure 2).

2.6. Health Effects of Orange Pigments in Fruits and Vegetables

The health effects of consuming orange bioactive pigments from FV were reported by MAs of beta-carotene (bioactive pigment subclass; n = 34 SLRs reporting n = 75 MAs including n = 16 dose–response MAs) (Tables S1 and S4).

Evidence for the effects of beta-carotene was largely represented by MAs of cohort studies (n = 59 MAs) measured over 1–26 years via dietary intake (n = 32 MAs), mixed sources (n = 16 MAs), serum levels (n = 10 MAs) or supplementation (n = 1 MA). Doses in the highest categories of intake were not usually reported, but when reported ranged from 2473–7000 µg/day intake or 16 to >120 µg/dL serum level. The one supplemental study provided a dose of 600 to 1991 µg/day (Table S4). Sixteen of the observational MAs were dose–response, examining effects per 500–5000 µg/day intake or per 0.1 µmol/L serum level.

The highest category of beta-carotene intake was associated with a decreased risk of several types of cancers, including cervical (OR 0.68; 95% CI 0.55, 0.84) [51], gastric (OR 0.74; 95% CI 0.61, 0.91) [62], larynx (OR 0.43; 95% CI 0.24, 0.77) [41], non-Hodgkin lymphoma (RR 0.80; 95% CI 0.68, 0.94) [48], oral cavity (OR 0.54; 95% CI 0.37, 0.80) [41], ovarian (RR 0.84; 95% CI 0.75, 0.94) [63] and pancreatic (OR 0.78; 95% CI 0.66, 0.92) [50] cancers, compared to the lowest category of beta-carotene intake (Table S4). Reductions in breast cancer risk were supported by dose–response MAs that found dietary beta-carotene intakes of 2000 μg/day, 3000 μg/day or 5000 μg/day reduced the risk of breast cancer by 3%, 4% and 7%, respectively [29] (Table S4). For each 1000 μg/1000 kcal increase in dietary beta-carotene the risk of endometrial cancer decreased by 26% (RR 0.74; 95% CI 0.61, 0.91) [64].

Highest categories of beta-carotene intake were also associated with a lower risk of all-cause mortality (RR 0.82; 95% CI 0.77, 0.86) [40], CHD (RR 0.73; 95% CI 0.65, 0.82) [65], CVD mortality (RR 0.68; 95% CI 0.52, 0.83) [66], total fracture (RR 0.63; 95% CI 0.52, 0.77) [67], hip fracture (OR 0.72; 95% CI 0.54, 0.95) [55] and the incidence of cataract (RR 0.90; 95% CI 0.83, 0.99) [45] and preeclampsia (SMD −0.40; 95% CI −0.72, −0.08) [54], when compared to the lowest intakes. In dose–response MAs, each 1 mg/day increase in beta-carotene intake decreased the risk of all-cause mortality by 5% (OR 0.95; 95% CI 0.92, 0.99) [40], whereas for every 0.5 μmol/L serum increase the risk of T2DM decreased by 35% (OR 0.65; 95% CI 0.48, 0.89) [44] (Table S4).

No differences were found for dietary beta-carotene and risk of bladder cancer [42], colon cancer [49], colorectal cancer [49], lung cancer [43], lung cancer or lung cancer mortality [43], melanoma [68], prostate cancer [56,62], rectal cancer [49], COPD [69], total fracture [70] and Alzheimer's disease [71] (Table S4).

The strongest evidence for the health effects of beta-carotene were decreased risk of all-cause and CVD mortality (dose–response relationship, very large effect size, GRADE: very low to low), T2DM (dose–response relationship, large to very large effect size, GRADE: low to medium), bladder cancer (dose–response relationship, very large effect size, GRADE: very low), breast cancer (dose–response relationship, large effect size, GRADE: very low to low) and endometrial cancer (dose–response relationship, large effect size, GRADE: very low) (Figure 2).

2.7. Health Effects of Yellow Bioactive Pigments in Fruits and Vegetables

The evidence for the health effects of yellow bioactive pigments were from MAs reporting on alpha-carotene (n = 16 SLRs reporting n = 41 MAs), lutein (n = 7 SLRs reporting n = 10 MAs), zeaxanthin (n = 2 SLRs reporting n = 3 MAs) or lutein and zeaxanthin as a combined group (n = 13 SLRs reporting n = 31 MAs) (Figure 2; Table S5).

2.7.1. Alpha-Carotene

All n = 41 MAs reporting on the health effects of alpha-carotene were based on cohort and/or case–control research, measured via dietary intake (n = 27 MAs with 1–25 years follow-up); serum levels (n = 10 MAs with 2–26 years follow-up); or mixed diet, serum levels, and/or supplements (n = 4 MAs with 9-months to 26-years follow-up) (Table S5). Most MAs compared an unspecified highest category against the unspecified lowest category; however, some category groups were defined as >881–2000 μg/day compared against <180 to 300 μg/day dietary intake or serum levels of >1 to >5 μg/dL compared against <1 to <2 μg/dL.

The highest category of alpha-carotene intake was associated with a reduced risk of gastric (OR 0.58; 95% CI 0.44, 0.76) [57], non-Hodgkin lymphoma (RR 0.87; 95% CI 0.78, 0.97) [48], oral cavity and pharynx (OR 0.57; 95% CI 0.41, 0.79) [41] and prostate (RR 0.87; 95% CI 0.76, 0.99) [56] cancers, and a reduced risk of T2DM (RR 0.91; 95% CI 0.85, 0.96) [44] and all-cause mortality (RR 0.79; 95% CI, 0.63, 0.94) [40]. In dose–response MAs, for each 1000 μg/day increase in alpha-carotene the risk of breast cancer decreased by up to 18% (RR 0.82; 95% CI 0.73, 0.93) [29] and the risk of non-Hodgkin lymphoma decreased by 13% (RR 0.87; 95% CI 0.78, 0.97) [48] (Table S5).

Alpha-carotene intake was reported to have no effect on risk of pre-eclampsia [54], cataract [45], early aged-related macular degeneration [46], cancer of the larynx [41], risk of colon, rectal, or colorectal cancer [49], hip fracture [55], lung cancer [43], pancreatic cancer [50] or Parkinson's disease [47].

The strongest evidence for the health effects of alpha-carotene were decreased risk of all-cause mortality (dose–response relationship, large effect size, GRADE: very low to low), bladder cancer (dose–response relationship, very large effect size, GRADE: high), non-Hodgkin lymphoma (dose–response relationship, moderate to large effect size, GRADE: very low) and T2DM (dose–response relationship, large to very large effect size, GRADE: medium) (Figure 2).

2.7.2. Lutein

All n = 10 MAs reporting on the health effects of lutein drew upon cohort or case–control data, measured via dietary intake (n = 4 MAs with 10–12 years follow-up), serum levels (n = 2 MAs with 8–10 years follow-up) or mixed sources (n = 4 MAs with 9-months to 26-years follow-up) (Table S5). Most of the MAs compared the highest unspecified category of lutein to the lowest unspecified category; however, one highest category was defined as 3701 to 4041 μg/day compared to 1413 to 1736 μg/day dietary intake.

When compared to the lowest category, the highest category of lutein intake improved the risk of stroke by 18% (RR 0.82; 95% CI 0.58, 0.78) [72] and the risk of T2DM by 35% (RR 0.65; 95% CI 0.55, 0.77). In dose–response MAs of serum levels, each 0.2 ugmol/L increase in lutein decreased the risk of T2DM by 21% (RR 0.79; 95% CI 0.72, 0.86). Lutein was reported to have no effect on risk of lung cancer [43], gastric cancer [57], Parkinson's disease [47], pre-eclampsia [54] or all-cause mortality [40] (Table S5).

The strongest evidence for the health effects of lutein was for decreased risk of T2DM (dose–response relationship, large to very large effect size, GRADE: medium) (Figure 2).

2.7.3. Zeaxanthin

All three MAs which measured the effect of zeaxanthin on human health were based on cohort studies, with n = 2 MAs based on serum zeaxanthin levels (8–10 years follow-up) and n = 1 MA based on mixed sources (2–26 years follow-up). When comparing the highest unspecified category against the lowest unspecified category, zeaxanthin had no effect on all-cause mortality [40] or risk of T2DM [44] (Table S5).

2.7.4. Lutein and Zeaxanthin

Thirty-one MAs investigated the effect of combined lutein and zeaxanthin on human health, n = 29 of which were based on cohort of case–control studies, and n = 2 were based on RCTs. The observational research primarily measured lutein and zeaxanthin via dietary intake (n = 22 MAs with 1–25 years follow-up) or serum levels (n = 5 MAs with 2–26 years follow-up), with only one MA considering mixed sources (5–18 years follow-up) (Table S5). Only n = 3 MAs defined the intake of lutein and zeaxanthin in the highest category (>1815 to 5000 μg/day) as compared to the lowest category (<775 to 1000 μg/day). The two RCT MAs both considered dietary or supplemental intake of lutein and zeaxanthin with interventions ranging from 8–32 weeks and doses of 8 mg/day to 27 mg/day.

When comparing the highest category versus lowest category of lutein and zeaxanthin status, higher dietary intakes reduced the risk of non-Hodgkin lymphoma by 18% (RR 0.82; 95% CI 0.69, 0.97) [48], while higher serum intakes reduced the risk of bladder cancer (RR 0.53; 95% CI 0.33, 0.84) [42] and all-cause mortality (RR 0.85; 95% CI 0.74, 0.97) [40]. Lutein and zeaxanthin intakes were associated with decreased CRP levels (SMD −0.3 mg/L; 95% CI −0.45, −0.15) [37] and a dose–response relationship found a favorable 17% decreased risk of breast cancer for every 3000 μg/day increase in lutein and zeaxanthin intake (RR 0.83; 95% CI 0.77, 0.89) [29]. Dose–response relationships were not found for any other level of lutein or zeaxanthin intake (Table S5).

For lutein and zeaxanthin, no differences were found for the risk of gastric cancer [57], lung cancer [43], lung cancer or lung cancer mortality [43], pancreatic cancer [50], oral cavity and pharynx cancer [41], colon [49], rectal [49] or colorectal cancer [49], early aged macular degeneration [46], hip fracture [55] or IL-6 [37] (Table S5).

The strongest evidence for combined lutein and zeaxanthin was for decreased risk of bladder cancer (dose–response relationship, large to very large effect size, GRADE: low to high) and breast cancer (dose–response relationship, large effect size, GRADE: very low to low) (Figure 2).

2.8. Health Effects of Pale-Yellow Bioactive Pigments in Fruits and Vegetables

The health effects of consuming pale yellow bioactive pigments from FV were reported by MA of flavonols (bioactive pigment subclass; n = 17 SLRs reporting n = 33 MAs), kaempferol (n = 1 SLR reporting n = 1 MA), myricetin (n = 1 SLR reporting n = 2 MA), and quercetin (n = 10 SLRs reporting n = 25 MAs) (Tables S1 and S6).

2.8.1. Flavonols

As a group, MAs of flavonols subclass were primarily based on cohort and/or case–control data (n = 25 MAs with 2–28 years follow-up); although there was substantial cause-and-effect investigation via n = 8 MAs of RCTs (14–84 days intervention duration). Over half (n = 14 of 25) of the observational MAs measured flavonols from dietary sources alone (1–27 years follow-up), with the remaining n = 11 MAs measuring flavonols from mixed sources (4–28 years follow-up) (Table S6). The doses of intake in the highest or lowest categories were not reported. Four of the observational MAs were dose–response, examining effects per 10 mg or 20 mg, and were based on cohort data. All the MAs based on RCTs tested the effect of flavonols delivered via supplementation from 14- to 90-days at doses of 6–1000 mg (Table S6).

When comparing the highest intake or levels with the lowest, flavonols were found to improve the risk of stroke (RR 0.86; 95% CI 0.75, 0.96), CVD (RR 0.85; 95% CI 0.79, 0.91), and CHD (RR 0.88; 95% CI, 0.79, 0.98), as well as CVD- (RR 0.79; 95% CI 0.63, 0.99) and CHD-related death (RR 0.80; 95% CI 0.69, 0.93) [73–77]. High categories of flavonols were also associated with a reduced risk of T2DM (RR 0.92; 95% CI 0.85, 0.98) [78] and risk of breast (RR 0.88; 95% CI 0.80, 0.96), colorectal (RR 0.71; 95% CI 0.63, 0.81), gastric (OR 0.80; 95% CI 0.70, 0.91), ovarian (RR 0.68; 95% CI 0.58, 0.80) and smoking related cancer (OR 0.77; 95% CI 0.63, 0.95) [79–83]. However, two other MAs found no association with breast cancer [84], one found no association with CHD [85], and no differences were found for effect on all-cause mortality [73], hypertension [86] or other types of cancer including liver, lung, pancreatic, esophageal or prostate [84,87,88] (Table S6).

In dose–response MAs, for each 20 mg/day increase in flavonols the risk of stroke decreased by 14% (RR 0.86; 95% CI 0.77, 0.96) [77], and for each 10 mg/day increase in flavonols the risk of CVD mortality decreased by 13% (RR 0.87; 95% CI 0.76, 0.99) [73]. MAs of RCTs examined chronic disease indicators, finding supplementation with flavonols improved systolic (MD −3.05 mmHg; 95% CI −4.83, −1.27) and diastolic (MD −2.63 mmHg; 95% CI −3.83, −1.42) blood pressure, HDL cholesterol (MD 0.05 mmol/L; 95% CI 0.02, 0.07), LDL cholesterol (MD −0.14 mmol/L; 95% CI −0.21, −0.07), and total cholesterol (MD −0.11 mmol/L; 95% CI −0.20, −0.02), blood glucose (MD −0.18 mmol/L; 95% CI −0.29, −0.08) and triglycerides (MD −0.11 mmol/L; 95% CI −0.18, −0.03) [89]; however, there was no effect on waist circumference [90] (Table S6).

2.8.2. Kaempferol, Quercetin and Myricetin

One SLR reported on highest versus lowest dietary intake of kaempferol, quercetin, and myricetin using case–control data (duration not reported) [84]; whereas the nine other SLRs reported on 30–1000 mg/day of supplemental quercetin via MA of RCTs (5-days to 12-weeks duration) [91–99]. There were no dose–response MAs (Table S6).

When comparing the highest dietary intake with the lowest, kaempferol, but not myricetin or quercetin, reduced the risk of lung cancer by 23% (RR 0.77; 95% CI 0.62, 0.97) [84]. Supplemental quercetin improved a range of CVD risk factors, including systolic (MD −3.09 mmHg; 95% CI −4.83, −1.27) and diastolic blood pressure (MD −2.86 mmHg; 95% CI −5.09, −0.63) [93], CRP (MD −0.33 mg/L; 95% CI −0.50, −0.16) [94], VO2 max (MD

1.94%; 95% CI 0.30, 3.59) [97] and exercise performance (MD 2.82%; 95% CI 2.05, 3.58) [99]. RCT evidence for quercetin found no effect on blood lipids [91,93], glycemic or insulin metabolism [95], other measures of inflammation [96,98] or adiposity [92] (Table S6).

The strongest evidence for the health effect of flavonols and flavonols sub-classes was for improved blood pressure (cause-and-effect relationship established, large effect size, GRADE: low to high), cholesterol (cause-and-effect relationship established, small effect size, GRADE: low to high), blood glucose (cause-and-effect relationship established, small effect size, GRADE: medium) and risk of CVD or CHD mortality (dose–response relationship, very large effect size, GRADE: medium) and stroke (dose–response relationship, moderate to large effect size, GRADE: very low) (Figure 2).

2.9. Health Effects of White Bioactive Pigments in Fruits and Vegetables

The evidence for the health effects of white bioactive pigments were from MAs reporting on flavones. All n = 19 MAs for flavones were based on cohort data (1–24 years duration) as measured via the diet (n = 13 MAs) or mixed sources (n = 6 MAs), and two MAs were dose–response analyses (Tables S1 and S7). The highest category of flavones was associated with a decreased risk of all-cause (RR 0.86; 95% CI 0.80, 0.93) and CVD mortality (RR 0.85; 95% CI 0.75, 0.96) [84], breast cancer (RR 0.81; 95% CI 0.68, 0.96) [83,84], CHD (RR 0.94; 95% CI 0.89, 0.99) [74], esophageal cancer (OR 0.78; 95% CI 0.64, 0.95) [87], liver cancer (RR 0.49; 95% CI 0.30, 0.78) [84] and smoking-related cancer (OR 0.77; 95% CI 0.69, 0.85) [80] (Table S7). In dose–response MAs, for each 1 mg/day increase in flavones, the risk of CVD mortality decreased by 7% (RR 0.93; 95% CI 0.90, 0.97) [84]. No differences were found for hypertension [86], risk of CVD [76], risk of T2DM, or risk of colorectal [79], lung [82,84], ovarian [84], pancreatic [84] or prostate cancer [88] (Table S7).

The strongest evidence for the health effect of flavones was for decreased risk of all-cause and CVD mortality (dose–response relationship, moderate to large effect size, GRADE: very low to low), liver cancer (very large effect size, GRADE: medium) and smoking-related cancers (moderate effect size, GRADE: medium) (Figure 2).

2.10. Health Effects of Purple/Blue Bioactive Pigments in Fruits and Vegetables

Purple/blue bioactive pigments were contributed to by anthocyanidins, anthocyanins, proanthocyanidins and proanthocyanins.

2.10.1. Anthocyanidins

All n = 7 MAs examining anthocyanidins were based on cohort data derived from the diet (n = 2 MAs, 4–20 years duration) or mixed sources (n = 5 MAs, 4–16 years duration). The highest and lowest categories were not defined, but the single dose–response MA analyzed effects per 10 mg/day (Tables S1 and S8).

Higher anthocyanidin serum levels were associated with an 11% decrease in both all-cause (RR 0.89; 95% CI 0.85, 0.94) and CVD mortality (RR 0.89; 95% CI 0.83, 0.95). In dose–response MAs, for each 10 mg/day increase in anthocyanidins the risk of CVD mortality improved by 6% (RR 0.94; 95% CI 0.88, 0.99) [73]. Greater anthocyanidin intake was also associated with a 32% decreased risk of colorectal cancer (RR 0.68; 95% CI 0.56, 0.82) [79], 14% decreased risk of T2DM (HR 0.86; 95% CI 0.81, 0.91) [78], but a 12% increased risk of prostate cancer (RR 1.12; 95% CI 1.03, 1.21) [88] (Table S8). No association was found for smoking-related cancer [80].

2.10.2. Anthocyanins

Most anthocyanin research was based on RCTs (n = 67 MAs) derived from diet (n = 19 MAs of 3-days to 6-weeks duration; dose not reported), mixed sources (n = 32 MAs of 4-h to 6-months duration, dose 1.3–1025 mg/day) or supplementation (n = 16 MAs of 1–96 weeks duration, dose 1.6–1323 mg/day). The n = 14 cohort MAs measured anthocyanins from the diet (n = 11 MAs, 1–24 years duration, dose not reported) or mixed sources (n = 3 MAs, 5–41 years, dose not reported) (Table S8).

The highest category of anthocyanin intake was associated with a decreased risk of CVD (RR 0.82; 95% CI 0.70, 0.96) [76], CHD (RR 0.90; 95% CI 0.83, 0.98) [74], CVD mortality (RR 0.92; 95% CI 0.87, 0.97) [100], hypertension (RR 0.92; 95% CI 0.88, 0.97) [86] and esophageal cancer (OR 0.60; 95% CI 0.49, 0.74) [87]. However, no association was found with risk of stroke [100], or multiple cancers including breast, liver, lung, pancreatic or gastric [83,84,101] (Table S8).

Thirty-three of the n = 67 (49%) RCT MAs reported improved inflammatory, oxidative, lipid, or glycemic markers (e.g., adiponectin, apolipoprotein A1/B, CRP, fasting glucose, HbA1c, HOMA-IR, LDL and HDL cholesterol, interleukin-6, TNF-alpha, triglycerides, see Table S8 for full list) [26,101–104], as well as vascular reactivity (SMD 0.77; 95% CI 0.37, 1.16) [105] and BMI (SMD −0.36 kg/m^2; 95% CI −0.58, −0.13) [27]. No improvements were found for liver enzymes [106], uric acid, blood pressure [107], waist circumference [107], delayed onset muscle soreness [101] or vascular stiffness [105].

The strongest evidence for the health effect of anthocyanins and anthocyanidins was for improved inflammatory and oxidative stress biomarkers (cause-and-effect relationship established, small to large effect size, GRADE: very low to low), glycemic and insulinemic biomarkers (cause-and-effect relationship established, small effect size, GRADE: medium), lipid profiles and vascular function (cause-and-effect relationship established, small to large effect size, GRADE: very low to medium) and adiposity (cause-and-effect relationship established, small effect size, GRADE: low to medium) (Figure 2).

2.10.3. Proanthocyanidins

There were n = 11 MAs which reported on the effects of proanthocyanidins (n = 4 RCT MAs, n = 7 cohort MAs) (Table S1). Proanthocyanidin RCT MAs were all based on supplemental interventions of 100–400 mg/day delivered over 5 to 16 weeks. Cohort MAs were delivered over 4–16 years with unspecified categories of highest and lowest intakes, measured via diet (n = 3 MAs) or mixed sources (n = 4 MAs). One of the n = 7 cohort MAs was a dose–response analyses examining effects per 100 mg/day (Table S8).

The highest serum levels of proanthocyanidin compared with the lowest was associated with a 11% improvement in CVD mortality risk (RR 0.89; 95% CI 0.81, 0.97), but this was not significant in a dose–response analysis [84]. Higher status was also associated with a 28% decreased risk of colorectal cancer (RR 0.72; 95% CI 0.61, 0.85) [79]. No differences were found with risk of all cause-mortality, T2DM, breast cancer or esophageal cancer [73,78,87]. MAs of RCT evidence showed that supplemental proanthocyanidin (100–400 mg for 5–16 weeks) improved systolic (MD −4.60 mmHg; 95% CI −8.04, −1.16) and diastolic (MD −2.75 mmHg; 95% CI −5.09, −0.41) blood pressure and mean arterial pressure (MD −3.37 mmHg; 95% CI −6.72, −0.01), but not pulse pressure [108] (Table S8).

2.10.4. Proanthocyanins

The two MAs of proanthocyanins were based on cohort data and measured the highest dietary intakes compared with the lowest for up to 16 years, and found an inverse association with risk of CVD (RR 0.83; 95% CI 0.73, 0.95) [76] and CHD (RR 0.78; 95%CI 0.65, 0.94) [74] (Table S8).

The strongest evidence for the health effect of proanthocyanidins and proanthocyanins was for decreased blood and arterial pressure (large effect size, GRADE: high) (Figure 2).

2.11. Health Effects of Green Bioactive Pigments in Fruits and Vegetables

The health effects of consuming green bioactive pigments from FV were reported by single RCT and cohort evidence for chlorophyll. Ten of the seventeen health outcome measures reported for chlorophyll were based on RCT data (Sweden and Japan, 8–12 weeks of 0.7–3000 mg supplementation/day); the remaining seven were from cohort data (Netherlands, 9-years duration, highest undefined quintile) (Table S9). One RCT reported chlorophyll supplementation improved seasonal allergic rhinitis rescue medication scores (MD −3.09; 95% CI −5.96, −0.22) [109] and 3000 mg supplementation per day trended towards 1.5 kg weight loss; however, this appeared underpowered (p = 0.06, n = 36 participants) [110]. RCT evidence reported no effect on other measures of body composition or levels of insulin, glucose, or leptin [110]. Analysis of cohort data found no association between the highest intakes of chlorophyll and colorectal, colon or rectal cancer [111] (Table S9).

2.12. Health Effects Unique to Each Bioactive Pigment

Many health outcomes were improved by three or more bioactive pigments, such as a decreased risk of all-cause mortality with the highest intakes of lycopene, beta-cryptoxanthin, beta-carotene, alpha-carotene, lutein and zeaxanthin, flavones and anthocyanin/anthocyanidin (Figure 2). Other improved health outcomes which were associated with three or more bioactive pigment colors were body weight; total cholesterol/lipid profiles; inflammatory biomarkers; CVD, CHD, CVD mortality; stroke; T2DM; and multiple cancers including breast, oral, lung, prostate, bladder, colorectal/colon/rectal and gastric (Figure 2; Tables S2–S9).

Some health effects were unique to only one or two bioactive pigments or colors. Every FV bioactive pigment color had a single highly unique health effect which was not associated with any other pigment color, except red and yellow (Table 2). For example, only red bioactive pigments were associated with a decreased risk of pancreatic and laryngeal cancer, and only pale-yellow pigments were associated with improved exercise performance. All bioactive pigment colors also had other unique health effects that were associated with only two bioactive pigment colors. For example, decreased risk of cervical cancer was associated with only red and orange bioactive pigments, and decreased risk of esophageal cancer was only associated with white and blue/purple bioactive pigments (Table 2).

Table 2. Unique health effects of bioactive pigment colors found in fruit or vegetables.

Bioactive Pigment Color	Highly Unique Health Effects [a,c]	Unique Health Effects [b,c]
Red/orange/yellow	↑ cognitive function (GRADE: medium) ↓ risk of IHD (GRADE: very low) ↑ HDL cholesterol (GRADE: high) ↓ waist circumference (GRADE: low to medium)	
Red		↓ risk of cervical cancer (GRADE: very low) ↓ risk of lung cancer (GRADE: very low) ↓ risk of pancreatic cancer (GRADE: very low) ↓ risk of pharyngeal cancer (GRADE: very low to medium) ↓ risk of hip fracture (GRADE: very low) ↓ risk of laryngeal cancer (GRADE: very low to medium)

Table 2. *Cont.*

Bioactive Pigment Color	Highly Unique Health Effects [a,c]	Unique Health Effects [b,c]
Orange	↓ risk of preeclampsia (GRADE: very low) ↓ risk of total fracture (GRADE: very low) ↓ endometrial cancer (GRADE: very low)	↓ risk of non-Hodgkin lymphoma (GRADE: very low) ↓ risk of ovarian cancer (GRADE: very low) ↓ risk of cervical cancer (GRADE: very low) ↓ risk of pancreatic cancer (GRADE: very low) ↓ risk of cataract (GRADE: very low) ↓ risk of hip fracture (GRADE: very low) ↓ risk of laryngeal cancer (GRADE: very low to medium)
Yellow		↓ risk of non-Hodgkin lymphoma (GRADE: very low) ↓ risk of cataract (GRADE: very low) ↓ risk of pharyngeal cancer (GRADE: very low)
Pale-yellow	↑ exercise performance (GRADE: very low)	↓ risk of ovarian cancer (GRADE: low) ↓ risk of cervical cancer (GRADE: very low) ↓ blood pressure (GRADE: low to high) ↓ glycemic biomarkers (GRADE: medium) ↓ risk of smoking-related cancers (GRADE: very low)
White	↓ risk of liver cancer (GRADE: medium)	↓ risk of smoking-related cancers (GRADE: medium) ↓ risk of esophageal cancers (GRADE: very low)
Blue/purple	↓ risk of hypertension (GRADE: very low) ↓ oxidative stress biomarkers (GRADE: very low to low) ↓ insulinemic biomarkers (GRADE: medium) ↓ vascular function (GRADE: very low to medium) ↓ arterial pressure (GRADE: high)	↓ glycemic biomarkers (GRADE: medium) ↓ risk of esophageal cancers (GRADE: very low) ↓ blood pressure (GRADE: high)
Green	↓ seasonal rhinitis (GRADE: N/A)	

[a] A health effect was considered highly unique if it was found to be associated with a single bioactive pigment color. [b] A health effect was considered unique if it was found to be associated with only two bioactive pigment colors. [c] GRADE working groups of evidence: high = further research is unlikely to change our confidence in the estimated effect; medium = further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate; low = further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate; very low = we are very uncertain about the estimate.

Of the highly unique health effects (i.e., significant effect in a single color of FV), only four outcomes have been confirmed as being truly unique by being tested for association with three or more different bioactive pigments. Waist circumference, unique to carotenoids, was found not to be affected by anthocyanins nor flavonols; risk of hypertension, unique to anthocyanins, was found to have no association with flavones nor flavonols; risk of preeclampsia, unique to beta-carotene, was found to have no association with alpha-carotene, lutein nor lycopene; and risk of liver cancer, unique to flavones, was found to have no association with anthocyanins nor flavanols (Tables 2 and S2–S9). The remaining highly unique health effects reported in Table 2 were only tested for association with one or two bioactive pigments, and it is therefore unknown if they may be improved by other bioactive pigments also.

3. Discussion

This umbrella review synthesized an extensive body of evidence of the health effects of bioactive pigments from FV, representing 83 SLRS, 2847 original research studies (cohorts and RCTs), and data from over 37 million participants. This review found that many health outcomes were improved by consuming three or more bioactive pigments classes or subclasses, reinforcing the importance of total FV in the diet, irrespective of color [112,113]. However, this review found that color-associated variety in FV may confer additional health benefits beyond total FV intake. This finding is strengthened by the 2020 umbrella review by Wallace et al., which reported a non-linear relationship between higher total intake of FV and lower risk of chronic disease, with a threshold of about 5 serves or 800 g, beyond which further benefits were not observed [114]. Wallace et al., also reported additional benefits of certain types of vegetables which tended to have greater or more unique health effects, such as dark-green leafy vegetables and dark-colored berries. Whilst most dietary guidelines worldwide recommend consuming a variety of healthy food or a variety of FV specifically, only a limited number of national dietary guidelines specifically recommend FV should consumed in a variety of colors, including the Australian, Gabon, Polish, and several South and Central American countries (Argentina, Chile, Costa Rica, Dominican Republic, Grenada and Panama) [115]. This umbrella review provides novel evidence to support the revision of dietary guidelines internationally regarding optimal FV intake for population health.

Despite the magnitude of the data presented, the health benefits of bioactive pigments may extend beyond the current findings as treatment effects and outcomes not relevant to population health were excluded, and many unique health outcomes have not yet been tested via MA with any bioactive pigment, including dementia, depression and anxiety, and infectious disease. Some of the unique health effects were anticipated due to an understanding of the physiological actions, such as carotenoids which have a structural and functional role in vision [116]. There is emerging evidence that some health effects may be mediated through protein-flavonoid interactions [117,118], which may result in changes to enzyme activity, receptors, antibodies and transcription factors such as inhibition of xanthine oxidase [117,118]. As flavonoids include all colors of FV, further research on the flavonoid subclasses and minor subclasses is required to understand their mechanisms of action. Two-way interactions between polyphenols and microbiota may mediate some health effects through improvements in gastrointestinal barrier function, butyrate production and down regulation of genes associated with inflammation [119,120]. Although mechanisms of action for unique health effects beyond vision are less understood, the anti-inflammatory and antioxidant behavior of bioactive pigments are known to play a mechanistic role for many health outcomes [110,121,122]. Considering that all bioactive pigments demonstrate anti-inflammatory and antioxidant behavior, investigation into the mechanisms of action of the truly unique health effects of specific pigments is required.

Most outcomes presented had limited certainty that the pooled estimates represented the true effects (91% had a GRADE rating of very low or low), with the principal reason for downgrading confidence being observational study design. Although observational data provide a lower certainty in the evidence according to the GRADE system and do not imply causality, many dietary guidelines worldwide are underpinned by observational evidence, and the observational nature strengthens translation. Observational data are based on the usual intakes and behaviors of sample populations, thereby showing that the level of bioactive pigments required to have a significant health effect are achievable using existing food environments and systems. However, it must be acknowledged that many factors related to health, social and economic equity also determine the ability of an individual or population to consume the required bioactive pigment doses for a health effect [120,121]. This supposition is reinforced by the majority of included RCTs using supplemental bioactive pigments for intervention delivery, usually at doses unachievable through usual dietary intake, and are therefore unrealistic for translation to public health policy and health promotion activities. Observational data further strengthen the evidence by allowing the measurement of long-term outcomes such as disease incidence, which is often infeasible to measure in RCTs.

There were some outcomes in this review where a combination of both observational and RCT evidence allowed for stronger conclusions to be drawn. Specifically, observational research demonstrates implementation feasibility and impact on disease outcomes, where RCT evidence demonstrates causation via the measurement of related biomarkers. For example, RCT evidence demonstrated that anthocyanins improved the CVD biomarkers of cholesterol, inflammation and blood glucose while cohort evidence confirmed a lower risk of CHD, hypertension, and CVD mortality. This alignment of observational and RCT data for anthocyanins is important; as other dietary strategies have a misalignment, for example, wholegrains are associated with decreased risk of CVD, yet RCT evidence is yet to confirm causality via association with related biomarkers [122]. Finally, the downgrading of certainty in the evidence due to the observational nature of the data may underestimate the strength of some findings as prospective cohort data are recognized to be the highest level of evidence for prognostic outcomes such as disease incidence [123].

While this review identified substantial evidence for the beneficial effects of bioactive pigments from FV on many health outcomes, both divergent and negative health effects were also identified. Divergent findings were expected, due to both variations in dose, measurement type (dietary versus supplemental versus serum), follow-up duration, study design (e.g., cohort versus case–control versus RCT), power and risk of bias, being reported within and across SLRs for a particular health effect. Additionally, other unreported sources of variation are also expected such as dataset quality, validity of the measurement tools, and sample characteristics. For example, n = 3 MAs based on RCT data from n = 3 different SLRs reported on the effect of anthocyanins on CRP; however, only one reported a significant effect. Differences between the three MAs possibly explaining the divergent findings include different measurement type, study duration, sample size, and dose. Of the n = 449 included MAs, n = 4 (<1%) reported negative health effects. Three of these negative health effects were based on the supplementation of beta-carotene and mortality [124,125]; one was based on dietary anthocyanin intake and risk of prostate cancer [88]. Due to the lack of a known and plausible mechanism, the negative effect of dietary anthocyanin intake on risk of prostate cancer is likely due to a type I error which is unable be addressed using the false discovery rate in an umbrella review study design. This explanation is supported by a small effect size and the p-value being higher than many other included significant findings (p = 0.011, where 60% of significant p-values were <0.01). In contrast, the negative effect of beta-carotene supplementation on all-cause and CVD-mortality may not be subject to error. Whilst effect sizes were small, p-values were highly significant, and 95% CIs were precise. Further, there is a plausible mechanism of action as well as precedence. Supplemental versus dietary antioxidants are suggested to have differing bioavailability, biomechanics and outcomes. For example, supplemental beta-carotene has been associated with pro-oxidation and increased risk of lung and stomach cancer [62,126], whereas dietary sources had no effect on cancer risk [43].

3.1. Implications for Future Research and Practice

This umbrella review provides a theoretical basis for improved health outcomes if color-associated FV variety of is increased by populations, and presents the first high-level evidence to substantiate existing health promotional messages which recommend community members to "eat a rainbow" of FV [15,127–129]. Translational and interventional research is required to improve translation to policy and practice. Valid and reliable diet quality assessment tools are required to facilitate the measurement and quantification of color associated FV variety and bioactive pigments from FV in both the clinical and research settings. Such tools will support the focus on color-associated FV variety and bioactive pigments as well as allow for interventional and observational research to directly measure association with health outcomes. To further support translation to practice, increased measurement of bioactive pigments in diverse FV is required so that FV rich in a particular bioactive pigment relevant to an individuals' health goals can be recommended. Agricultural methods should continue be explored to maximize the bioactive pigment concentrations in various FV, and modifications to agricultural practices which have other goals (e.g., improved sustainability or yield) should also consider their impact on bioactive pigment concentrations. Additionally, the reductionist approach utilized in many food systems to decrease the variety of FV available for the purposes of streamlining production should be addressed via reintroduction of FV varieties no longer or rarely commercially available, e.g., yellow watermelon, white tomatoes, purple cauliflower or rainbow chard.

3.2. Limitations

The findings of this review have been strengthened by a strong study design and the utilization of validated and best-practice methodology. However, inherent limitations must be acknowledged to ensure conclusions are drawn in context. The findings of this review do not represent the entirety of the evidence for the effect of bioactive pigments on population-relevant health outcomes, as data were extracted for only the highest level of evidence available. Although the CCA methodology was used to prevent overlap, some overlap remains. For example, although original studies have low levels of overlap, it is possible that multiple original studies in the included SLRs drew upon the same datasets for their analyses. Additionally, while data from more than 37 million participants were extracted, a single participant may have contributed to two or more of the individual MAs (e.g., participant A included in MAs for the effect of both lutein and alpha-carotene on risk of T2DM). Conclusions are also limited to adults as no studies were found for children or adolescents. Each finding should be interpreted in the context of its' GRADE rating as well as the SLR characteristics including study type, measurement type, risk of bias and length of follow-up.

4. Materials and Methods

The study protocol was prospectively registered with the International Prospective Register of Systematic Reviews (PROSPERO, https://www.crd.york.ac.uk/prospero/ (accessed on 4 October 2021)); registration number: CRD42021276401, and has been reported according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 Statement [130].

4.1. Characterization of Natural Pigments

This review focused on the health effects of natural pigments that are responsible for the visible colors of FV. Four major classes of natural plant pigments have demonstrated bioactivity in humans: carotenoids, flavonoids, betalains and chlorophylls. Within each major pigment class there are distinct subclasses that have been associated with typical colors in plants and some minor sub-classes that have received further examination in the literature (Table 1).

4.2. Eligibility Criteria

Studies were deemed eligible if they satisfied the PICOS (Participant, Intervention, Comparator, Outcome, Study design) eligibility criteria described in Table 3.

Table 3. PICOS Eligibility Criteria.

PICOS Elements	Inclusion Criteria	Exclusion Criteria
Participant/ population	Humans	Animal and in vitro
Intervention/ exposure	Natural pigments found in fruits and vegetables that contribute to their visible color (as described in Table 1). The pigment must be: (1) consumed through whole fruit or vegetable; (2) extract from fruits or vegetables; or (3) provided as a supplement derived from fruits or vegetables. SLRs which included a mix of natural and synthetic bioactive pigments, or the derivation of the bioactive pigment was not described, were included.	Pigments within pharmaceuticals or synthetic forms. Pigments sourced from non-fruit or vegetable foods (e.g., nuts, soy, tea). Nutrients or phytonutrients that are not pigments and do not contribute to the visible color of the FV, but may be high in concentration in FV of a particular color (e.g., folate in green fruits and vegetables). Pigments delivered as a co-intervention or administered via non-oral routes (e.g., topical, aromatherapy, moxibustion).
Comparator	Placebo, presence of the pigment versus no pigment, or varying levels of the pigment (comparison of high versus low).	No control or comparator group. Alternative intervention.
Outcome	Health-related outcomes relevant to population health including the prevention of disease and optimization of disease risk factors, general wellbeing, function (cognitive function, physical function, and exercise performance), growth and development in children, maternal and neonatal health.	Biomarkers of pigment intake, disease treatment (e.g., cancer treatment), in-born errors of metabolism, biomarkers not related to disease prevention.
Study design/ source	SLRs with MAs of RCTs and/or cohort studies. RCTs and/or cohort studies if no eligible SLRs available. Case–control studies were included if based on longitudinal data.	SLRs without MAs, cross-sectional studies, single arm interventions, narrative reviews, expert opinion articles, or consensus guidelines. Studies unable to be translated into English via Google Translate or manual translation by multilingual colleagues.

MA, meta-analysis; RCT, randomized controlled Trial; SLR, systematic literature review.

4.3. Search Strategy

The electronic databases PubMed, EMBASE, CINAHL and Cochrane Library (Reviews and CENTRAL) were searched from inception to 29 October 2021, without restrictions (Tables S10–S12). The systematic search strategy was designed to include a combination of both controlled vocabulary (e.g., MeSH terms) and title and abstract keywords. The keywords repeated the controlled vocabulary terms if relevant, plus additional keywords specific to the topic. The search strategy was designed in PubMed and then translated to the other databases using Polyglot Search Translator [131]. Reference lists from umbrella reviews were also examined to identify any further relevant studies. References were imported into Endnote X9 reference management software (version X9.3.3, Clarivate Analytics, Philadelphia, PA, USA) and deduplication performed. Remaining records were uploaded to Covidence, a web-based systematic review software for screening (https://www.covidence.org/ (accessed on 29 October 2021)).

4.4. Selection Process

Two researchers independently screened records for potential eligibility using the title and abstract (MB and SM/HM). Full texts were retrieved for all potentially eligible studies and two researchers (MB and SM) independently assessed each study against the full eligibility criteria (Table 3). Any discrepancies between researchers were resolved by consensus. The inter-rater reliability between reviewers at full text review is summarized in Table S13.

If multiple meta-analyses (MAs) examined the same pigment and health outcome, the degree of overlapping of studies included in eligible meta-analyzed groups were assessed by calculating the corrected covered area (CCA) for each type of intervention [132]. If a

CCA was greater than 15% (very high overlapping), the meta-analysis (MA) with the largest number of total participants and/or the lowest statistical inconsistency/heterogeneity, as indicated by the I^2 or Chi-squared statistic, was selected.

4.5. Data Extraction

The following data were extracted from each study: study and participant characteristics, bioactive pigment name and color, intervention (type, duration, and dose), comparator (type, duration, and dose), number of meta-analyzed studies/intervention groups, model, meta-analyzed outcome, original research study design, original studies risk of bias, sample size (intervention/case, comparator/control, and total), effect size, confidence interval, *p*-value, heterogeneity, publication bias and the Grading of Recommendations Assessment, Development and Evaluation (GRADE) quality rating (if reported). The GRADE approach considers the internal validity and external validity of all studies reporting on a particular outcome so as to judge confidence in the estimated effect across the body of research [133]. As few original authors applied GRADE, current investigators (SM and MB) completed GRADE assessments for each extracted MA using information provided in the relevant SLRs or collated from individual RCTs/cohort studies reported by the SLR. GRADE was not applied to outcomes reported by included RCTs/cohort studies due to insufficient number of studies. Data were extracted into a Microsoft Excel (Version 1908; Excel for Office 365) spreadsheet by one researcher (MB or SM), checked for accuracy by another researcher (MB or SM).

During data extraction, included studies were assessed for methodological quality using the Oxford University, Centre for Evidence-Based Medicine (CEBM) critical appraisal tool for systematic reviews [134], RCTs [135] or prognostic studies [136]. Internal validity was assessed by determining if the study met multiple criteria (yes, no, or unclear), with a 'yes' judgment indicating good study quality and reduced risk of bias.

5. Conclusions

A potential benefit to population health was found to be associated with eating a rainbow of FV. High consumption of FV, irrespective of color or bioactive pigment concentration, was associated with many significant health improvements in adults; however, unique health benefits were found to be associated with individual bioactive pigments. Research to support both the measurement and recommendation of color-associated FV variety and specific bioactive pigments is needed to support translation to policy and practice.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/molecules27134061/s1, Table S1. Summary of the number of SLRs and MAs included in this umbrella review, by bioactive pigment sourced from fruit or vegetables and heath outcome; Table S2. Meta-analysis results of included SLRs for the health effects of total carotenoid pigments found in fruit and vegetables; Table S3. Meta-analysis results of included SLRs for the health effects of red pigments found in fruit and vegetables; Table S4. Meta-analysis results of included SLRs for the health effects of orange pigments found in fruit and vegetables; Table S5. Meta-analysis results of included SLRs for the health effects of yellow pigments found in fruit and vegetables; Table S6. Meta-analysis results of included SLRs for the health effects of pale-yellow pigments found in fruit and vegetables; Table S7. Meta-analysis results of included SLRs for the health effects of white pigments found in fruit and vegetables; Table S8. Meta-analysis results of included SLRs for the health effects of purple/blue pigments found in fruit and vegetables; Table S9. Results of included RCTs and cohort studies for the health effects of green pigments found in fruit and vegetables; Table S10: PubMed systematic search strategy to identify umbrella reviews and systematic literature reviews of meta-analyses; Table S11. Systematic search strategy for EMBASE, CINAHL and Cochrane Library; Table S12. Secondary systematic search strategy for chlorophyll studies in PubMed, EMBASE, CINAHL and Cochrane Library; Table S13. Inter-rater reliability between reviewers at full text review.

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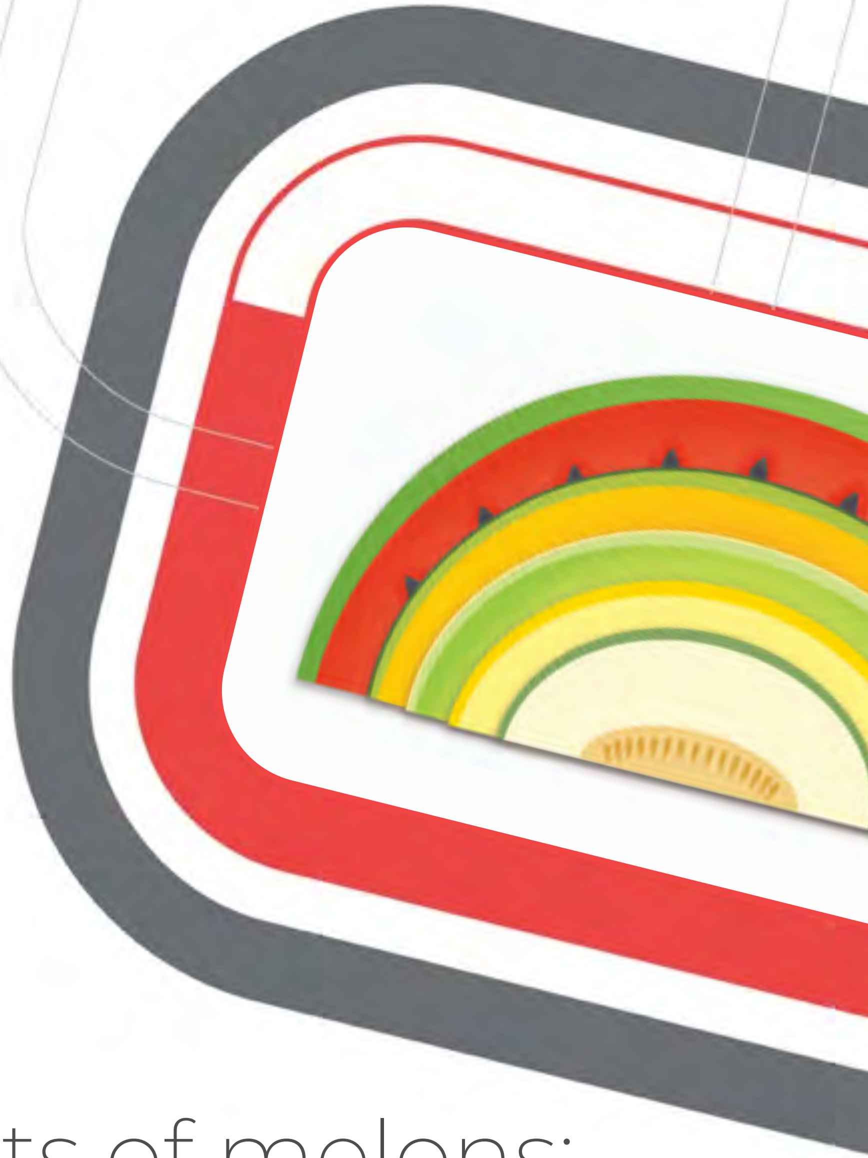
APPENDIX 4



Health benefits of melons:

Technical report

Prepared for:

Horticulture Innovation Australia Ltd
July 2022

Prepared by:

Nutrition Research Australia Pty Ltd

Contents

Executive Summary

Hort Innovation commissioned NRAUS to undertake research on the nutrition and health benefits of melons. The research is to be used to educate health care professionals and to assist with the development of communication messages. The project focuses on the ability of melons to provide a range of colour-associated nutrients and bioactives. The specific Australian melons covered in the project are watermelon, rockmelon, honeydew melon, and Piel de Sapo.

The technical report aimed to develop key messages by bringing together information from three areas:

- The NUTRITIONiQ™ scientific literature database, containing relevant scientific literature specific to Australian melons and their nutrition and health benefits.
- A systematic literature review covering the health benefits associated with colour-associated bioactive pigments.
- A Meltwater media search.

A schematic summary of this approach is shown in **Figure 1**. A subset of key messages aligning with the Food Standards code were also identified.

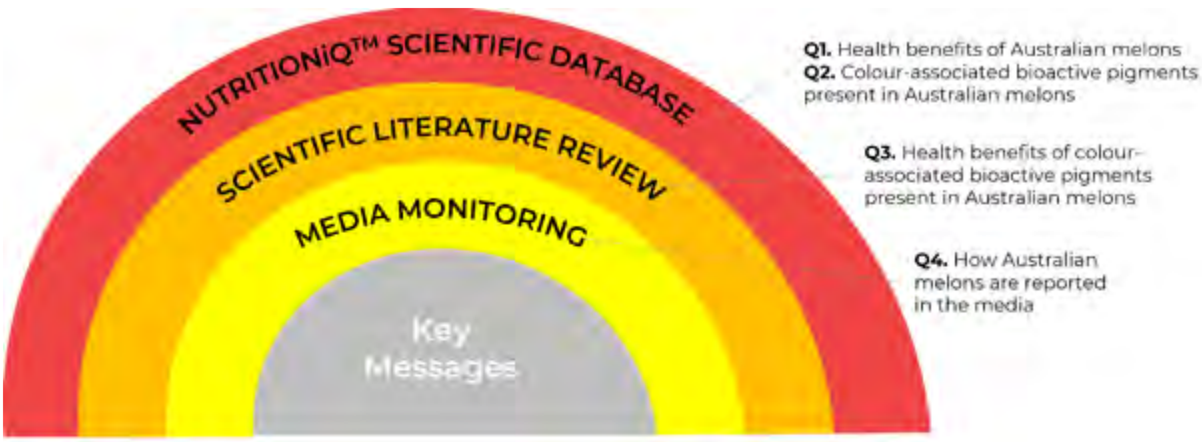


Figure 1. The approach used to produce key messages communicating the nutrition and health benefits of melons.

Key messages

Melons and health

All human research on the health effects associated with Australian melons was specific to watermelon; no human studies investigating the health benefits of other melon types were identified.

- The consumption of at least two servings of watermelon per day for 4 weeks is associated with a range of health benefits including improvements in markers of cardiovascular health, metabolic health, and exercise performance.
- Melon by-products show potential health benefits in emerging research conducted in animals or cultured cells for markers of cardiovascular (watermelon rind) and metabolic (watermelon seeds) health, the prevention of infection (watermelon rind and seeds), liver health and oxidative stress (watermelon seeds), gut microbiota composition (watermelon rind), and the inhibition of cancer cell growth (watermelon rind, rockmelon peel and seeds, and honeydew melon seeds).
- These health benefits are attributed to the bioactive composition of melon and its by-products, including colour-associated bioactive pigments.

Colour-associated bioactive pigments in melons and their by-products

Melons (watermelon, rockmelon, honeydew melon, and Piel de Sapo) and their by-products contain colour-associated bioactive pigments that are **red, orange, yellow, white**, and **green**.

These pigments are associated with a range of health benefits:

- Watermelon flesh: red bioactive pigments lycopene and beta-cryptoxanthin, which are associated with reduced risks for cardiovascular disease, a range of cancers, and type 2 diabetes mellitus.
- Honeydew and rockmelon flesh: orange bioactive pigment beta-carotene, which is associated with reduced risks for a range of cancers, mortality, type 2 diabetes mellitus, and bone fractures, and a decreased incidence of pre-eclampsia in pregnant women.
    - Beta-carotene is also present in watermelon rind and seeds.
- Watermelon and rockmelon flesh: white bioactive pigments called flavones, which are associated with a reduced risk for a range of cancers, as well as mortality, type 2 diabetes mellitus, and cardiovascular disease.
- Watermelon and rockmelon flesh: total carotenoids, which have been associated with decreased risk factors for obesity, type 2 diabetes mellitus, and coronary heart disease, and improved cognitive function.
- Green honeydew melon and Piel de Sapo melon flesh: chlorophylls, green bioactive pigments found to relieve symptoms of seasonal allergic rhinitis.
    - Chlorophyll is also present in watermelon rind and seeds.

Takeaway

Australian melons and their by-products play a role in supporting a wide range of health outcomes, including cardiovascular disease, type 2 diabetes, cognitive function, and bone fractures, by providing **red, orange, yellow, white,** and **green bioactive pigments** to a diet that contains a variety of colours of fruits and vegetables.

Background

The brief

Hort Innovation commissioned NRAUS to undertake the project "Educating Health Care Professionals on Australian Melons." The project will develop unique, credible, and impactful communication messages that highlight the unique nutrition and health benefits of melons via an education strategy targeted toward healthcare professionals (HCPs). The Australian melons covered by the project are watermelon, rockmelon, honeydew melon, and Piel de Sapo.

The overall objectives of this 3-year project are to:

- Establish Australian Melons as a fruit that can provide a range of colour-associated nutrients and bioactives required to achieve optimal health and wellbeing.
- Increase the awareness and knowledge of HCPs on the nutrition and health benefits of melons and empower them to recommend melons to clients.

The technical report

The purpose of the technical report is to establish the evidence for the health benefits of Australian melons, to communicate to HCPs. Three sources of information were utilised in this report:

- The NRAUS NUTRITIONiQ™ database, which was set up to obtain relevant scientific literature specific to melons and their nutrition and health benefits;
- A systematic literature review conducted by NRAUS as part of this project, investigating the health benefits associated with colour-associated bioactive nutrients present in melons; and
- The media monitoring database Meltwater, to determine how melons are reported in the media.

Research Questions:

1. What are the health benefits associated with the consumption of Australian melons?
2. What are the health benefits associated with the consumption of Australian melon by-products (rind, skin/peel, and seeds)?
3. What colour-associated bioactive compounds are present in Australian melons and their by-products?
4. What are the health benefits of the colour-associated bioactive compounds present in Australian melons?
5. How are Australian melons reported in the media?

Approach

A summary of the methodology used for each stage is provided below.

NUTRITIONiQ™ (NiQ™) Scientific Database

Which studies were included?

To develop the NUTRITIONiQ™ melons literature database, three databases (PubMed, EMBASE, and SCOPUS) were searched on November 12th, 2021, with no date restrictions. Search terms relating to melons and human health outcomes were identified in a scientific brainstorming session by the NRAUS team, and included terms related to melons such as "watermelon", "muskmelon", "rockmelon", and "*Citrullus lanatus*", as well as terms related to health and nutrition such as "nutrient", "vitamin", "mineral", "bioactive", "health", and "cardiovascular". A supplementary search using only the melons-related search terms restricted to the previous 12 months was also conducted to ensure that all recent scientific literature related to melons was captured.

A full list of the search terms and technical details about the search strategy are provided in **Appendix 1**.

Which studies were selected?

Studies included in the NiQ™ database were screened by title, abstract, and then full text, to determine their relevancy to the research questions. Any studies relating to Australian Melons (watermelon, rockmelon, honeydew melon, and Piel de Sapo melons) were considered for inclusion in the NiQ™ database. All study types (including clinical, pre-clinical, and *in vitro*) were considered, providing the material was directly related to human health and nutrition. Papers relating to production, harvest, and post-harvest handling were included only if there was a direct translation related to human health and nutrition or are otherwise of interest to the current education campaign. Evidence related to the edible portion (flesh), as well as melon by-products (the rind, skin/peel, and seeds) were included.

How were studies evaluated?

For each study selected, data were extracted and summarised in a narrative manner, following organisation according to melon type, bioactive nutrients, and health outcomes. Findings for each health outcome were graded according to the average level of evidence of all study types included for that health outcome. The level of evidence was which graded according to their level of accuracy as follows, based on the National Health and Medical Research Council (NHMRC) framework (1),:

- **High:** Systematic literature review of randomised controlled trials (RCTs) or cohort studies.
- **Moderate to high:** RCTs.

- **Moderate:** Non-randomised controlled trials and controlled prospective cohort or case-control studies.
- **Low to moderate:** Cross-sectional or case study, or intervention study without concurrent controls.
- **Low:** Pre-clinical research, including animal and *in vitro* studies.

Pre-clinical studies are not normally included in the NHMRC framework but were added due to being a predominant study type used for investigating mechanisms and emerging research associated with the nutrition and health benefits of melons.

Systematic Literature Review (SLR)

The purpose of the systematic literature review was to synthesise the evidence on the health effects of a variety of colour-associated bioactive pigments found in fruits and vegetables, including melons, in humans. The SLR was focused on the health effects associated with bioactive pigments due to there being insufficient evidence for a SLR on the health effects associated with melons. The SLR was carried out by combining individual data from published SLRs and meta-analyses (MAs), which is a quantitative synthesis of results from a SLR and the highest level of scientific evidence available.

The methods used for the SLR were of high scientific credibility and followed the standard procedures according to the Preferred Reporting Items for Systematic reviews and Meta- Analyses (PRISMA) 2020 Statement (2). Detailed methods can be found in the full manuscript, which is provided as **Appendix 2**. The SLR is titled "Should we 'Eat a Rainbow'? An umbrella review of the health effects of colourful bioactive pigments in fruits and vegetables" and was accepted for publication on 13 June 2022 in the journal *Molecules*.

Which studies were included?

Studies were included if they:

- Were SLRs with MAs of RCTs and/or cohort studies in the first instance.
    - Individual RCTs and/or cohort studies were included if no eligible SLRs available.
    - Case-control studies were included if based on longitudinal data.
- Were in humans.
- Included natural pigments found in fruits and vegetables that contribute to their visible colour.
- Compared to a placebo, presence of the pigment versus no pigment, or varying levels of the pigment (comparison of high versus low).
- Investigated health-related outcomes relevant to population health, including the prevention of disease and optimisation of disease risk factors, general wellbeing, function (cognitive function, physical function, and exercise performance), growth and development in children, maternal and neonatal health.

How were studies found?

A systematic search of the PubMed, EMBASE, CINAHL and CENTRAL electronic databases was conducted on 20th October 2021, without date limits. Reference lists from systematic literature reviews were also examined to identify any further relevant studies. Studies were screened for inclusion using Covidence, a web-based systematic review software (https://www.covidence.org/). Screening (title and abstract, followed by full-text) was performed by two independent researchers.

What information was extracted from the studies?

The following data were extracted from each study:

Study and participant characteristics, bioactive pigment name and colour, intervention (type, duration, and dose), comparator (type, duration, and dose), number of meta-analysed studies/intervention groups, model, meta-analysed outcome, original research study design, original studies risk of bias, sample size (intervention/case, comparator/control, and total), effect size, confidence interval, p-value, heterogeneity, publication bias, and the Grading of Recommendations Assessment, Development and Evaluation (GRADE) quality rating (if reported). Data were synthesised in a narrative manner.

Each health outcome was evaluated for certainty via the GRADE system.

The GRADE approach considers the validity of all studies reporting on a particular outcome to judge the overall level of confidence in the effect found across the body of research (3). Where original study authors did not apply the GRADE system, the researchers of this SLR completed GRADE assessments for each meta-analysis using information provided by or reported in the SLR or its individual studies. The included studies were also assessed for methodological quality using the Oxford University, Centre for Evidence-Based Medicine (CEBM) critical appraisal tools (4-6).

Media Monitoring

The Meltwater media monitoring software (www.meltwater.com) was used to capture a snapshot of how melons are reported in the media. Media included printed articles published in Australia and New Zealand, and the social media platforms Twitter, YouTube, and Facebook, without geographic limitations. Searches were conducted on November 29th, 2021, and March 28th, 2022.

What was searched?

Search terms included: (watermelon OR “rock melon” OR rockmelon OR cantaloupe OR “piel de sapo” OR “honeydew melon”) AND (food OR fruit) AND (nutrition OR nutrient OR science OR taste OR flavour OR health OR antioxidant). A keyword analysis was conducted to identify trending themes in both printed and social media. Posts and articles with the highest reach and engagement were reviewed.

Results

Q1. What are the health benefits associated with the consumption of Australian melons?

All research identified was specific to watermelon. There were no studies investigating the health benefits of other melons.

Watermelon fruit and/or juice was found to have beneficial effects on:

- Cardiovascular health
- Metabolic health
- Exercise performance

In addition, there were:

- No benefits on cognitive function (from a single study)
- Potential adverse effects in those who suffer from migraines (low to moderate level evidence).

An overview of the key findings by each health outcome, including the grading according to level of evidence for each, is tabulated in **Table A2, Appendix 3**.

Cardiovascular health

Key findings

- Evidence from 6 studies on watermelon consumption (fruit or juice).
- Four RCTs, one non-randomised controlled trial, and one non-controlled intervention study.
- Consistent benefit of daily watermelon consumption on cardiovascular disease risk factors.
- The overall strength of the evidence was rated as moderate to high.

Improved markers of cardiovascular health in those with dyslipidemia (7) (a major risk factor for cardiovascular disease) and in those overweight or obese (8) with the daily consumption of **watermelon fruit:**

- Reduced total cholesterol (by around 8%), LDL cholesterol (up to 20%), and blood triglycerides (by around 15%) (7, 8).
- Inconsistent effects on HDL cholesterol, with either no change (7), or increased levels (8).
- Decreased systolic blood pressure (by 3%) (8).
- No change in very LDL-cholesterol levels (7) or the inflammatory marker C-reactive protein (CRP) (8).
- Doses ranged from 300 g to 1.04 kg every day for 4 to 6 weeks.
    - As one serve of fruit is considered to be 150 g in the Australian Dietary Guidelines (9), this amount equates to **2 to 7 serves of watermelon.**

Benefits for blood vessel health (10, 11) and blood pressure (11, 12) in healthy men and women with the daily consumption of 500 to 710 mL **watermelon juice**:

- Increased flow-mediated dilation (FMD, the widening of an artery when blood flow increases in that artery), a marker of vascular health, by 55% after 2 weeks or 3.7% after one dose (10, 11).
- Improved microvascular blood flow and oxygen delivery to the muscle (tissue oxygen saturation, or StO_2) (10).
- Decreased systolic blood pressure by 2.4 mmHg to 2.9 mmHg (11, 12).
    - No effects on diastolic blood pressure.
- As one serve of juice is considered to be 125 mL (9), this amount equates to 4 to 6 serves of watermelon juice.

No effects on flow-mediated dilation (FMD) (13), a technique used to measure the health of the blood vessels, after a single dose of watermelon flesh.

- FMD was measured in the 7 hours immediately following the one-time consumption of 100 kcal of watermelon (around 300 g).

What are the possible underlying mechanisms?

These benefits have been attributed primarily to the activity of bioactive molecules present within watermelon (7, 8). They are:

- **Citrulline and arginine**, which support the production of nitric oxide (NO), a vasodilator that increases blood flow and subsequently reduces blood pressure (7).
- **Lycopene and beta-carotene**, members of the carotenoid family of colour-associated bioactive pigments, which have strong antioxidant and anti-inflammatory activity.
    - Oxidation (the formation of free radicals) and inflammation have been found to play key roles in the development of cardiovascular disease, and both lycopene and beta-carotene have been suggested to be potential treatment molecules (14).

These mechanisms have been investigated in **animal studies**:

- In rats, 9 weeks of watermelon powder led to improvements in blood lipids, antioxidant capacity, and inflammation, compared to control (15).
    - These results were driven in part by changes in the expression of key genes involved in reducing oxidative stress, such as antioxidant enzymes.
    - The human equivalent dose of fresh watermelon is around 500 g per day.
- In obese mice fed a high-fat diet, 10 weeks of watermelon led to changes in the expression of genes involved in liver function, inflammation, the stress response, and fat-burning (16).
    - The amount of watermelon fed was reflective of typical levels of human consumption.

Key messages: Watermelon and cardiovascular health

- The daily consumption of at least 300 g watermelon or 500 mL watermelon juice for at least 2 weeks may be beneficial for cardiovascular health by:
  - Reducing blood pressure (around 3%);
  - Reducing blood lipids (up to 20%); and
  - Improving markers of vascular health by 55%.

- This is most likely due to bioactive components present within watermelon:
  - Citrulline and arginine, which increase the production of the vasodilator nitric oxide;
  - Lycopene and beta-carotene, colour-associated bioactive pigments with antioxidant and anti-inflammatory activity.

Metabolic health

Key findings

Results from a single 2019 RCT (moderate to high level evidence) on overweight and obese subjects (8), found an overall beneficial effect of watermelon on metabolic health.

The consumption of 2 daily cups of watermelon (around 300 g, or 2 serves) for 4 weeks decreased biomarkers associated with risk for metabolic issues, and increased satiety, compared to low fat cookies containing the same amount of energy (calories) in 33 overweight or obese subjects.

- Increased fullness, and decreased hunger, prospective food consumption, and desire to eat, up to 50%.
    - This was attributed to the increased water consumption compared to control.
    - There was no effect on the production of appetite regulating hormones.
- Significant decreases in body weight (1 kg), BMI (0.3 kg/m^2), the waist to hip ratio (0.012), and body fat percentage (0.2%), compared to the low fat cookie control.
- Reduced levels of oxidative stress (by around 33%) and increased total antioxidant capacity (by around 25%) compared to baseline, which were not observed with the control.
- There were no differences in blood glucose or insulin levels, inflammatory markers (such as CRP), or markers of liver function.

What are the possible underlying mechanisms?

The beneficial effects have been attributed to the arginine and citrulline content of watermelon (7, 8), as well as the presence of the antioxidant and anti-inflammatory carotenoids lycopene and beta-carotene, as well as vitamin C (17).

- Arginine has been found to increase the breakdown of fats and glucose to reduce blood glucose levels and improve dyslipidemia, as well as reduce fat mass in obese diabetic animals [43].
- Citrulline is converted into arginine in the body and both also support the formation of nitric oxide (NO), which can reduce oxidative stress by scavenging free radicals (8).
- Lycopene, beta-carotene, and vitamin C have antioxidant and anti-inflammatory activity which has been suggested to have a beneficial effect, since metabolic issues such as diabetes are characterised by high levels of oxidative stress and inflammation (17).

These mechanisms have been investigated in pre-clinical research:

- In rats with diabetes, watermelon juice showed potential for use in the management of diabetes (18):
    - Reduced fasting blood glucose and blood lipids.
    - Showed antioxidant and anti-inflammatory properties and increased the activity of antioxidant enzymes.

- Inhibited enzymes involved in the digestion, absorption, and metabolism of starch and sugar.
- The dose of watermelon juice was from 500 to 1000 mg per kilogram of bodyweight, which is within reasonable levels of human intake.
- These effects were attributed to the presence of beta carotene, citrulline, vitamin C and lycopene.

- A 2019 SLR of eight pre-clinical studies, both watermelon extract and the bioactive compound citrulline reduced blood glucose (n=4, 50% of studies) and decreased markers of inflammation (n=2, 25% of studies).
  - There were inconsistent results for insulin levels, with some studies showing a reduction in insulin, some studies showing an increase in insulin, and others having no effect.
  - The amount of citrulline found to produce beneficial effects was equivalent to doses between 523 mg and 10 g per day in an adult human weighing 70 kg.
  - The citrulline concentration of watermelon ranges from 15 to 525 mg per 150 g serve, indicating that one serve of watermelon may have beneficial effects on metabolic health.
  - As these results are from animal studies, the results cannot be directly translated to humans and research in humans is needed to confirm the findings.

Key messages: Watermelon and metabolic health

- The daily consumption (at least 4 weeks) of around 300 g of watermelon may be beneficial for metabolic health by:
  - Decreasing body weight (by 1 kg);
  - Reducing oxidative stress (up to 33%); and
  - Decreasing appetite (up to 50%).

- Emerging evidence suggests that beneficial effects may start with as little as one serve (150 g) of watermelon per day.

- Benefits are most likely due to bioactive components present within watermelon:
  - Arginine, a molecule that has been found to support healthy blood glucose and lipid levels;
  - Citrulline and arginine, which increase the production of nitric oxide, a molecule that can reduce oxidative stress;
  - Lycopene, beta-carotene, and vitamin C, all of which possess antioxidant and anti-inflammatory activity.

Exercise performance

Key findings

- Evidence from two RCTs on watermelon, either as puree or juice, were shown to benefit markers of exercise performance.
- Benefits for antioxidant capacity and molecules related to increased blood flow, but there was no increase in exercise performance or recovery.
- The level of evidence was moderate to high, although the quantity of evidence was limited (2 RCTs).

Supports markers of exercise performance
Watermelon puree (980 mL, or 7 serves per day for 2 weeks) was able to support markers of exercise performance in a 75 km cycling time trial in comparison to a standard carbohydrate drink (19).

- Compared to the carbohydrate control, watermelon:
    - Increased antioxidant capacity (around 10%).
    - Increased blood levels of L-citrulline (up to 300%), L-arginine (around 100%), and nitrate (up to 40%), indicating a greater potential for oxygen delivery to the muscles.
    - Increased perceived level of exertion (by 4%, a subject's perception of how difficult the exercise was) compared to carbohydrate.
        - This was suggested to be due to the higher fibre content of the watermelon, which also increased feelings of fullness.
    - Had no influence on post-exercise inflammation and or immune function.

Improves exercise-induced blood pressure in females
Watermelon juice (355 mL, almost 3 serves) prevented the exercise-induced increase in both systolic and diastolic blood pressure in healthy non-athletic females, but not in males (20).

- Compared to three different controls: water; a Gatorade sports beverage; and sugar water.
- No change on heart-rate recovery time, lactic acid levels, or post-exercise muscle soreness.
- The reason for the difference between males and females was unclear but was suggested to include sex differences in the production of nitric oxide.
- Longer term supplementation or higher doses may be required to produce additional effects.

What are the possible underlying mechanisms?

Attributed primarily to the citrulline content of watermelon, as well as the colour-associated bioactive pigments lycopene and beta-carotene (12).

Support for the effects of citrulline can be observed in two RCTs (21, 22) where one dose (500 mL) of watermelon juice enriched with citrulline and antioxidants was found to:

- Increase peak force, reduce perceived exertion during lower-body resistance exercise, and reduce markers of muscle damage in male athletes (21).
- Reduce post-exercise muscle soreness and blood concentrations of lactate in amateur male runners (22).
- The citrulline content of the enriched watermelon juice was between 3.3 and 3.45 g.
    - As the citrulline concentration of watermelon ranges from 15 to 525 mg per 150 g serve (13, 23-26), at least seven serves of watermelon would be needed to elicit comparable results.
- Citrulline supports the formation of NO, which increases blood flow and therefore the supply of oxygen and more nutrients to the muscles, increasing VO2max, a measure of exercise performance.
- During exercise, an increased level of free radicals are produced which can lead to oxidative stress and inflammation, decreasing exercise performance (27).
    - The provision of antioxidant molecules, particularly those from whole foods, may help to alleviate oxidative stress and inflammation, improving exercise performance.
    - Lycopene and beta-carotene have antioxidant and anti-inflammatory activity (12).

Key messages: Watermelon and exercise performance

- Watermelon puree (980 mL, every day for 2 weeks) may be beneficial for markers related to exercise performance, such as:
    - Increasing the body's capacity to deal with oxidative stress by 10%; and
    - Increasing levels of molecules that promote blood flow (up to 300%).
- A one-time dose of watermelon juice (355 mL) may provide additional performance benefits by preventing exercise-induced increases in blood pressure.
- These effects are most likely due to the presence of citrulline and the colour-associated bioactive pigments lycopene and beta-carotene:
    - Citrulline increases the production of the vasodilator nitric oxide;
    - Lycopene and beta-carotene have antioxidant and anti-inflammatory activity.

Cognitive function

Key findings

2021 RCT involving 16 postmenopausal women found no effect of watermelon juice on cognitive function (28).

- Participants consumed two daily 360 mL servings (almost 6 serves) of watermelon juice for 4 weeks.
- While there was an 81% increase in blood levels of lycopene after the 4 weeks, there were no changes in cognitive function, inflammation, or oxidative stress.
- The mean daily provision of lycopene from the watermelon juice was 14.4 mg.

How might watermelon have had a benefit for cognitive function?

It was hypothesised that the lycopene content of watermelon would benefit cognitive function due to its antioxidant and anti-inflammatory function (28).

Key messages: Watermelon and cognitive function

- It has been proposed that watermelon may have benefits for cognitive function due to the presence of colour-associated bioactive pigments with antioxidant and anti-inflammatory activity, such as lycopene.
- Although watermelon juice consumption increases blood levels of lycopene, benefits for cognitive function have not been shown from a singular study.

Migraine

Key findings

Watermelon has been identified as a trigger food for migraines. A 2021 study (29) interviewed over 5000 migraine and/or tension-type headache patients, representing low to moderate level evidence.

- Watermelon was found to have the highest frequency of triggering headaches (29.5%), followed by passion-fruit (3.7%) and orange (2.9%).
- The effect occurred on average, 90 minutes after consumption.

How might watermelon be a trigger for migraine headaches?

The effect of watermelon on migraine headaches has been linked to the high citrulline content of watermelon, which increases the production of NO.

- NO is a vasodilator and has been proposed to be a key molecule involved in migraine and tension-type headaches by increasing blood flow and activating pathways involved in pain (30).

Key messages: Watermelon and migraine

- Watermelon has been identified as a major trigger for people who report migraine and tension-type headaches, with the highest frequency of triggering headaches (29.5%).
- This effect has been linked to the high citrulline content of watermelon, which increases nitric oxide production, blood flow, and the pain response.

Q2. What are the health benefits associated with the consumption of Australian melon by-products (rind, skin/peel, and seeds)?

Melon by-products include the rind, the skin or peel, and the seeds. A diagram highlighting each type of by-product, alongside melon fled (or pulp) is shown in **Figure 2.**

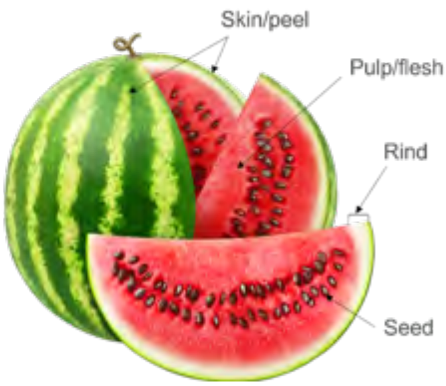


Figure 2. The components of Australian melons, including flesh and the by-products of skin/peel, rind, and seeds, shown here in watermelon. Figure reproduced from (31).

The majority of research identified was focused on watermelon by-products, with one study identified for each of rockmelon and honeydew melon by-products. There were no studies investigating the health benefits of Piel de Sapo by-products.

Overall, the findings suggest that melon by-products may have potential benefits on human health outcomes. However, the evidence underpinning these health benefits is predominantly emerging research of very low to low quality only. Only one study in humans (a RCT published in 2020 on markers of cardiovascular health (13)) was identified across all melon types. All other research was pre-clinical, conducted in either animals, cultured cells (animal and human), or in solution. In addition, the information on dose used in pre-clinical studies is, for the most part, not directly translatable to a human equivalent, due to there being vast differences between the environment of cultured cells and in the physiology, metabolism, and background diet of laboratory animals, compared to humans. In many cases, the melon by-product being studied was also produced and delivered as a powdered or dried extract with insufficient information available for the conversion this back to a fresh amount. Instances where the researchers have stated the human equivalent dose have been highlighted. Therefore, while the preliminary findings show promise, further research, including human clinical research, is required to confirm the observed effects and understand the relevant human dose.

The key findings are summarised by each health outcome, for each melon and by-product type, including the grading according to level of evidence for each, in **Table A3, Appendix 4**.

Watermelon by-products

Watermelon rind was found to have potential beneficial effects on:

- Markers of cardiovascular health
  - A bioactive carbohydrate isolated from watermelon rind showed the ability to inhibit the activity of the angiotensin I-converting enzyme (ACE) by up to 93% (32); this is the mode of action used by a number of medications to lower blood pressure.
  - In rats fed watermelon rind as 10% of their diet (equivalent to 10 g rind for every 100 g of diet) for 8 weeks, there was a decrease in both total cholesterol (by 16%) and LDL cholesterol (by 41%) compared to rats fed the control diet (33).
  - The consumption of a single dose of 100 calories of watermelon rind by overweight/obese subjects resulted in a significant increase in blood levels of citrulline (by approximately 3-fold) compared to control.
    - However, there was no effect on flow mediated dilation (FMD), a measure of vascular function in humans (13).

- Growth of cancer cells
  - A bioactive carbohydrate isolated from watermelon rind was found to inhibit the growth of human laryngeal carcinoma (cancer of the larynx) cells in a dose-dependent manner (2.5 to 10 µg/mL) and by up to 65% (34).

- Gut microbiota composition
  - Inclusion of 2.25% (equivalent to 2.25 g watermelon rind extract per 100 g diet) into the high-fat diet of obese mice for 10 weeks led to improvements in the gut microbiota, including an increase in the level of the beneficial microbe *Bacteroides* (35).
  - The composition of the gut microbiota returned to be comparable to that of mice fed a low-fat diet.

- Prevention of infection
  - A watermelon rind extract (500 mg/mL) showed the ability to inhibit the growth of a number of microbes, including *Staphylococcus albus, Micrococcus luteus,* and *Escherichia coli* (31).
  - The inhibition was comparable with that shown by a standard amount (30 µg/mL) of the antibiotic chloramphenicol.

In addition, there were inconsistent effects on:

- Markers of metabolic health
  - In three pre-clinical studies (16, 35, 36) of diabetic or obese mice fed a diet containing 1 to 2.25% (equivalent to between 1 g and 2.25 g per 100 g diet) watermelon rind for 4 to 10 weeks, there was:
    - Inconsistent effects on blood glucose (either a decrease or no change) and insulin (both increase and decrease); as well as
    - No change in bodyweight; but

    - A decrease in insulin resistance (by around 50%); and
    - Increased expression of genes involved in lipid metabolism.
  - In addition, a watermelon rind extract (60 mg/mL) showed potential ability to hinder the absorption of glucose into the bloodstream, via inhibiting the activity of the alpha-glucosidase enzyme up to 45% (37); alpha-glucosidase is responsible for breaking down carbohydrates in the gut.

- Markers of reproductive health
  - Rats fed 500 mg of watermelon rind extract/kg bw/day for 42 days were found to have an increased sperm count (by 78%), and increased levels of reproductive hormones (including testosterone, up to 10%) (38).
  - The watermelon rind also had a protective effect on oxidative damage in the testes caused by nicotine, by reducing levels of oxidative stress by around 20%.
  - However, there was a decrease in sperm motility by almost 30% and increased levels (over double) of abnormal sperm with the watermelon rind extract, which were not discussed by the authors.

Watermelon seeds were found to have potential beneficial effects on:

- Markers of metabolic health
  - In three pre-clinical studies (16, 39, 40) on mice or rats, seed oil or kernels were found to:
    - Decrease bodyweight (by 38%) and blood glucose (by 37%);
    - Increase glucose tolerance (by up to 20%); and
    - Increase the expression of genes involved in lipid metabolism.
  - Doses used included 2 to 5 mL seed oil/kg bw/day for 28 days, 9 g/day seed kernels for 28 days or 2.25% of diet (2.25 g seed extract per 100 g diet) for 4 to 10 weeks.
    - The 2.25% of diet dose was based on the use of common dietary fibre supplements in humans.
  - In addition, a watermelon seed extract (60 mg/mL) showed potential ability to hinder the absorption of glucose into the bloodstream, via inhibiting the activity of the alpha-glucosidase enzyme up to 45% (37); alpha-glucosidase is responsible for breaking down carbohydrates in the gut.

- Oxidative stress
  - Two pre-clinical studies in rats (40, 41) found that watermelon seed oil (2 or 5 mL/day for 28 days) or watermelon seed extract (500 or 1000 mg/kg bw/day for 65 days) was able to increase the activity of antioxidant enzymes up to 89%, including superoxide dismutase (SOD), catalase, and glutathione peroxidase (GSH-Px);
  - These benefits were also observed in hydrogen peroxide-damaged liver cells treated with 50 µL purified watermelon seed protein peptides (42), as well as increased cell viability (over 200%) and decreased levels of reactive oxygen species (by up to 60%), compared to damaged cells.

- Prevention of infection
    - In mice infected with the parasite *Toxoplasma gondii*, additional of a 1% watermelon seed mixture to the diet, in combination with the drug sulfadiazine, increased animal survival (from 22.6 days to 27 days) and the rate of cure (from 12.5 % to 27.5%), compared to drug alone (43).

- Liver health
    - Addition of watermelon seed extract (100, 200, 400, and 800 mg/kg bw) to the diet of mice with hepatic fibrosis for 8 weeks provided protection from liver damage, including lesions and necrosis, decreased oxidative lipid damage (by 48% at the highest dose), and increased the activity of the antioxidant enzymes SOD (by 37% at the highest dose) and GSH-Px (by 59% at the highest dose) (44).

In addition, there were inconsistent effects on markers of cardiovascular health:

- In rats fed 2 and 5 mL/kg bw/day seed oil or 9 g/day seed kernels for 28 days (39, 40), there was:
    - Decreased LDL cholesterol (up to 23%); but
    - No change in HDL cholesterol; and
    - Either no change or a decrease in total cholesterol and triglycerides; and
    - Either an increase or decrease in VLDL cholesterol.
- There was also no effect of the consumption of a single dose of 100 calories of watermelon seeds on flow mediated dilation (FMD), a measure of vascular function in humans (13).

How might watermelon by-products be producing beneficial effects on health?

The mechanisms suggested to underpin these beneficial effects are predominantly focused on the composition of watermelon by-products, including:

- Citrulline and arginine, which have vasodilatory and anti-diabetic activity;
- Bioactive compounds with antioxidant, hypoglycemic, hypolipidemic, antibacterial, and anti-tumour activity;
- Fibre and bioactives with prebiotic activity;
- A high proportion of linoleic acid, which has been associated with the control of blood glucose levels.
- A high ratio of unsaturated to saturated fatty acids, which has a protective effect on health.

Key messages: Watermelon by-products and health

- Watermelon rind was found to have potential benefits for markers of cardiovascular health, cancer, gut microbiota, and infection in predominantly emerging research.

- Watermelon seeds were found to have potential benefits for markers of metabolic health, oxidarive stress, liver health, and infection in emerging research.
    - For markers of metabolic health, the dose may be equivalent to the use of common dietary fibre supplements in humans.

- A single RCT in obese/overweight subjects found that watermelon rind was able to increase blood levels of citrulline, but neither rind nor seeds had an effect on flow-mediated dilation, a measure of vascular function.

- These benefits have been linked to the bioactive composition of watermelon by-products, which has shown antioxidant, hypoglycemic, hypolipidemic, antibacterial, and anti-tumour activity, as well as the high linoleic acid composition of watermelon seeds.

Rockmelon by-products

Rockmelon seeds and peel were found to have potential anti-tumour effects, by inhibiting the growth of cultured human cervical, colorectal, and kidney cancer cells (45).

- Rockmelon seed extracts (from 0.1 to 1.0 mg/mL) inhibited the growth of cervical cancer cells up to 90%, the growth of colorectal cancer cells up to 50%, and the growth of kidney cancer cells up to 75%, at the highest concentration.
- Rockmelon peel extracts (from 0.1 to 1.0 mg/mL) inhibited the growth of cervical cancer cells up to 80%, the growth of colorectal cancer cells up to 45%, and the growth of kidney cancer cells up to 75%, at the highest concentration.
- The anti-tumour effect was often dose-dependent (depending on the method of extraction and cell line) and was attributed to the presence of a range of biologically active phytocompounds with antioxidant activity.

Key messages: Rockmelon by-products and health

- Rockmelon peel and seeds were found to have potential anti-tumour activity in emerging research, inhibiting the growth of human cancer cells by up to 90%.
- This effect has been linked to the bioactive composition of rockmelon by-products, which has antioxidant activity.

Honeydew melon by-products

Honeydew melon seeds were found to have potential anti-tumour effects in four different lines of human cancer cells, in a dose-dependent manner.

- Honeydew melon seed extracts (from 0.05 to 0.45 mg/mL) inhibited the growth of cultured human cervical cancer cells up to 68%, colon cancer cells up to 80%, prostate cancer cells up to 68%, and leukemia cells up to 84%, at the highest concentration (46).
- The anti-tumour effect was attributed to the presence of a range of biologically active phytocompounds, predominantly polyphenols.

Key messages: Honeydew melon by-products and health

- Honeydew melon seeds were found to have potential anti-tumour activity in emerging research, inhibiting the growth of human cancer cells by up to 84%.
- This effect has been linked to the bioactive composition of honeydew melon seeds, which includes polyphenolic compounds.

Q3. What are the colour-associated bioactive pigments present in Australian melons and their by-products?

Summaries of the colour-associated bioactive pigments present in of each type of Australian melons, (including flesh and juice) and their by-products (peel/rind/skin and seeds), and the identified levels of each, are provided in **Table A4**, **Appendix 5** and **Table A5, Appendix 6,** respectively. Levels of other bioactive compounds such as citrulline, arginine, and vitamin C, are also presented.

Watermelon

Watermelons are represented in the literature as red/pink, orange, and yellow varieties, and as watermelon juice. Red/pink watermelon and watermelon juice contain several colour-associated bioactive pigments. Data were limited for orange and yellow watermelon.

<u>Red/pink watermelon flesh and juice contain:</u>

- **Carotenoids**, including lycopene and beta-carotene, in both the flesh (26, 47-49) and in watermelon juice (10, 11, 24, 28).
    - Levels of total carotenoids ranged between 4.9 to 8.06 mg/100 g in red/pink watermelon flesh (47).
    - Levels of beta-carotene were 0.30 mg/100 mL (10, 49).
    - Levels of lycopene ranged from 1 mg/100 g to 11.34 mg/100 mL (10, 11, 24, 28).
- **Vitamin A retinol equivalents**, at 48 µg/100 g for watermelon flesh (50).
- **Vitamin C,** at levels ranging from 0.4 to 8.6 mg/100 g or mL (26, 48-50).
- **Citrulline**, at levels up to 350 mg/100 g (25).
- **Lutein and zeaxanthin** at a level of 8 µg/100 g (49).
- **Flavones** (1.84 mg/100 g), a type of flavonoid (51).
- **Total polyphenols** at a moderate level in juice (16.94 to 20.23 mg/100 mL) (24, 48).
    - Levels of total polyphenols in fruit were not identified.

<u>Orange watermelon flesh contains:</u>

- **Lycopene** in small amounts (0.6 to 0.9 mg/100g) of (23).

<u>Yellow watermelon flesh contains:</u>

- **Vitamin C** in a comparable amount (5.2 mg/100 g) (48) to other melons.

<u>Watermelon rind or skin/peel contains:</u>

- **Beta-carotene,** at levels up to 0.23 mg/100 g rind extract (37, 52).
- **Lutein,** at 1.12 mg/100 g rind extract (37).
- **Chlorophyll,** at 2.64 mg/100 g rind extract (37).
- **Citrulline,** at levels ranging from 13 mg/100 g fresh weight (53) to 387.4 mg/100 kcal of rind (13, 54), and **arginine,** at 75.3 mg/100 kcal of rind (13, 54).

- **Vitamin C,** at a level of 5.35 mg/100 g fresh weight (52), or 7.23 mg/100 g rind extract (55).
- Other bioactive compounds including total phenols up to 0.87 mg/100 g rind extract (31) and **saponins, alkaloids,** and **triterpenoids** at unspecified amounts (31).

Watermelon seeds contain:

- **Beta-carotene,** at 0.21 mg/100 g seed extract (37).
- A higher level of both **lutein,** at 127.3 mg/100 g seed extract (37), and **chlorophyll**, at 788.0 mg/100 g seed extract (37), compared to watermelon rind.
- **Flavonoids** (1.9 mg/100 g ground seeds) (31, 40), including **tannins** (0.4 mg/100 g ground seeds) (40).
- The black/brown pigment **melanin,** at an unspecified amount (40).
- **Citrulline** and **arginine,** at slightly lower levels compared to watermelon rind, of 231.3 and 69.3 mg/100 kcal of seeds, respectively (13, 54).
- **Vitamin C,** at 6.8 mg/100 g seed extract (55).
- Other bioactive compounds including total phenols at 0.42 mg/100 g seed extract (31), **saponins at** 2.1 mg/100 g ground seeds (40), **alkaloids at** 1 mg/100 g ground seeds (40), and **triterpenoids** at an unspecified amount (31).

Honeydew melon

Honeydew melon was represented in the literature as either orange or green (flesh) varieties. Data were limited.

Both honeydew melon varieties contain:

- A notable level of **total polyphenols** (59.33 mg/100 g) (51) and **vitamin C** (7 to 34 mg/100 g) (49, 56-58).
- Carotenoids present as **vitamin A retinol equivalents**, at 9 µg/100 g (50).
- **Vitamin C,** at 12 mg/100 g (50).
- **Beta-carotene** with higher levels in orange honeydew melon (0.9 to 2.7 mg/100 g) compared to green honeydew melon (0.03 mg/100 g) (49, 56, 59).

Green honeydew melon contains:

- **Lutein and zeaxanthin**, at 7 µg/100 g (49).
- **Chlorophyll,** at 0.17 to 0.2 mg/100 g (60).

Honeydew melon peel contains:

- **Total phenols** at a level of 9.6 mg/100 g peel powder (61).

Honeydew melon seeds contain:

- **Rutin,** at a level of 191.6 mg/100 g seed extract (46), which belongs to the flavonoid group.

Rockmelon

There was a substantial amount of data related to the bioactive composition of rockmelon in the literature. Rockmelon was also referred to as cantaloupe.

- Source of **total carotenoids** (4.5 mg/100 g), predominantly beta-carotene (1.3 to 2.7 mg/100 g).
    - Small amounts of alpha-carotene (16 µg/100 g), and lutein, and zeaxanthin (26 µg/100 g) (49, 59, 62, 63).
    - The level of carotenoids present as **vitamin A retinol equivalents** was 130 µg/100 g, the highest of all melons (50).
- Source of **flavones** (2.58 mg/100 g) (51).
- **Lutein and zeaxanthin** at up to 1.3 mg/100 g (49, 60).
- Highest levels of **vitamin C** (up to 36.7 mg/100 g) (49, 50) compared to other melons.

Rockmelon peel contains:

- **Total flavonoids**, at up to 262.0 mg/100 g peel extract (45, 64) including **tannins**, at a level of 118.3 mg/100 g peel extract (64).
- **Polyphenols,** at 254.8 mg/100 g peel extract (64).
- Phenolic compounds, including **total phenols** up to 14.2 mg/100 g peel powder (45, 61) and **ortho-diphenols** at 178.6 mg/100 g peel extract (64).

Rockmelon melon seeds contain:

Reduced levels of bioactive compounds compared to rockmelon peel:

- **Total flavonoids** at 7.4 mg/100 g seed extract (64), and **tannins**, at 9.2 mg/100 g seed extract (64).
    - Not all tannins belong to the flavonoid group.
- **Polyphenols** at 15 mg/100 g seed extract (64).
- **Ortho-diphenols** at 9.2 mg/100 g seed extract (64).

Piel de Sapo melon

There were limited data related to the bioactive composition of Piel de Sapo flesh in the literature, and no data for Piel de Sapo by-products. While no information regarding carotenoids was identified, it is likely that Piel de Sapo contains carotenoids, given the levels found for the other melon varieties.

- Contains **total polyphenols** (22.1 mg/100 g) (65) and **vitamin C** (18.7 mg/100 g) (65).
- Contains **chlorophyll** in the fruit at 0.161 mg/100 g (65).

Q4. What are the health benefits associated with the colour-associated bioactive pigments present in Australian melons?

The health benefits associated with the colour-associated bioactive pigments present in fruits and vegetables (including Australian melons) can be found in the SLR performed by NRAUS titled: “Should we ‘Eat a Rainbow’? An umbrella review of the health effects of colourful bioactive pigments in fruits and vegetables”. The SLR was accepted on 13 June 2022 for publication in Molecules. The full manuscript is provided in **Appendix 2.** The SLR was performed to provide health benefits associated with the colour-associated bioactive pigments present in the flesh of Australian melons, to be communicated with healthcare professionals.

Overview

Health outcomes associated with multiple colour-associated pigments included improvements in body weight, lipid profile, inflammation, CVD, mortality, type 2 diabetes mellitus (T2DM) and cancer. Findings showed that colour-associated fruit and vegetable (FV) variety may confer additional benefits to population health beyond that of just total FV intake.

The colour-associated bioactive pigments covered by the systematic literature review included:

- **Carotenoids:**
  - Lycopene, beta-cryptoxanthin, capsorubin, and capsanthin (red)
  - Beta-carotene (orange)
  - Alpha-carotene, lutein, zeaxanthin, and violaxanthin (yellow)
- **Flavonoids:**
  - Anthocyanins/anthocyanidins (red, purple, and blue)
  - Aurones, chalcones, and flavonols (pale yellow)
  - Flavones (white)
  - Tannins (red, purple, blue, and brown)
- **Betalains**
  - Betacyanins and betaxanthin (red, violet, orange, and yellow)
- **Chlorophylls**
  - Chlorophyll a and chlorophyll b (green)

What does this mean for Australian melons?

The colour-associated bioactive pigments investigated in the SLR and relevant to Australian melons, including the dose of each bioactive pigment per serve (as defined by the Australian Dietary Guidelines) are shown in **Table 1.**

A summary of key findings of the systematic literature review for each colour-associated bioactive pigment present in Australian melons, as well as the dose associated with significant health effects for each, is presented in **Table A4**, **Appendix 5.** No findings were identified for tannins.

Table 1. Colour-associated bioactive pigments investigated in the systematic literature review for their effects on health and contained within Australian melons.

PIGMENT CLASS	PIGMENT SUBCLASS	TYPICAL COLOURS	MELON VARIETIES CONTAINING PIGMENT	DOSE PER SERVING[1,2]
Carotenoids	Total carotenoids	Red, orange, yellow	Watermelon (red/pink) Rockmelon	7.4 - 12.1 mg 6.8 mg
	Lycopene	Red	Watermelon (red/pink) Watermelon (orange) Watermelon juice	1.5 - 10.2 mg 0.9 - 1.35 mg 3.0 - 14.2 mg
	Beta-cryptoxanthin	Red	Watermelon (red/pink) Rockmelon	117 µg 1.5 µg
	Beta-carotene	Orange	Watermelon (red/pink) Watermelon juice Watermelon rind/seeds Honeydew (orange) Honeydew (green) Rockmelon	0.45 mg 0.36 mg N/A 1.3 - 4.1 mg 0.045 mg 1.9 - 4.0 mg
	Alpha-carotene	Yellow	Rockmelon	0.024 mg
	Lutein and zeaxanthin	Yellow	Watermelon (red/pink) Honeydew (green) Rockmelon	0.012 mg 0.041 mg 0.045 – 1.95 mg
Flavonoids	Flavones	White	Watermelon (red/pink) Rockmelon	2.8 mg 3.9 mg
	Tannins	Red, purple, blue, brown	Watermelon seeds Rockmelon peel/seeds	N/A N/A
Chlorophylls	Chlorophyll a/b	Green	Honeydew (green) Piel de sapo Watermelon rind/seeds	0.26 – 0.3 mg 0.24 mg N/A

[1] One serving is equivalent to 150 g for whole fruit and 125 mL for juice, based on the Australian Dietary Guidelines (9). Dose per serve values were calculated using the values (per 100 g) presented in **Table A3, Appendix 4.** References for dose values are equivalent to those cited in **Table A3, Appendix 4.**

[2] Serving information for melon peel, rind, and seeds was not considered applicable due to quantitative data being provided in the literature as a dry extract and not being translatable to levels of human consumption.

Total carotenoids (red, orange, and yellow pigments)

Total carotenoids had beneficial effects on obesity, T2DM, CVD, and cognitive function (evidence from 12 unique MAs).

Obesity and T2DM, and CVD

- Reductions in risk factors for obesity, T2DM, and CVD, including body weight (by 2.34 kg), BMI (by 0.95 kg/m^2), waist circumference (by 1.84 cm), total cholesterol (by 2.10 mg/dL), and increased HDL cholesterol (by 0.76 mg/dL), with consumption for up to 16 weeks (66).
  - Dose ranges associated with a beneficial effect were from 1.2 to 60 mg/day.
- 15% decreased risk for coronary heart disease in people consuming the highest amounts compared to those consuming the lowest amounts (67).

Cognitive function

- A modest improvement in cognitive outcomes with doses between 0.5 to 50 mg/day (68).

Key messages: Total carotenoids, health, and melons

- The daily consumption of the red, orange, and yellow bioactive pigments called carotenoids, at doses ranging from 0.5 to 60 mg/day, has beneficial effects for health, including:
  - Decreased risk factors for obesity and T2DM;
  - 15% reduced risk for coronary heart disease;
  - Improved cognitive function.
- Total carotenoids in line with these health benefits are provided by:
  - One serve of red/pink watermelon (7.4 to 12.1 mg/serve)
  - One serve of rockmelon (6.8 mg/serve).

Beta-cryptoxanthin (red pigment)

Beta-cryptoxanthin had beneficial effects on cancer, CVD, mortality, bone health, and T2DM.

Cancer

- In people consuming the highest amounts compared to those consuming the lowest amounts, there was:
    - 69% decreased risk of larynx cancer (69);
    - 64% decreased risk of oral cavity and pharynx cancer (69);
    - 42% decreased risk of bladder cancer (70);
    - 20% decreased risk of lung cancer (71).
- For lung cancer, the intakes representing the highest vs lowest intake diets were >56 to 371 µg/1000kcal/d vs <5 to <56 µg/1000kcal/d (71).
- No effect was found for risk of non-Hodgkin lymphoma (72), breast cancer (73), colorectal cancer (74), pancreatic cancer (75), or lung cancer mortality (71).

CVD

- A small reduction in blood levels of the inflammatory biomarker C-reactive protein (by 0.35 mg/L), after individuals consumed 6 mg beta-cryptoxanthin over 12-weeks (76).

Mortality

- 27% decreased risk of all-cause mortality (77) in people consuming the highest amounts compared to those consuming the lowest amounts.
    - Each 0.1 µmol/L increase in the blood level of beta-cryptoxanthin decreased the risk of all-cause mortality by 6% (77).

Bone health

- 28% decreased risk of hip fracture (78) in people consuming the highest amounts compared to those consuming the lowest amounts.
- No differences were found for risk of osteoporosis (78).

T2DM

- Every increase of 0.5umol/L in the serum levels of beta-cryptoxanthin decreased the risk of T2DM by 15% (79).

Key messages: Beta-cryptoxanthin, health, and melons

- The consumption of the red bioactive pigment beta-cryptoxanthin, at higher intakes or doses ranging from 0.15 to 6 mg/day, has beneficial effects for health, including:
    - Decreased risk for a range of cancers (up to 69%), all-cause mortality (27%), and T2DM (15%);
    - Reduced levels of inflammatory markers of CVD;
    - 28% decreased risk of hip fracture.

- Beta-cryptoxanthin in line with these health benefits is provided by:
    - One and a half serves of red/pink watermelon (117 µg/serve).

Lycopene (red pigment)

Beneficial effects were observed for some cancers, CVD, mortality, and T2DM.

Cancer

- Reduced risk for cervical (by 46%) (80), larynx (by 50%) (69), lung (by 29%) (71), oral cavity and pharynx (by 26%) (69), prostate (by 12%) (81), and breast (by 29%) cancers (73) in people consuming the highest amounts compared to those consuming the lowest amounts.
    - Strongest evidence for reduction in breast cancer risk.
- 12% reduction in the risk for prostate cancer (81) in people consuming the highest amounts compared to those consuming the lowest amounts, but no effect on advanced prostate cancer (81, 82), (83), or prostate specific antigen (PSA) levels (84), a blood marker for prostate cancer.
- No effect on colon/colorectal/rectal cancer (74), bladder cancer (70), gastric cancer (85), non-Hodgkin lymphoma (72), or ovarian cancer (83).

CVD

- Lower risk of CHD (by 13%) (86), CVD (by 14%) (87), and stroke (26%) (87), in people consuming the highest amounts compared to those consuming the lowest amounts.

Mortality

- Decreased risk of mortality (by 37%) (87) and all-cause mortality (by 28%) (77) in people consuming the highest amounts compared to those consuming the lowest amounts.

T2DM

- Decreased risk of T2DM (by 15%) in people consuming the highest amounts compared to those consuming the lowest amounts (79).
    - 17% decreased risk of T2DM with each 0.5umol/L increase in serum lycopene (79).

Key messages: Lycopene, health, and melons

- The consumption of the red bioactive pigment lycopene, at higher intakes or doses ranging from 2 to 18.2 mg/day, has beneficial effects for health, including:
    - Decreased risk for a range of cancers (up to 46%), mortality (37%), and T2DM (15%);
    - Benefits for cardiovascular health, with a lower risk of CHD (13%), CVD (14%), and stroke (26%).
- Lycopene in line with these health benefits is provided by:
    - At least one serve of red/pink watermelon (1.5 to 10.2 mg/serve).
    - One serve of watermelon juice (3.0 to 14.2 mg/serve).

Beta-carotene (orange pigment)

Beneficial effects were identified for some cancers, obesity, T2DM, bone health, pregnancy health, eye health, and CVD and mortality (from fruit and vegetables sources only).

Cancer

- Decreased risk of several types of cancers, including cervical (by 32%) (80), gastric (by 26%) (88), larynx (by 57%) (69), non-Hodgkin lymphoma (by 20%) (72), oral cavity (by 46%) (69), ovarian (by 16%) (89) and pancreatic (by 22%) (75) cancers, in people consuming the highest amounts compared to those consuming the lowest amounts.
    - Strongest evidence for bladder cancer, breast cancer, and endometrial cancer.
    - Intakes of 2 mg/day, 3 mg/day, and 5 mg/day reduced the risk of breast cancer by 3%, 4% and 7%, respectively (73).
    - Intake of 7 mg/day was associated with a 25% decreased risk in breast cancer compared to an intake of 1.5 mg/day (73).
    - For each 1 mg/1000 kcal increase in intake, the risk of endometrial cancer decreased by 26% (90).
- No effects were seen for risk of bladder cancer (70), colon cancer (74), colorectal cancer (74), lung cancer (71), lung cancer mortality (71), melanoma (91), prostate cancer (82, 88), or rectal cancer (74).

CVD

- Decreased risk of CHD (by 27%) (92) in people consuming the highest amounts compared to those consuming the lowest amounts.
- Decreased risk of CVD mortality (by 32%) (93), in people with the highest blood levels of beta-carotene compared to those with the lowest levels.
    - Important note: Beta-carotene in **supplemental doses** (rather than from fruits and vegetables) of 15 to 50 mg per day was associated with a small **increase** (by 10%) in the risk for CVD mortality (94).

Mortality

- Lower risk of all-cause mortality (by 18%) in people consuming the highest amounts compared to those consuming the lowest amounts (77).
    - Each 1 mg/day increase in beta-carotene intake was associated with a 5% decreased risk of all-cause mortality) (77).
- Important note: Supplemental doses of 15 to 50 mg per day were associated with a slightly **increased risk** (between 5% and 7%) of mortality (94, 95).

T2DM

- Decreased risk of T2DM (by 35%) for every 0.5µmol/L increase in blood levels of beta-carotene (79).

Bone health

- Decreased risks of total fracture (by 37%)(96) and hip fracture (by 28%) (97) in people consuming the highest amounts compared to those consuming the lowest amounts.

Pregnancy health

- Decreased incidence of preeclampsia (high blood pressure) in pregnant women consuming the highest amounts compared to those consuming the lowest amounts (98).

Eye health

- Decreased incidence of cataract (by 10%) in people consuming the highest amounts compared to those consuming the lowest amounts (99).

Key messages: Beta-carotene, health, and melons

- The consumption of the orange bioactive pigment beta-carotene, at higher intakes or doses ranging from 2 to 7 mg/day, has beneficial effects for health, including:
    - Decreased risk for a range of cancers (up to 57%), all-cause mortality (18%), T2DM (35%), CHD (27%), and CVD mortality (32%);
    - Reduced risks of total fracture (37%) and hip fracture (28%);
    - Decreased incidence of preeclampsia in pregnant women;
    - Decreased incidence (by 10%) of cataract.

- Supplementation (i.e., not from food) with high doses of beta-carotene (15 to 50 mg/day), may be detrimental for health, increasing the risk of all-cause mortality and CVD mortality.

- Beta-carotene in line with these health benefits is provided by:
    - At least one serve of orange honeydew melon (1.3 to 4.1 mg/serve)
    - At least one serve of rockmelon (1.9 to 4.0 mg/serve)

- Red/pink watermelon, watermelon juice, and green honeydew melon can contribute to the daily dietary intake of beta-carotene.

- Beta-carotene is also provided by watermelon rind and watermelon seeds.

Alpha-carotene (yellow pigment)

Beneficial health effects of alpha-carotene were observed for cancer, mortality, and T2DM.

Cancer

- Reduced risks of gastric cancer (by 42%)(85), non-Hodgkin lymphoma (by 13%) (72), oral cavity and pharynx cancer (by 43%) (69) and prostate cancer (by 13%) (82), in people consuming the highest amounts compared to those consuming the lowest amounts.
  - Decreased risk of breast cancer of up to 9%, 18%, and 25%, for each 0.5 mg/day, 1 mg/day, and 1.5 mg/day increase in alpha-carotene intake, respectively (73).
    - 18% decrease in the risk of breast cancer with an alpha-carotene intake of 2 mg/day (73).
  - Decreased risk of non-Hodgkin lymphoma by 13% with every 1 mg/day increase in alpha-carotene intake (72).
  - The strongest evidence was that for bladder cancer and non-Hodgkin lymphoma.
- No effect on the risk of cancer of the larynx (69), colon, rectal, or colorectal cancer (74), lung cancer (71), or pancreatic cancer (75).

Mortality

- Decreased risk of all-cause mortality (by 21%) (77) in people consuming the highest amounts compared to those consuming the lowest amounts.

T2DM

- Reduced risk of T2DM (by 9%) (79) in people consuming the highest amounts compared to those consuming the lowest amounts.

Key messages: Alpha-carotene, health, and melons

- The consumption of the yellow bioactive pigment alpha-carotene, at higher intakes or doses ranging from 0.5 to 2 mg/day, has beneficial effects for health, including:
  - Decreased risk for a range of cancers (up to 45%), all-cause mortality (21%), and T2DM (9%).
- Alpha-carotene at doses in line with these health benefits are not provided by any of the Australian melons.
  - Rockmelon contains small amounts of alpha-carotene and can make an important contribution towards the total daily dietary intake of alpha-carotene.

Lutein and zeaxanthin (yellow pigments)

Studies showed a beneficial effect of lutein and zeaxanthin **combined** on human health:

Cancer

- Reduced risk of non-Hodgkin lymphoma by 18% in people consuming the highest amounts compared to those consuming the lowest amounts (72).
- Higher blood levels of lutein and zeaxanthin were associated with a reduced risk of bladder cancer (by 47%) (70).
- There was a 17% decreased risk of breast cancer for every 3 mg/day increase in lutein and zeaxanthin intake (73).
- The strongest evidence for the relationship between lutein and zeaxanthin and cancer was observed for bladder cancer and breast cancer.
- No effect on the risk of gastric cancer (85), lung cancer or lung cancer mortality (71), pancreatic cancer (75), oral cavity and pharynx cancer (69), colon cancer (74), rectal cancer (74), or colorectal cancer (74).

Mortality

- Higher blood levels of lutein and zeaxanthin were associated with a reduced risk of all-cause mortality (by 15%) (77).

CVD

- Intakes of 8-20 mg/day were associated with decreased levels of C-reactive protein (CRP), an inflammatory biomarker and risk factor for CVD (76).
    - No effects on the inflammatory marker IL-6 (76).

Studies showed a beneficial effect of lutein, independently on:

T2DM

- Strong evidence supporting a reduced risk of T2DM by 35% in people with the highest blood levels of lutein compared to those with the lowest levels (79).
    - Each 0.2 µmol/L increase in the blood level of lutein decreased the risk of T2DM by 21% (79).

CVD

- Reduced risk of stroke by 18% in people consuming the highest amounts compared to those consuming the lowest amounts (100).

Studies did not show an effect of zeaxanthin independently on all-cause mortality (77) or risk of T2DM (79).

No studies showed a beneficial effect of zeaxanthin independently.

Key messages: Lutein + zeaxanthin, health, and melons

- The consumption of a combination of the yellow bioactive pigments lutein and zeaxanthin, at higher intakes or doses ranging from 8 to 20 mg/day, has beneficial effects for health, including:
    - Decreased risk for a range of cancers (up t0 47%), all-cause mortality (15%), stroke (18%), and T2DM (35%, blood levels);
    - Reduced levels of CRP, an inflammatory biomarker and risk factor for CVD.

- The consumption of increased intakes of lutein in isolation has beneficial effects for health, including:
    - Decreased risk for a range of T2DM and stroke.

- Lutein and/or zeaxanthin at doses in line with these health benefits are not provided by any of the Australian melons.
    - Red/pink watermelon, green honeydew melon and rockmelon flesh contain small to moderate amounts of lutein and/or zeaxanthin and can make an important contribution to the daily dietary intake of lutein and zeaxanthin.
    - Watermelon rind and seeds also contain lutein.

Flavones (white pigments)

Beneficial effects were observed for some cancers, CVD, and mortality.

Cancer

- Reduced risk of breast cancer (by 19%) (101, 102), oesophageal cancer (by 22%) (103), liver cancer (by 51%) (101), and smoking-related cancer (by 23%) (104) in people consuming the highest amounts compared to those consuming the lowest amounts.
  - The strongest evidence was for liver cancer and smoking-related cancer.
- No differences were found for risk of colorectal (105), lung (101, 106), ovarian (101), pancreatic (101), or prostate (107) cancers.

CVD

- Decreased risks of CHD (by 6%) (108) and CVD mortality (by 15%) (101) in people consuming the highest amounts compared to those consuming the lowest amounts.
  - 7% decreased risk of CVD mortality for every 1 mg/day increase in flavones (101).
- No differences were found for hypertension (109) or risk of CVD (110).

Mortality

- There was strong evidence suggesting a 14% decreased risk of all-cause mortality in people consuming the highest amounts compared to those consuming the lowest amounts (101).

Key messages: Flavones, health, and melons

- The consumption of the white bioactive pigments flavones, at higher intakes or a dose of 1 mg/day, has beneficial effects for health, including:
  - Decreased risk for a range of cancers (up to 51%), CHD (6%), CVD mortality (15%), and all-cause mortality (14%).

- Flavones in line with these health benefits are provided by:
  - One serve of red/pink watermelon (2.8 mg/serve).
  - One serve of rockmelon (3.9 mg/serve).

Chlorophylls (green pigments)

Beneficial effects were reported for seasonal allergic rhinitis.

CVD and cancer

No effects were observed for CVD risk factors (111) or in a cohort study investigating risk of colorectal, colon, or rectal cancers (112).

Seasonal allergic rhinitis

Supplementation with 0.7 mg chlorophyll improved relief from symptoms of seasonal allergic rhinitis in a 2016 RCT (113).

In another RCT, supplementation with 3 g chlorophyll per day for three months led to weight loss of 1.5 kg in overweight women. However, this effect was not significant (111) compared to control, and there was no effect on other measures of body composition or levels of insulin, glucose, or leptin (111).

Key messages: Chlorophylls, health, and melons

- The consumption of the green bioactive pigments chlorophylls, at a dose of 0.7 mg/day, provides relief from symptoms of seasonal allergic rhinitis.
- Chlorophylls in line with these health benefits would be provided by:
    - Three serves of Piel de Sapo melon (0.24 mg/serve).
    - Green honeydew melon (0.26 to 0.3 mg/serve).
- Chlorophylls are also provided by watermelon rind and seeds.

What do the findings mean for Australian melons?

Colour-associated bioactive pigments present in fruits and vegetables, which include Australian melons, play an important role in the health benefits associated with total fruit and vegetable intake.

- This finding agrees with other published reviews (114).
- Australian melons were found to contain a selection of the colour-associated bioactive pigments covered in this review.
- Australian melon by-products (rind and seeds) were also found to contain some of the colour-associated bioactive pigments covered in this review.

Fruits and vegetables should be consumed in a variety of colours, which is stated in the dietary guidelines of several countries worldwide, including Australia.

- Australian melons can play an important role in the Australian diet by improving the variety of fruit and vegetable colours it contains.

There was limited certainty in the evidence for most health outcomes, due to the evidence being from observational studies.

- This means that the evidence is sufficient to conclude that there is an association between each bioactive pigment and the health outcomes identified as being affected, but not sufficient to say that each bioactive pigment *causes* a change in a health outcome.
- Note that most of the evidence to support recommendations for the consumption of fruits and vegetables are observational in nature.

To support the findings of the SLR being translated into practice, there should be:

- Increased measurement of bioactive pigments in diverse fruits and vegetables;
- Exploration of agricultural methods that maximise the bioactive pigment concentrations in various fruits and vegetables; and
- Investigation of the impact of agricultural practices aimed at increasing yield, for example, on bioactive pigment concentrations.
- Investigation into the inclusion of melon by-products within the diet.

An overview of the health benefits associated with all colour-associated bioactive pigments covered by the SLR is provided in **Figure 3.** The colour-associated bioactive pigments present at levels in Australian melons that are associated with health benefits have been highlighted.

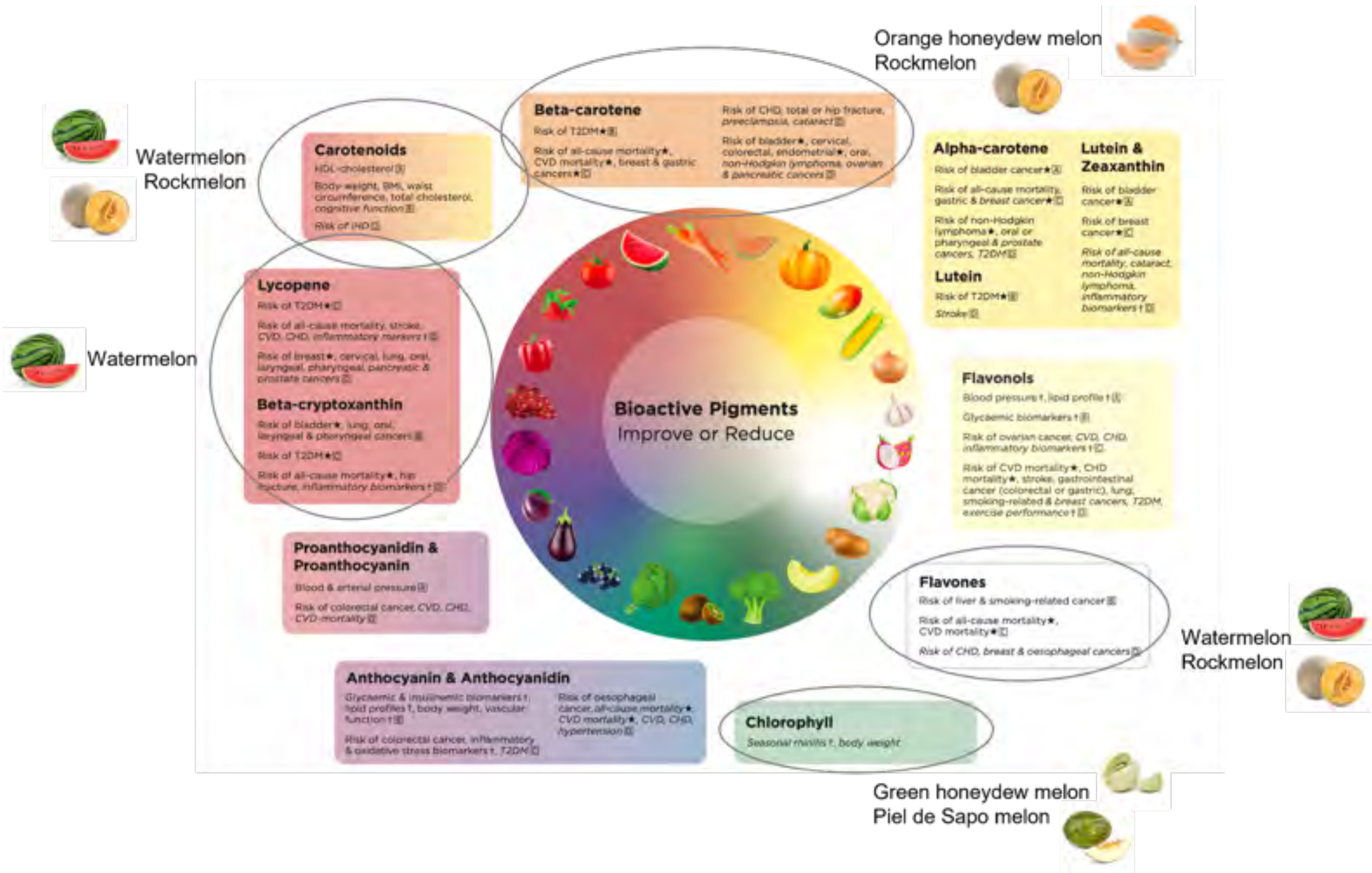


Figure 3. The health promoting effects of bioactive pigments in Australian melons.

This figure is based on Figure 2 in the published manuscript (**Appendix 2**). Colour-associated bioactive pigments identified to be contained in Australian melons at levels associated with health effects are circled and labelled. Full details of legend provided in full manuscript. BMI, body mass index. CVD, cardiovascular disease. CHD, coronary heart disease. IHD, ischemic heart disease. T2DM, type 2 diabetes.

Q5. How are melons reported in the media?

Global media

Globally, there were >107,000 media hits related to melons. The distribution of hits according to social media vs traditional (news) media is shown in **Figure 3.**

- Social media was the source of more melons-related content (69% of hits) compared with news media (31% of hits).
    - Compatibility with social media and capacity for sharing on social media should be considered in the design and delivery of education and communication messages as part of this project.

Figure 3. Distribution of melons hits between social and traditional (news) media.

Trending themes for melons

The trending themes in social and news media are shown in **Figure 4 A** and **B**, respectively.

Themes highlighted an overall sentiment towards melons that denoted summer, flavour, and freshness/refreshing.

- Resources developed throughout the project should capture these themes for maximum impact.

A.

B.

Figure 4. Trending themes for melons according to **A.** social and **B.** news media.

Highest performing trends

The highest performing articles or content on social media were dominated by watermelon and included:

- Content creators on Tik Tok created a new taste sensation by adding mustard to watermelon https://www.countryliving.com/food-drinks/a36623076/watermelon-mustard-tiktok-hack/

- Coles using unsold or excess fruit to create craft beers https://www.news.com.au/lifestyle/food/drink/coles-uses-unsold-or-excess-fruit-and-bread-for-craft-beer/news-story/5c71093b4ade12bcdb511d10db9d3c37?btr=8684209f5cf4abb3e6939b94fe9d83db

- Recipes for a ‘Very Aussie Christmas’ https://www.stayathomemum.com.au/occasions/how-to-have-an-australian-christmas/

- Using watermelon as a ‘meat substitute’ to create visually appealing meat replacements https://www.dailymail.co.uk/femail/article-10205835/Can-spot-whats-unusual-tuna-steak.html

These articles demonstrate that:

- People are interested in fun and innovative uses of melons.
- There is a high public interest in watermelon.
- There is an opportunity to elevate the health and nutrition messages of melons and its goodness in every colour.

Summary: Melons in the media

- There is an opportunity to elevate the health and nutrition messages of melons using both social and traditional (news) media.
- Compatibility with social media is a valuable factor to consider in the design and delivery of project resources.
- The predominant themes to be captured for maximum impact are:
    - Summer, flavour, and freshness/refreshing.
    - Fun and innovative uses of melons.

Key Messages

Key messages for health care professionals

A wide range of health benefits associated with the consumption of watermelon, and the colour-associated bioactive pigments contained in watermelon, rockmelon, green and orange honeydew melon, and Piel de Sapo melon, were uncovered in the scientific literature. These findings provide an evidence-based platform for the communication of the health benefits associated with the consumption of Australian melons to healthcare professionals.

In particular:

- The consumption of watermelon was associated with health benefits at levels in line with daily levels of consumption (2 serves per day).

- The consumption of melon by-products, including watermelon rind and seeds, honeydew melon seeds, and rockmelon peel and seeds, was associated with potential health benefits in emerging research.

- All melons contained one or more colour-associated bioactive pigments at levels associated with health benefits with the consumption of 1 to 3 servings per day:
    - Watermelon and rockmelon contain total carotenoids, which have been associated with decreased risk factors for obesity, type 2 diabetes mellitus, and coronary heart disease, and improved cognitive function.
    - Two of the carotenoids found in watermelon at high levels, lycopene and beta-cryptoxanthin, are associated with reduced risks for cardiovascular disease, a range of cancers, and type 2 diabetes mellitus.
        - Beta-cryptoxanthin was also associated with a reduced risk for hip fracture.
    - Orange honeydew melon and rockmelon contain the orange bioactive pigment beta-carotene, which is associated with reduced risks for a range of cancers, mortality, type 2 diabetes mellitus, and bone fractures, and a decreased incidence of pre-eclampsia in pregnant women and cataracts.
    - Watermelon and rockmelon contain white bioactive pigments called flavones, which are associated with a reduced risk for a range of cancers, as well as mortality, type 2 diabetes mellitus, and cardiovascular disease.
    - Green honeydew melon and Piel de Sapo melon contain chlorophylls, green bioactive pigments found to relieve symptoms of seasonal allergic rhinitis.

- Melon by-products, including rind and seeds, also contain colour-associated bioactive pigments that may provide additional health benefits:
    - Watermelon rind and seed extracts contain beta-carotene, lutein, and chlorophyll.
    - Rockmelon peel and seed extracts contain flavonoids, including tannins.

  - Honeydew seeds contain rutin, a type of flavonoid.

- Watermelon by-products contain a number of additional bioactive compounds that may be involved in their health benefits, including citrulline and arginine (watermelon by-products), and vitamin C.
  - Watermelon rind and seeds, honeydew melon peel, and rockmelon peel and seeds also contain a range of phenolic compounds.

Australian melons and their by-products can play a role in supporting the health outcomes associated with colour-associated bioactive pigments by providing **red, orange, yellow, white**, and **green** bioactive pigments, to a diet containing a variety of colours of fruits and vegetables.

Key considerations for communicating with health professionals via media

The use of social media shows predominant value for the elevation of the health and nutrition messages of melons.

While media hits were focused on watermelons, the following themes are important to consider for all melons:

- Summer, flavour, and freshness/refreshing.
- Fun and innovative uses of melons.

Food regulatory considerations

The Australia New Zealand Food Standards Code is a collection of standards that set the legal requirements for the labelling of food in Australia and New Zealand.

Standard 1.2.7 (Nutrition, Health and Related claims) of the Food Standards Code sets out the claims that may be made **on labels** or **in advertisements** about the nutritional content of food (115).

Key parts of this Standard applicable in this report include:

- **Nutrition content claims:** a claim that is about the presence or absence of a nutrient or bioactive substance in a food and is not a health claim, e.g., “source of vitamin C”.
  - If a property of food is mentioned in section S4 – 3 of the Code, a nutrient content claim must meet the criteria in this section [1.2.7 – 12(1)].
  - If a property of food is not mentioned in section S4 – 3 of the Code, a nutrient content claim may only state that the food contains or does not contain the property of food, or that the food contains a specified amount of that nutrient [1.2.7 – 13(1)].

- **Health claim:** a claim which states or implies that a property of a food has, or may have, an effect in the human body, e.g., "vitamin C for immunity".
    - Health claims must be based on i) a pre-approved food-health relationship, or ii) a food-health relationship self-substantiated via a systematic literature review.
    - The standard does not prescribe the words that must be used when making a claim (1.2.7 – 10).
    - Health claims can only be made in the instance that a food passes nutrient profiling scoring criterion (NPSC) requirements (S4 – 6 of the Code).
        - All melons and their juices (if 100% juice) pass NPSC requirements.

Key messages complying with the Food Standards Code for labelling or advertisement

For vitamin A and vitamin C:

- Nutrition content claims and the associated pre-approved health claims can be made.
    - Vitamin A claims were found to be applicable to watermelon and honeydew melon.
    - Vitamin C claims were found to be applicable to all four varieties of Australian melons investigated.

For all other bioactives:

- The presence of the compound can be stated.

For all other health effects discussed in this report:

- These are not pre-approved. Communication of these in labelling or advertisement requires self-substantiation.

Key messages associated with each the health benefits of each variety of Australian melons and the bioactives they contain are summarised in **Tables 3 to 6**, as follows:

- **Table 3:** Watermelon
- **Table 4:** Honeydew melon
- **Table 5:** Rockmelon
- **Table 6:** Piel de Sapo melon.

For each table presenting key messages:

- The specified levels of bioactives are based on those reported in the scientific literature and the USDA food composition database, with one serve taken as 150 g for whole fruit, and 125 mL for juice (9) (references are provided in **Table A4, Appendix 5**).
- As the actual amount will differ between fruits depending on growing conditions and location, direct measurement is recommended to obtain an accurate measurement of levels contained within a fruit.

- Levels of bioactives contained within melon by-products were not included due to being presented in the literature as dry extracts or powders in studies involving cultured cells or animals, which are not translatable to levels of human consumption.

Table 3. Key messages associated with health benefits of **watermelon** and the bioactives present within watermelon.

KEY MESSAGES FOR HEALTH-CARE PROFESSIONALS	
HEALTH BENEFITS OF WHOLE FRUIT	• Beneficial effects for cardiovascular disease risk factors such as blood lipids and blood pressure with 2 serves of watermelon or 500 mL watermelon juice daily for least 2 weeks. • Beneficial effects for bodyweight, appetite and oxidative stress with 2 serves of watermelon daily for least 4 weeks. • Improvements in markers of exercise performance with high doses of watermelon (around 7 serves per day for 2 weeks) or watermelon juice (3 serves at one time).
POTENTIAL HEALTH BENEFITS OF FRUIT BY-PRODUCTS	• Potential beneficial effects of watermelon rind on markers of cardiovascular health, cancer development, gut microbiota, and infection, in emerging research. • Potential beneficial effects of watermelon seeds on markers of metabolic health, oxidative stress, infection, and liver health, in emerging research.
HEALTH BENEFITS OF COLOUR-ASSOCIATED BIOACTIVE NUTRIENTS	One to three servings of watermelon flesh contain levels in line with health benefits of: • Total carotenoids, associated with decreased risk factors for obesity, T2DM, and coronary heart disease, and improved cognitive function. • Beta-cryptoxanthin, associated with decreased risk for a range of cancers, all-cause mortality, T2DM and hip fracture, and reduced markers of CVD. • Lycopene, associated with decreased risk for a range of cancers, mortality, T2DM, and cardiovascular diseases. • Flavones, associated with decreased risk for a range of cancers, cardiovascular diseases, and all-cause mortality.
MEDIA TARGETS	• Focus on watermelon in the media. • Reference to summer, flavour, and refreshment. • Innovation in use, taste, and presentation.
KEY MESSAGES COMPLYING WITH FOOD STANDARDS CODE	
BIOACTIVE COMPOUNDS PRESENT IN FRUIT[1]	Watermelon flesh contains: • Minimum of 7.4 mg/serving total carotenoids

	• Minimum of 1.5 mg/serving lycopene (red/pink watermelon) • Minimum of 117 µg/serving beta-cryptoxanthin • Minimum of 2.8 mg/serving flavones • Minimum of 15 mg/serving citrulline Watermelon juice contains: • Minimum of 3.0 mg/serving lycopene • Minimum of 21.2 mg/serving total polyphenols • Minimum of 176 mg/serving citrulline
NUTRITION CONTENT CLAIMS[2,3]	Source of Vitamin C (15% of RDI)
GENERAL LEVEL HEALTH CLAIMS[3]	**Vitamin C** • Contributes to iron absorption from food • Necessary for normal connective tissue structure and function • Necessary for normal blood vessel structure and function • Contributes to cell protection from free radical damage • Necessary for normal neurological function • Contributes to normal growth and development (children) • Contributes to normal collagen formation for the normal structure of cartilage and bones • Contributes to normal collagen formation for the normal function of teeth and gums • Contributes to normal collagen formation for the normal function of skin • Contributes to normal energy metabolism • Contributes to normal psychological function • Contributes to the normal immune system function • Contributes to the reduction of tiredness and fatigue

[1] Food Standard 1.2.7—13 Nutrition content claims about properties of food not in section S4—3 (115).
[2] Based on Australian Food Composition Database amounts per 100 g of fruit (50), multiplied by 1.5 for dose per 150 g serve (9). %RDI calculated as dose per serve divided by RDI x 100. RDI for vitamin A is 750 µg and for vitamin C is 40 mg (116).
[3] As detailed in Schedule 4-5. Conditions for permitted general level health claims. Part 2 – Vitamins (117).

Table 4. Key messages associated with health benefits of the bioactives present within **honeydew melon**.

KEY MESSAGES FOR HEALTH-CARE PROFESSIONALS	
HEALTH BENEFITS OF WHOLE FRUIT	NA
HEALTH BENEFITS OF COLOUR-ASSOCIATED BIOACTIVE NUTRIENTS	At least one serving of orange honeydew melon contains levels in line with health benefits of: • Beta-carotene, associated with a decreased risk for a range of cancers, all-cause mortality and mortality associated with CVD, T2DM, fractures, and a decreased incidence of pre-eclampsia in pregnant women, and cataract. Two to three servings of green honeydew melon contains levels in line with the health benefits of: • Chlorophylls, associated with relief from seasonal allergic rhinitis.
POTENTIAL HEALTH BENEFITS OF FRUIT BY-PRODUCTS	• Potential beneficial effects of honeydew melon seeds on cancer development via the inhibition of human cancer cell growth in emerging research.
MEDIA TARGETS	• Reference to summer, flavour, and refreshment • Innovation in use, taste, and presentation
KEY MESSAGES COMPLYING WITH FOOD STANDARDS CODE	
BIOACTIVE COMPOUNDS PRESENT IN FRUIT[1]	Orange honeydew melon contains: • Minimum of 1.3 mg/serving beta-carotene Green honeydew melon contains: • Minimum of 0.26 mg/serving chlorophylls.
NUTRITION CONTENT CLAIMS[2,3]	For all honeydew melon varieties: Good source of vitamin C (45% of RDI)
GENERAL LEVEL HEALTH CLAIMS[3]	For all honeydew melon varieties: **Vitamin C** • Contributes to iron absorption from food • Necessary for normal connective tissue structure and function • Necessary for normal blood vessel structure and function • Contributes to cell protection from free radical damage • Necessary for normal neurological function • Contributes to normal growth and development (children) • Contributes to normal collagen formation for the normal structure of cartilage and bones • Contributes to normal collagen formation for the normal function of teeth and gums • Contributes to normal collagen formation for the normal function of skin • Contributes to normal energy metabolism • Contributes to normal psychological function • Contributes to the normal immune system function

	• Contributes to the reduction of tiredness and fatigue

[1] Food Standard 1.2.7—13 Nutrition content claims about properties of food not in section S4—3 (115).
[2] Based on Australian Food Composition Database amounts per 100 g of fruit (50), multiplied by 1.5 for dose per 150 g serve (9). %RDI calculated as dose per serve divided by RDI x 100. RDI for vitamin C is 40 mg (116).
NA, not applicable.
[3] As detailed in Schedule 4-5. Conditions for permitted general level health claims. Part 2 – Vitamins (117).

Table 5. Key messages associated with health benefits of the bioactives present within **rockmelon**.

KEY MESSAGES FOR HEALTH-CARE PROFESSIONALS	
HEALTH BENEFITS OF WHOLE FRUIT	NA
HEALTH BENEFITS OF COLOUR-ASSOCIATED BIOACTIVE NUTRIENTS	At least one serving of rockmelon contains levels in line with health benefits of: • Total carotenoids, associated with decreased risk for obesity, T2DM, and coronary heart disease, and improved cognitive function. • Beta-carotene, associated with a decreased risk for a range of cancers, all-cause mortality and mortality associated with CVD, T2DM, fractures, and a decreased incidence of pre-eclampsia in pregnant women, and cataract. • Flavones, associated with decreased risk for a range of cancers, cardiovascular diseases, and all-cause mortality.
POTENTIAL HEALTH BENEFITS OF FRUIT BY-PRODUCTS	• Potential beneficial effects of rockmelon seeds and peel for cancer via the inhibition of human cancer cell growth in emerging research.
MEDIA TARGETS	• Reference to summer, flavour, and refreshment. • Innovation in use, taste, and presentation.
KEY MESSAGES COMPLYING WITH FOOD STANDARDS CODE	
BIOACTIVE COMPOUNDS PRESENT IN FRUIT[1]	• Minimum of 6.8 mg/serving total carotenoids • Minimum of 1.9 mg/serving beta-carotene • Minimum of 3.9 mg/serving flavones
NUTRITION CONTENT CLAIMS[2,3]	Good source of vitamin A retinol equivalents (26% of RDI) Good source of vitamin C (128% of RDI)
GENERAL LEVEL HEALTH CLAIMS[3]	**Vitamin A retinol equivalents** • Necessary for normal vision • Necessary for normal skin and mucous membrane structure and function • Necessary for normal cell differentiation • Contributes to normal growth and development (children) • Contributes to normal iron metabolism • Contributes to normal immune system function **Vitamin C** • Contributes to iron absorption from food • Necessary for normal connective tissue structure and function • Necessary for normal blood vessel structure and function • Contributes to cell protection from free radical damage • Necessary for normal neurological function • Contributes to normal growth and development (children)

	• Contributes to normal collagen formation for the normal structure of cartilage and bones • Contributes to normal collagen formation for the normal function of teeth and gums • Contributes to normal collagen formation for the normal function of skin • Contributes to normal energy metabolism • Contributes to normal psychological function • Contributes to the normal immune system function • Contributes to the reduction of tiredness and fatigue

[1] Food Standard 1.2.7—13 Nutrition content claims about properties of food not in section S4—3 (115).
[2] Based on Australian Food Composition Database amounts per 100 g of fruit (50), multiplied by 1.5 for dose per 150 g serve (9). %RDI calculated as dose per serve divided by RDI x 100. RDI for vitamin C is 40 mg (116).
[3] As detailed in Schedule 4-5. Conditions for permitted general level health claims. Part 2 – Vitamins (117).
NA, not applicable.

Table 6. Key messages associated with health benefits of the bioactives present within **Piel de sapo melon**.

KEY MESSAGES FOR HEALTH-CARE PROFESSIONALS	
HEALTH BENEFITS OF WHOLE FRUIT	NA
HEALTH BENEFITS OF COLOUR-ASSOCIATED BIOACTIVE NUTRIENTS	Three serves of Piel de sapo melon contains levels in line with health benefits of: • Chlorophylls, associated with relief from seasonal allergic rhinitis.
MEDIA TARGETS	• Reference to summer, flavour, and refreshment. • Innovation in use, taste, and presentation.
KEY MESSAGES COMPLYING WITH FOOD STANDARDS CODE	
BIOACTIVE COMPOUNDS PRESENT IN FRUIT[1]	• Minimum of 0.24 mg/serving chlorophyll
NUTRITION CONTENT CLAIMS[2,3]	Good source of vitamin C (70% of RDI)
GENERAL LEVEL HEALTH CLAIMS[3]	**Vitamin C** • Contributes to iron absorption from food • Necessary for normal connective tissue structure and function • Necessary for normal blood vessel structure and function • Contributes to cell protection from free radical damage • Necessary for normal neurological function • Contributes to normal growth and development (children) • Contributes to normal collagen formation for the normal structure of cartilage and bones • Contributes to normal collagen formation for the normal function of teeth and gums • Contributes to normal collagen formation for the normal function of skin • Contributes to normal energy metabolism • Contributes to normal psychological function • Contributes to the normal immune system function • Contributes to the reduction of tiredness and fatigue

[1] Food Standard 1.2.7—13 Nutrition content claims about properties of food not in section S4—3 (115).
[2] Based on levels identified in the scientific literature per 100 g fruit (65), multiplied by 1.5 for dose per 150 g serve (9).
[3] As detailed in Schedule 4-5. Conditions for permitted general level health claims. Part 2 – Vitamins (117).
NA, not applicable.

Recommendations

The following opportunities for further research and communication have been identified:

1. Additional research and messaging on melon by-products, including rind, peel, and seeds.

In addition to health outcomes associated with the edible portions of watermelon, the scientific literature uncovered health benefits associated with the rind, peel, and seeds of melons, particularly watermelon. This research was predominantly conducted in animals or cultured cells and is therefore considered to be emerging research only, of low quality.

To further investigate and confirm the findings of these preliminary studies and understand the beneficial effects of melon by-products in humans, further research involving melon by-products, including clinical trials, is needed. For example, in one RCT, a single dose of watermelon rind (100 kcal) was found to increase blood citrulline levels but had no effect on markers of vascular function. Since citrulline has been suggested to have beneficial impacts on blood pressure and blood lipids, a longer-term intervention (2 to 4 weeks) study providing watermelon rind and measuring blood pressure and blood lipids (including total cholesterol and LDL cholesterol) would allow insight into these health benefits.

This research would provide key insights into innovative uses of melons that are beneficial from both a human health and environmental sustainability perspective.

This recommendation is supported by the findings of the media search, which suggested a focus on innovative uses of melons.

2. Research focused on the health benefits of honeydew melon, rockmelon, and Piel de Sapo melon, including bioactive composition.

There was a lack of research (both human and pre-clinical) on the health benefits of honeydew melon, rockmelon, and Piel de Sapo melon. For Piel de Sapo melon, information regarding bioactive composition was also lacking. To further communicate the evidence-based health benefits of these melons, additional research is recommended.

Research examples could include:

- Laboratory-based analysis of the bioactive composition of Piel de Sapo melon.
- Randomised controlled trial to determine the effects of daily consumption of melons (honeydew melon, rockmelon, or Piel de Sapo melon) on cardiovascular disease risk factors.

- Prospective cohort study to determine the health outcomes associated with a high vs low dietary intake of melon varieties.
- Dietary modelling to investigate the potential impact of increased melon consumption on diet quality and nutritional composition, as well as associated non-communicable disease incidence.

3. Communication of the health benefits associated with the colours of melons in schools.

The purpose of this technical report is to to develop key communication messages for healthcare professionals that will highlight the unique nutrition and health benefits of melons and their by-products. An additional line of communication that has the potential to benefit population health significantly, is the translation of the key messages included in this report into a communications program for school children. This program would aim to increase the knowledge of schoolchildren around both the fun and health-associated aspects of melons, with a specific focus on colour.

4. Further research into and communication of the health benefits provided by watermelon, including reference to its citrulline composition.

Watermelon stands apart from the other melons in that it contains the amino compounds citrulline and arginine. In combination with colour-associated bioactive pigments, citrulline and arginine have been proposed to provide benefits for cardiovascular health, metabolic health, and exercise performance through the promotion of vasodilation and antioxidant activity.

While this technical report was focused predominantly on the colour-associated bioactive components present in melons, there is further scope for detailed research into the full complement of bioactive compounds present in watermelon, and subsequent communication of the health benefits associated with watermelon consumption.

Research could include:

- A longer-term (2 to 4 weeks) intervention study on the relationship between watermelon consumption, nitric oxide production, and vascular function;
- A focus on the benefits of watermelon consumption for different population groups, for example, postmenopausal women and athletes.

Publication of the research findings would provide the foundations for a highly credible and evidence-based communications campaign showcasing the specific health benefits associated with regular consumption of watermelon.

Conclusions

A technical report was produced to develop key communication messages for healthcare professionals that would highlight the unique nutrition and health benefits of melons and their by-products. The health benefits and bioactive composition of watermelon, rockmelon, honeydew melon, and Piel de Sapo melon, including flesh, rind, peel, and seeds, were investigated in the scientific literature, which included the publication of a systematic literature review on health outcomes associated with colour-associated bioactive pigments found in fruit and vegetables. The key finding is that the daily consumption of 1 to 3 servings of Australian melons and their by-products can play a role in supporting a wide range of health outcomes, including cardiovascular disease, type 2 diabetes, cognitive function, a range of cancers, and bone fracture, by providing **red, orange, yellow, white,** and **green** bioactive pigments to a diet that contains a variety of colours of fruits and vegetables. Key messages complying with the Food Standards Code are detailed and recommendations for future research and communication are provided.

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Appendices

Appendix 1. Search terms for NUTRITIONiQ™ database.

A full list of the search terms used to establish the NUTRITIONiQ™ database on the health benefits of melons is shown in **Table A1.** Truncated words (*) and wildcards (?) were used where appropriate to ensure spelling variations (e.g. foetal/fetal) and alternate forms of words (e.g. inflammation/inflammatory) were captured. Search terms within each category were joined by "OR", and each category combined using "AND" (e.g., melon term AND health term). To optimise the search strategy, search terms in PubMed and SCOPUS were restricted to title and abstract, while search mapping was used in EMBASE.

Table A1. Search terms used to establish the NUTRITIONiQ™ database on the health benefits of Australian melons.

MELON TERMS	HEALTH TERMS
Watermelon	Nutrient (nutr*)
Citrullus lanatus	Nutrition
Muskmelon	Vitamin
Rockmelon	Mineral
Cantaloupe	Bioactive
Cucumis melo var cantalupensis	Health
Honeydew Melon	Metabolic (metab*)
Cucumis melon var inodorus	Cardiovascular
Piel de Sapo	Respiratory
	Inflammation (inflamm*)
	Obesity
	Body weight
	Diabetes (diab*)
	Cognitive
	Cognition
	Macular
	Eyesight or eyesight or vision
	Cancer
	Exercise
	Sports performance
	Bone
	Renal / kidney
	Hepatic / liver
	Neural / nervous system
	Neonatal (neonat*)
	Maternal
	Foetal (f?tal*)
	Pregnancy

Appendix 2. Systematic literature review manuscript.

Should we 'Eat a Rainbow'? An umbrella review of the health effects of colourful bioactive pigments in fruits and vegetables

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Authorship: All authors have reviewed and approved the final version of this manuscript prior to submission and declare this work has not been submitted for publication elsewhere. MB, SM, FFM, and HLM contributed to study concept. MB and SM, led the drafting of the manuscript, with contributions from KA and NDV. HLM led the design and reporting of the methodology and implemented the search strategy. HLM, MB, and SM contributed to study selection. SM and MB led data extraction and quality checking. SM led GRADE assessment, reviewed by MB. All authors contributed to the revision of the manuscript.

Abstract

Health promotion campaigns have advocated for individuals to 'eat a rainbow' of fruits and vegetables (FV). However, literature has only focused on individual colour pigments or individual health outcomes. This umbrella review synthesised the evidence on the health effects of a variety of colour-associated bioactive pigments found in FV (carotenoids, flavonoids, betalains, and chlorophylls), compared to placebo or low intakes. A systematic search of PubMed, EMBASE, CINAHL and CENTRAL was conducted on 20th October 2021, without date limits. Meta-analysed outcomes were evaluated for certainty via the GRADE system. Risk of bias was assessed using the Centre for Evidence-Based Medicine critical appraisal tools. A total of 86 studies were included, 449 meta-analysed health outcomes, and data from over 37 million participants were identified. 42% of health outcomes were improved by colour-associated pigments (91% GRADE rating very low to low). Unique health effects were identified: n=6 red, n=10 orange, n=3 yellow, n=6 pale yellow, n=3 white, n=8 purple/blue and n=1 green. Health outcomes associated with multiple colour pigments were body weight, lipid profile, inflammation, cardiovascular disease, mortality, type 2 diabetes and cancer. Findings show that colour-associated FV variety may confer additional benefits to population health beyond total FV intake.

Keywords: fruit, vegetables, colour, health, phytochemicals, carotenoids, flavonoids, chlorophyll, systematic review.

Introduction

Inadequate intake of fruits and vegetables (FV) is a leading modifiable dietary risk factor for mortality and contributes to the increasing burden of both communicable and non-communicable diseases (118, 119). In 2017, poor FV intake were responsible for 3.9 million deaths (120), and were among the top dietary risk factors affecting disability-adjusted life years worldwide (118). Not only is meeting recommended serves of FV important, but greater variety in the types of FV consumed has been independently associated with a lower risk of diabetes (121), cancer (122-124), and mortality (125, 126), and improved cognitive function (15). Increasing variety of FV is particularly critical during childhood to support growth and development, and to establish healthy eating habits that track into adulthood (127).

FV contain an abundance of nutrients, including vitamins, minerals, and bioactive compounds known as phytonutrients. Phytonutrients improve health through their antioxidant, anti-inflammatory, antibacterial, antifungal, antiallergic, chemoprotective, neuroprotective, hypolipidemic, and/or hypotensive properties (128). Despite the unequivocal health benefits of eating FV, 78% of adults worldwide do not consume the daily recommended servings (129), leading to a 'phytonutrient gap'. Naturally occurring and pigmented phytonutrients (herein referred to as bioactive pigments) give FV their vibrant colour and correspond to one or more phytonutrient categories; e.g., red corresponds to lycopene, yellow to alpha-carotene, orange to beta-carotene, green to chlorophyll, purple and blue to anthocyanins, and white to flavones (**Table 1**) (130). Given the range of colours and bioactive pigments in FV, both the nutrient profile and physiological functions of FV may differ in part due to their variations in colour, and those of the same colour are likely to have similar health benefits.

Population-based data have shown that the diets of eight out of ten American adults fall short in every colour of phytonutrient (i.e., have a phytonutrient gap), when compared to the median phytonutrient intake in adults who meet the recommended daily intake of FV, with the proportion of insufficient intakes per colour category reported as 88% for the colour purple/blue, 86% for white, 79% for yellow/orange, 78% for red, and 69% for green (131). In an attempt to improve health, dietary guidelines and health promotion campaigns have advocated for individuals to 'eat by colour' or 'eat a rainbow' of FV (130). Associating each colour with a health benefit is a simplified strategy designed to: (i) help individuals relate to the health properties of FV, (ii) promote greater recognition of their importance, and (iii) increase the diversity of FV colours consumed across all life stages (130). Despite these campaigns, assessment of FV variety in both clinical practice and research has been typically based on the number of individual types of FV a person consumes rather than assessing variety of bioactive pigments (132, 133). Observational studies have shown that FV intakes, grouped by their colour, are associated with improvement in a range of health outcomes including cognitive decline, cardiovascular disease (CVD) and colorectal cancer (134-137). The body of evidence linking bioactive pigments in FV to beneficial health effects is growing, but the reviews and syntheses of the evidence have focused either on individual pigments or on individual health outcomes (68, 73, 138-144). There is a gap in practice and in research whereby the evidence for consuming a variety of colour and bioactive pigments from FV for human health and wellbeing is summarised and synthesised.

Collating the evidence will support recommendations for improving health related to the types of bioactive pigments found in FV and highlight important research opportunities. Findings for each bioactive pigment colour are relevant to all FV which contain them, and are not limited to a specific

FV, thereby increasing the translational impact of existing messaging around eating a variety of FV. The aim of this umbrella review was to synthesise the evidence on the effects of a variety of colour-associated bioactive pigments found in FV (carotenoids, flavonoids, betalains, and chlorophylls), as compared to placebo or low intakes, on human health outcomes relevant to population health.

Materials and Methods

The study protocol was prospectively registered with the International Prospective Register of Systematic Reviews (PROSPERO, https://www.crd.york.ac.uk/prospero/); registration number: CRD42021276401, and has been reported according to the Preferred Reporting Items for Systematic reviews and Meta- Analyses (PRISMA) 2020 Statement (2).

Characterisation of natural pigments

This review focused on the health effects of natural pigments which are responsible for the visible colours of FV. Four major classes of natural plant pigments have demonstrated bioactivity in humans: carotenoids, flavonoids, betalains, and chlorophylls. Within each major pigment class there are distinct subclasses which have been associated with typical colours in plants, and some minor sub-classes which have received further examination in the literature (**Table 1**).

Table 1. Natural bioactive pigment classes and subclasses and the typical colours they produce in fruits and vegetables (145).

PIGMENT CLASS	PIGMENT SUBCLASS	PIGMENT MINOR SUBCLASS	TYPICAL COLOURS
Carotenoids	Lycopene Beta-cryptoxanthin Capsorubin Capsanthin		Red
	Beta-carotene		Orange
	Alpha-carotene Lutein Zeaxanthin Violaxanthin		Yellow
Flavonoids	Anthocyanins / anthocyanidins	Cyanidin Malvidin Peonidin Delphinidin Pelargonidin Petunidin	Red, purple, blue
	Aurones Chalcones Flavonols	 Kaempferol Quercetin Myricetin	Pale yellow

	Flavones	Apigenin Luteolin Isoetin	White
	Tannins	Proanthocyanidins Proanthocyanins	Red, purple, blue, brown
Betalains	Betacyanins Betaxanthin	Betanin Indicaxanthan Vulgaxanthin	Red, violet, orange, yellow
Chlorophylls	Chlorophyll a and b		Green

Eligibility criteria

Studies were deemed eligible if they satisfied the PICOS (Participant, Intervention, Comparator, Outcome, Study design) eligibility criteria described in **Table 2.**

Table 2. PICOS Eligibility Criteria

PICOS ELEMENTS	INCLUSION CRITERIA	EXCLUSION CRITERIA
Participant/ Population	Humans.	Animal and *in vitro*.
Intervention / Exposure	Natural pigments found in fruits and vegetables that contribute to their visible colour (as described in **Table 1**). The pigment must be: (1) consumed through whole fruit or vegetable; (2) extract from fruits or vegetables; or (3) provided as a supplement derived from fruits or vegetables. SLRs which included a mix of natural and synthetic bioactive pigments, or the derivation of the bioactive pigment was not described, were included.	Pigments within pharmaceuticals or synthetic forms. Pigments sourced from non-fruit or vegetable foods (e.g., nuts, soy, tea). Nutrients or phytonutrients that are not pigments and do not contribute to the visible colour of the FV, but may be high in concentration in FV of a particular colour (e.g., folate in green fruits and vegetables). Pigments delivered as a co-intervention or administered via non-oral routes (e.g., topical, aromatherapy, moxibustion).
Comparator	Placebo, presence of the pigment versus no pigment, or varying levels of the pigment (comparison of high versus low).	No control or comparator group. Alternative intervention.
Outcome	Health-related outcomes relevant to population health including the prevention of disease and optimisation of disease risk factors, general wellbeing, function (cognitive function, physical function, and	Biomarkers of pigment intake, disease treatment (e.g., cancer treatment), in-born errors of metabolism, biomarkers not related to disease prevention.

	exercise performance), growth and development in children, maternal and neonatal health.	
Study design/ Source	SLRs with MAs of RCTs and/or cohort studies. RCTs and/or cohort studies if no eligible SLRs available. Case-control studies were included if based on longitudinal data.	SLRs without MAs, cross-sectional studies, single arm interventions, narrative reviews, expert opinion articles, or consensus guidelines. Studies unable to be translated into English via Google Translate or manual translation by multilingual colleagues.

MA, meta-analysis; RCT, randomised controlled Trial; SLR, systematic literature review.

Search strategy

The electronic databases PubMed, EMBASE, CINAHL, and Cochrane Library (Reviews and CENTRAL) were searched from inception to 29th October 2021, without restrictions (**Table S1; S2; S3**). The systematic search strategy was designed to include a combination of both controlled vocabulary (e.g., MeSH or Emtree terms) and title and abstract keywords. The keywords repeated the controlled vocabulary terms if relevant, plus additional keywords specific to the topic. The search strategy was designed in PubMed and then translated to the other databases using Polyglot Search Translator (146). Reference lists from umbrella reviews were also examined to identify any further relevant studies. References were imported into Endnote X9 reference management software (version X9.3.3, Clarivate Analytics, Philadelphia, USA) and deduplication performed. Remaining records were uploaded to Covidence, a web-based systematic review software for screening (https://www.covidence.org/).

Selection process

Two researchers independently screened records for potential eligibility using the title and abstract (MB and SM/HM). Full texts were retrieved for all potentially eligible studies and two researchers (MB and SM) independently assessed each study against the full eligibility criteria (**Table 2**). Any discrepancies between researchers were resolved by consensus. The inter-rater reliability between reviewers at full text review is summarised in **Table S4**.

If multiple meta-analyses (MAs) examined the same pigment and health outcome, the degree of overlapping of studies included in eligible meta-analysed groups were assessed by calculating the corrected covered area (CCA) for each type of intervention (147). If a CCA was greater than 15% (very high overlapping), the meta-analysis (MA) with the largest number of total participants and/or the lowest statistical inconsistency/heterogeneity, as indicated by the I^2 or Chi-squared statistic, was selected.

Data extraction

The following data were extracted from each study: study and participant characteristics, bioactive pigment name and colour, intervention (type, duration, and dose), comparator (type, duration, and dose), number of meta-analysed studies/intervention groups, model, meta-analysed outcome, original research study design, original studies risk of bias, sample size (intervention/case, comparator/control, and total), effect size, confidence interval, p-value, heterogeneity, publication bias, and the Grading of Recommendations Assessment, Development and Evaluation (GRADE) quality rating (if reported). The GRADE approach considers the internal validity and external validity of all studies reporting on a particular outcome so as to judge confidence in the estimated effect across the body of research (3). As few original authors applied GRADE, current investigators (SM and MB) completed GRADE assessments for each extracted MA using information provided in the relevant SLRs or collated from individual RCTs/cohort studies reported by the SLR. GRADE was not applied to outcomes reported by included RCTs/cohort studies due to insufficient number of studies. Data were extracted into a Microsoft Excel [Version 1908; Excel for Office 365] spreadsheet by one researcher (MB or SM), checked for accuracy by another researcher (MB or SM).

During data extraction, included studies were assessed for methodological quality using the Oxford University, Centre for Evidence-Based Medicine (CEBM) critical appraisal tool for systematic reviews (4), RCTs (5), or prognostic studies (6). Internal validity was assessed by determining if the study met multiple criteria (yes, no, or unclear), with a 'yes' judgment indicating good study quality and reduced risk of bias.

Results

The systematic search strategy identified 5,616 records, of which 137 SLRs containing 449 MAs were eligible for inclusion (**Figure 1a**). Fifty-four SLRs were excluded due to a very high degree of overlapping of studies included in MAs of the same pigment and health outcome, resulting in 83 SLRs included in this umbrella review. When the search was extended to include single RCTs or cohort studies for chlorophyll, three additional studies were included: two RCTs and one cohort **(Figure 1b)**.

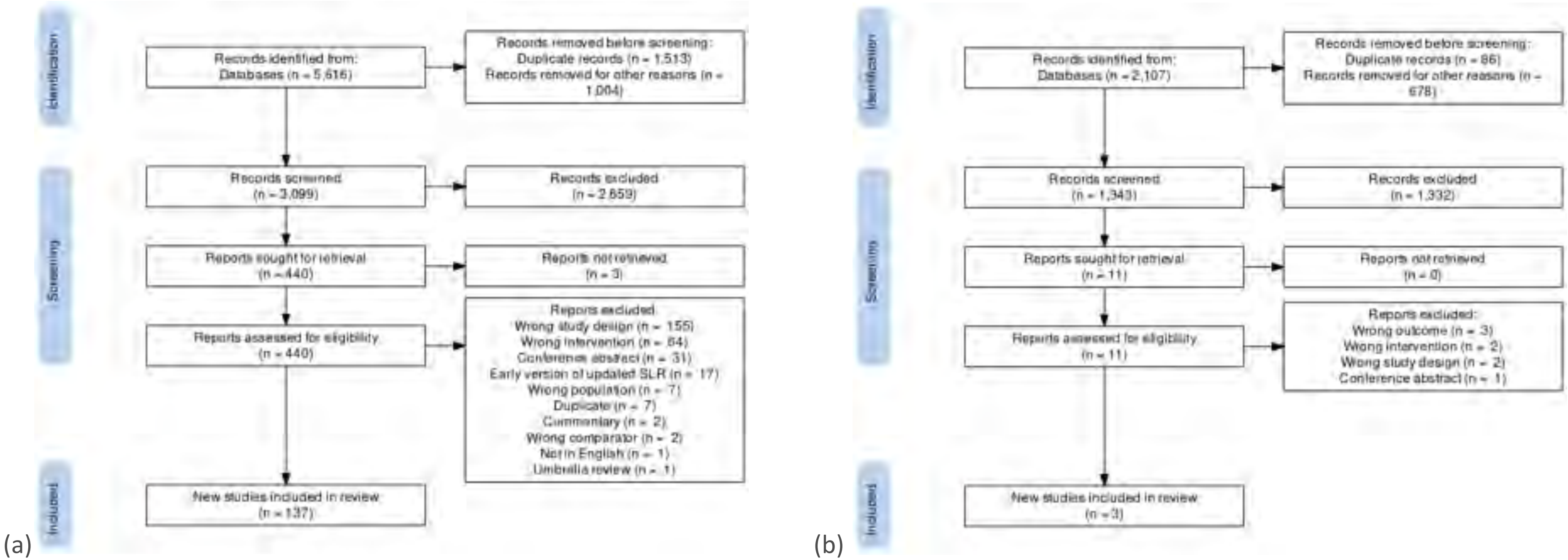


Figure 1. PRISMA flow diagram of the literature search and selection.

(a) Flow chart for the search for systematic literature reviews with meta-analyses for all colour pigments; (b) Flow chart for the search for randomised controlled trials and cohort studies for the green pigment chlorophyll.

Characteristics of included studies

Characteristics of included studies are presented in the data extraction spreadsheet published elsewhere (148). The included SLRs were published between 1998 and 2021 and were conducted in adults. The number of primary studies within the included SLRs ranged from 2 to 38. Of the 83 included SLRs, n=33 included only RCTs, n=12 only cohort studies, n=6 only case-control studies and n=32 both cohort and case-control studies. The number of SLRs and MAs included in this umbrella review, by pigment and health outcome are summarised in **Table S5**.

MAs included participants of both sexes, except for outcomes relating to pregnancy health (females only), breast or ovarian cancer (females only), prostate cancer (males only), and a single MA of osteoporosis (males only (81)). None of the included MAs reported on health effects in children or adolescents, and only n=7 MAs (0.02%) were reported exclusively in older adults. The countries of the original research were rarely and poorly reported by the included SLRs, and therefore were not extracted.

For chlorophyll, included RCT (n=2) and cohort (n=1) studies were published between 2006 and 2016, and were conducted in adults of both sexes from the Netherlands, Sweden and Japan.

Bioactive pigment interventions

<u>SLRs and meta-analyses</u>

The review of SLRs identified MAs on 17 different bioactive pigments which included all colours of fruits and vegetables except green (i.e., chlorophyll) (**Table S5**). No MAs were found for betalains or it's sub-classes; however, the betalains colours of red, violet, orange, and yellow were represented by the included carotenoids and flavonoids.

The only major class of bioactive pigment included for data extraction was carotenoids (n=4 SLRs reporting n=12 MAs), as all other health outcomes identified were reported at the bioactive pigment subclass. The bioactive pigment sub-classes which reported unique health outcomes were flavonols, and they were all pale yellow in colour (kaempferol n=1 SLR reporting n=1 MA, myricetin n=1 SLR reporting n=1 MA, quercetin n=10 SLRs reporting n=25 MAs) and tannins (proanthocyanidins n=5 SLRs reporting n=11 MAs, proanthocyanins n=2 SLRs reporting n=2 MAs), which can be red, blue, purple or brown (**Table S5**).

Anthocyanin (red/blue/purple) was the most extensively researched bioactive pigment (n=18 SLRs reporting n=81 MAs, representing n=729 original research studies), followed by beta-carotene (orange; n=34 SLRs reporting n=74 MAs) and lycopene (red; n=25 SLRs reporting n=65 MAs). Of the bioactive pigment subclasses included, zeaxanthin (yellow; n=2 SLRs reporting n=3 MAs) was the least explored (**Table S5**); and no MAs were identified for the sub-classes capsorubin, capsanthin, violaxanthin, aurones, and chalcones.

Bioactive pigments were primarily investigated via dietary intake (n=20 MAs of RCTs, n=186 MAs of cohort studies), followed by natural supplements or a mix of natural and synthetic supplements (n=74 MAs of RCTs, n=1 MA of observational research), and serum levels (n=47 MAs of observational studies). However, a large number of MAs included bioactive pigments measured from a variety of sources including diet, supplement, and/or serum levels (n=68 MAs of observational research, n=53 MAs of RCTs).

Intervention duration varied widely, from 4-hours to 18-years in RCTs, and from 3-months to 41-years in observational studies. Comparator groups were either placebo or non-specified controls for RCTs, and the lowest category of intake for cohort studies.

Single RCTs and cohort studies

Two RCTs delivered chlorophyll as a supplement containing 3000 mg extracted from green spinach leaves; and another as 0.7 mg of chlorophyll c2. A cohort study examined chlorophyll intake from the usual diet.

Health outcomes and confidence in the body of evidence

SLRs and meta-analyses

This umbrella review of SLRs identified many unique meta-analysed outcomes (n=98), which were grouped as cancer (n=192 MAs), CVD (n=135 MAs), exercise (n=28 MAs), mortality (n=27 MAs), type 2 diabetes mellitus (T2DM; n=24 MAs), obesity (n=13 MAs), bone health (n=9 MAs), eye health (n=9 MAs), the nervous system (n=5 MAs), pregnancy health (n=4 MAs), cognitive function (n=2 MAs), and the respiratory system (n=1 MA) (**Table S5**).

Of the 449 MAs included, 42% (n = 89 MAs) reported at least one significant improvement in a pooled health outcome, with n=35 (19%) having a significant dose-response. There was also n=4 MAs (0.009% of included MAs) which reported a significant negative effect from having the bioactive pigment (**Table S6-S12**).

Using GRADE, confidence in the body of evidence ranged from very low (n=349 MAs), low (n=61 MAs), medium (n=28 MAs), and high (n=11 MAs). Of the 28 included SLRs that reported their own GRADE level, the current investigators allocated a higher GRADE rating for seven MAs, agreed with the GRADE rating for six MAs, and allocated a lower GRADE rating for 15 MAs. The most common reason for downgrading the confidence in the body evidence was that most (67%) MAs were based on observational data; which downgraded all GRADE ratings to at least “low” confidence. Other common reasons for downgrading were moderate to high risk of bias in the original studies included in the SLRs, wide confidence intervals, or substantial statistical heterogeneity.

Single RCTs and cohort studies

Each included RCT and cohort study for chlorophyll examined a unique health outcome: cancer (n=1 case-cohort study), CVD (n=1 RCT), and allergy (n=1 RCT) (**Table S13**). Of the 16 included health variables extracted from these three studies, only one was significant, with a second variable with borderline significance and likely underpowered by a small sample size (n=36 participants; p=0.06). As no two included original research studies on chlorophyll examined the same health outcome, meta-analysis and GRADE assessment were not performed.

Health effects of total carotenoid pigments in fruits and vegetables

Total carotenoids represent red, orange, and yellow pigments (**Table 1, Figure 2**). There was n=12 unique MAs (n=10 MAs of RCTs, n=2 MAs of cohort studies) which were reported by the bioactive pigment class carotenoids. Carotenoid intervention was measured via dietary intake (n=1 MA with 4-24 years follow-up), serum (n=1 MA with 12-14 years follow-up), supplement (n=8 MAs with 12-16 weeks intervention duration), or mixed (n=2 MAs with 2-months to 18-years intervention duration) (**Table S5; S6**). The intervention doses in RCTs were not reported (n=5 MAs) or were 0.5mg to

60mg/day; and cohort studies compared the highest categories of intake or serum levels with the lowest.

Carotenoid supplementation had a large effect on risk factors for obesity and CVD, including reductions in body weight (SMD -2.34 kg; 95% CI -3.80, -0.87), BMI (SMD -0.95 kg/m^2; 95% CI -1.88, -0.01), waist circumference (SMD -1.84 cm; 95% CI -3.14, -0.54), total cholesterol (SMD -2.10 mg/dL; 95% CI -3.20, -0.99), and increased HDL cholesterol (SMD 0.76 mg/dL; 95% CI 0.10, 1.41) when consumed for up to 16 weeks (66) (**Table S6**).

The highest category of dietary carotenoid intake was associated with a 15% decreased risk of ischemic heart disease (RR 0.85; 95% CI 0.77, 0.93), compared to the lowest category of intake (67). High carotenoid levels (0.5-50mg) modestly improved cognitive outcomes (SMD 0.14, 95% CI, 0.08, 0.20) (68) (**Table S6**). Total carotenoid intake was found to have no effect on tumor necrosis factor alpha (TNF-alpha), triglycerides, low density lipoprotein (LDL) cholesterol, or change in fat ratio (66, 76) (**Table S6**). No dose-response MAs were included for total carotenoids.

The strongest evidence for the health effect of carotenoids was for improved adiposity (very large effect sizes, GRADE: low to medium) and lipid profiles (large to very large effect sizes, GRADE: medium to high) (**Figure 2**).

Health effects of red pigments in fruits and vegetables

Data on the effect of red bioactive pigments were from beta-cryptoxanthin (n=15 SLRs reporting n=33 MAs) and lycopene (n=25 SLRs of n=65 MAs) (**Table S5; S7**). Anthocyanins may also be red in an acidic environment; but were reported with the blue/purple bioactive pigments (149).

<u>Beta-cryptoxanthin</u>

Only two of the included MAs on beta-cryptoxanthin were based on RCT data (12-weeks; 6mg/day; mixed sources of beta-cryptoxanthin), and the remaining 31 MAs were based on cohort data (1-26 years). Most cohort MAs compared an unspecified highest category with the lowest; but where the highest categories were specified, they provided 56-200 µg/day compared with the lowest at <1.8 to 20 µg/day. Cohort data were derived from diet (n=21 MAs), mixed sources (n=3 MAs), or serum levels (n=7 MAs); and included seven dose-response MAs.

The highest category of beta-cryptoxanthin intake was associated with a 28% decreased risk of hip fracture (OR 0.72; 95% CI 0.60, 0.87) (78) and up to a 27% decreased risk of all-cause mortality (RR 0.73; 95% CI, 0.58, 0.88) (77), compared to the lowest category of intake. A small effect was also found for the inflammatory biomarker C-reactive protein (CRP; MD -0.35 mg/L; 95% CI -0.54, -0.15), after individuals consumed 6mg beta-cryptoxanthin over 12-weeks (76) (**Table S7**).

In relation to cancer, the highest category of dietary beta-cryptoxanthin intake was associated with a 69% decreased risk of larynx cancer (OR 0.41; 95% CI 0.33, 0.51) (69), 64% decreased risk of oral cavity and pharynx cancer (OR 0.46; 95% CI 0.29, 0.74) (69), 42% decreased risk of bladder cancer (RR 0.58; 95% CI 0.36, 0.94) (70), and 20% decreased risk of lung cancer (RR 0.80; 95% CI 0.72, 0.89) (71), compared to the lowest category of intake (**Table S7**).

In dose-response MAs of serum levels, each 0.1mg/day increase in beta-cryptoxanthin, decreased the risk of all-cause mortality by 6% (RR 0.94; 95% CI 0.89, 0.99) (77), whereas for every daily increase of 0.5 µmol/L, the risk of T2DM decreased by 15% (RR 0.85; 95% CI 0.76, 0.94) (79) (**Table S7)**.

No differences were found for beta-cryptoxanthin and risk of: cataracts (99), early age-related macular degeneration (150), osteoporosis (78), Parkinson's disease (151), non-Hodgkin lymphoma (72), breast cancer (73), colorectal cancer (74), pancreatic cancer (75), or lung cancer mortality (71), (**Table S7**).

The strongest evidence for the health effect of beta-cryptoxanthin was for a decreased risk of all-cause mortality (dose-response relationship, moderate to large effect size, GRADE: very low), bladder cancer (dose-response relationship, very large effect size, GRADE: medium), oral, laryngeal, or pharyngeal cancer (very large effect size, GRADE: very low to medium), and T2DM (dose-response relationship, large effect size, GRADE: low) (**Figure 2**).

Lycopene

There was n=14 MAs included based on RCT data (1-day to 6-months duration; 2-50mg/day); with the remaining n=51 MAs based on observational cohort data (3-months to 26-years duration; 2,035-10,000 µg/day), n=11 of which were dose-response MAs (per 1000 µg/day or incremental serum levels) (**Table S7**). Most MAs analysed dietary intake data (n=32 MAs), followed by mixed sources (n=22 MAs), serum values (n=10 MAs), and one MA measured supplemental intake.

The highest category of dietary lycopene intake was associated with reductions in the risk of cervical (OR 0.54; 95% CI, 0.39, 0.75) (80), larynx (OR 0.50; 95% CI, 0.28, 0.89) (69), lung (RR 0.71; 95% CI, 0.51, 0.98) (71), oral cavity and phyarynx (OR 0.74; 95% CI, 0.56, 0.98) (69) and prostate (RR 0.88; 95% CI, 0.79, 0.99) (81) cancers, compared to the lowest category of dietary lycopene intake. Reductions in the risk of breast cancer were only reported in case control studies, where greater reductions in risk up to 29% (OR 0.71; 95% CI, 0.56, 0.92) (73) were found with greater dietary lycopene intake (**Table S7**).

Higher lycopene intake was also associated with cardiovascular improvements with small to moderate clinical significance, including a lower risk of CHD (RR 0.87; 95% CI, 0.76, 0.98) (86), CVD (HR 0.86; 95% CI 0.77, 0.95) (87), stroke (HR 0.74; 95% CI 0.62, 0.89) (87), T2DM (RR 0.85; 95% CI 0.76, 0.96) (79), mortality (HR 0.63; 95% CI 0.49, 0.81) (87) and all-cause mortality (RR 0.72; 95% CI 0.49, 0.95) (77) (**Table S7**). In dose-response MAs of serum levels, each 0.5 µmol/L increase in serum lycopene decreased the risk of T2DM by 17% (RR 0.83; 95% CI 0.74, 0.92) (79).

Lycopene status had no effect on preeclampsia (98), early age-related macular degeneration (150), risk of hip fracture (97), advanced prostate cancer (81, 82), colon/colorectal/rectal cancer (74), bladder cancer (70), gastric cancer (85), non-Hodgkin lymphoma (72), ovarian cancer (83), Parkinson's disease (151), inflammatory biomarkers (except a small effect in interleukin-6 (MD -1.08 pg/mL; 95% CI -2.03, -0.12) (76), lipid profiles (152, 153), blood pressure (153), and prostate specific antigen (PSA) levels (84) (**Table S7**).

The strongest evidence for the health effects of lycopene were decreased risk of breast cancer (dose-response relationship, large to very large effect size, GRADE: very low) and T2DM (dose-response relationship, moderate to large effect size, GRADE: very low to low) (**Figure 2**).

Health effects of orange pigments in fruits and vegetables

The health effects of consuming orange bioactive pigments from FV were reported by MAs of beta-carotene (bioactive pigment subclass; n=34 SLRs reporting n=75 MAs including n=16 dose-response MAs) (**Table S5; S8**).

Evidence for the effects of beta-carotene was largely represented by MAs of cohort studies (n=59 MAs) measured over 1-26 years via dietary intake (n=32 MAs), mixed sources (n=16 MAs), serum levels (n=10 MAs), or supplementation (n=1 MA). Doses in the highest categories of intake were not usually reported, but when reported ranged from 2,473-7,000 µg/day intake or 16 to >120 µg/dL serum level. The one supplemental study provided a dose of 600 to 1,991 µg/day (**Table S8**). Sixteen of the observational MAs were dose-response, examining effects per 500-5000 µg/day intake or per 0.1 µmol/L serum level.

The highest category of beta-carotene intake was associated with a decreased risk of several types of cancers, including cervical (OR 0.68; 95% CI 0.55, 0.84) (80), gastric (OR 0.74; 95% CI 0.61, 0.91) (88), larynx (OR 0.43; 95% CI 0.24, 0.77) (69), non-Hodgkin lymphoma (RR 0.80; 95% CI 0.68, 0.94) (72), oral cavity (OR 0.54; 95% CI 0.37, 0.80) (69), ovarian (RR 0.84; 95% CI 0.75, 0.94) (89) and pancreatic (OR 0.78; 95% CI 0.66, 0.92) (75) cancers, compared to the lowest category of beta-carotene intake (**Table S8**). Reductions in breast cancer risk were supported by dose-response MAs that found dietary beta-carotene intakes of 2000 µg/day, 3000 µg/day, or 5000 µg/day reduced the risk of breast cancer by 3%, 4% and 7%, respectively (73) (**Table S8**). For each 1000 µg/1000kcal increase in dietary beta-carotene the risk of endometrial cancer decreased by 26% (RR 0.74; 95% CI 0.61, 0.91) (90).

Highest categories of beta-carotene intake were also associated with a lower risk of all-cause mortality (RR 0.82; 95% CI 0.77, 0.86) (77), CHD (RR 0.73; 95% CI 0.65, 0.82) (92), CVD mortality (RR 0.68; 95% CI 0.52, 0.83) (93), total fracture (RR 0.63; 95% CI 0.52, 0.77) (96), hip fracture (OR 0.72; 95% CI 0.54, 0.95) (97), and the incidence of cataract (RR 0.90; 95% CI 0.83, 0.99) (99) and preeclampsia (SMD -0.40; 95% CI -0.72, -0.08) (98), when compared to the lowest intakes. In dose-response MAs, each 1mg/day increase in beta-carotene intake decreased the risk of all-cause mortality by 5% (OR 0.95; 95% CI 0.92, 0.99) (77), whereas for every 0.5 µmol/L serum increase the risk of T2DM decreased by 35% (OR 0.65; 95% CI 0.48, 0.89) (79) (**Table S8**).

No differences were found for dietary beta-carotene and risk of bladder cancer (70), colon cancer (74), colorectal cancer (74), lung cancer (71), lung cancer or lung cancer mortality (71), melanoma (91), prostate cancer (82, 88), rectal cancer (74), COPD (154), total fracture (155) and Alzheimer's disease (156) (**Table S8**).

The strongest evidence for the health effects of beta-carotene were decreased risk of all-cause and CVD mortality (dose-response relationship, very large effect size, GRADE: very low to low), T2DM (dose-response relationship, large to very large effect size, GRADE: low to medium), bladder cancer (dose-response relationship, very large effect size, GRADE: very low), breast cancer (dose-response relationship, large effect size, GRADE: very low to low), and endometrial cancer (dose-response relationship, large effect size, GRADE: very low) (**Figure 2**)

Health effects of yellow bioactive pigments in fruits and vegetables

The evidence for the health effects of yellow bioactive pigments were from MAs reporting on alpha-carotene (n=16 SLRs reporting n=41 MAs), lutein (n=7 SLRs reporting n=10 MAs), zeaxanthin (n=2 SLRs reporting n=3 MAs), or lutein and zeaxanthin as a combined group (n=13 SLRs reporting n=31 MAs) (**Figure 2; Table S9**).

Alpha-carotene

All n=41 MAs reporting on the health effects of alpha-carotene were based on cohort and/or case-control research, measured via dietary intake (n=27 MAs with 1-25 years follow-up), serum levels (n=10 MAs with 2-26 years follow-up), or mixed diet, serum levels, and/or supplements (n=4 MAs with 9-months to 26-years follow-up) (**Table S9**). Most MAs compared an unspecified highest category against the unspecified lowest category; however, some category groups were defined as >881-2000 µg/day compared against <180 to 300 µg/day dietary intake, or serum levels of >1 to >5 µg/dL compared against <1 to <2 µg/dL.

The highest category of alpha-carotene intake was associated with a reduced risk of gastric (OR 0.58; 95% CI 0.44, 0.76) (85), non-Hodgkin lymphoma (RR 0.87; 95% CI 0.78, 0.97) (72), oral cavity and pharynx (OR 0.57; 95% CI 0.41, 0.79) (69) and prostate (RR 0.87; 95% CI 0.76, 0.99) (82) cancers, and a reduced risk of T2DM (RR 0.91; 95% CI 0.85, 0.96) (79) and all-cause mortality (RR 0.79; 95% CI, 0.63, 0.94) (77). In dose-response MAs, for each 1000 µg/day increase in alpha-carotene the risk of breast cancer decreased by up to 18% (RR 0.82; 95% CI 0.73, 0.93) (73) and the risk of non-Hodgkin lymphoma decreased by 13% (RR 0.87; 95% CI 0.78, 0.97) (72) (**Table S9**).

Alpha-carotene intake was reported to have no effect on risk of pre-eclampsia (98), cataract (99), early aged-related macular degeneration (150), cancer of the larynx (69), risk of colon, rectal, or colorectal cancer (74), hip fracture (97), lung cancer (71), pancreatic cancer (75), or Parkinson’s disease (151).

The strongest evidence for the health effects of alpha-carotene were decreased risk of all-cause mortality (dose-response relationship, large effect size, GRADE: very low to low), bladder cancer (dose-response relationship, very large effect size, GRADE: high), non-Hodgkin lymphoma (dose-response relationship, moderate to large effect size, GRADE: very low), and T2DM (dose-response relationship, large to very large effect size, GRADE: medium) (**Figure 2**).

Lutein

All n=10 MAs reporting on the health effects of lutein drew upon cohort or case-control data, measured via dietary intake (n=4 MAs with 10-12 years follow-up), serum levels (n=2 MAs with 8-10 years follow-up), or mixed sources (n=4 MAs with 9-months to 26-years follow-up) (**Table S9**). Most of the MAs compared the highest unspecified category of lutein to the lowest unspecified category; however, one highest category was defined as 3701 to 4041 µg/day compared to 1413 to 1736 µg/day dietary intake.

When compared to the lowest category, the highest category of lutein intake improved the risk of stroke by 18% (RR 0.82; 95% CI 0.58, 0.78) (100) and the risk of T2DM by 35% (RR 0.65; 95% CI 0.55, 0.77). In dose-response MAs of serum levels, each 0.2ugmol/L increase in lutein decreased the risk of T2DM by 21% (RR 0.79; 95% CI 0.72, 0.86). Lutein was reported to have no effect on risk of lung cancer (71), gastric cancer (85), Parkinson's disease (151), pre-eclampsia (98), or all-cause mortality (77) (**Table S9**).

The strongest evidence for the health effects of lutein was for decreased risk of T2DM (dose-response relationship, large to very large effect size, GRADE: medium) (**Figure 2**).

Zeaxanthin

All three MAs which measured the effect of zeaxanthin on human health were based on cohort studies, with n=2 MAs based on serum zeaxanthin levels (8-10 years follow-up) and n=1 MA based on mixed sources (2-26 years follow-up). When comparing the highest unspecified category against the lowest unspecified category, zeaxanthin had no effect on all-cause mortality (77) or risk of T2DM (79) (**Table S9**).

Lutein and zeaxanthin

Thirty-one MAs investigated the effect of combined lutein and zeaxanthin on human health, n=29 of which were based on cohort of case-control studies, and n=2 were based on RCTs. The observational research primarily measured lutein and zeaxanthin via dietary intake (n=22 MAs with 1-25 years follow-up) or serum levels (n=5 MAs with 2-26 years follow-up), with only one MA considering mixed sources (5-18 years follow-up) (**Table S9**). Only n=3 MAs defined the intake of lutein and zeaxanthin in the highest category (>1815 to 5000 µg/day) as compared to the lowest category (<775 to 1000 µg/day). The two RCT MAs both considered dietary or supplemental intake of lutein and zeaxanthin with interventions ranging from 8-32 weeks and doses of 8 mg/day to 27 mg/day.

When comparing the highest category versus lowest category of lutein and zeaxanthin status, higher dietary intakes reduced the risk of non-Hodgkin lymphoma by 18% (RR 0.82; 95% CI 0.69, 0.97) (72), while higher serum intakes reduced the risk of bladder cancer (RR 0.53; 95% CI 0.33, 0.84) (70) and all-cause mortality (RR 0.85; 95% CI 0.74, 0.97) (77). Lutein and zeaxanthin intakes were associated with decreased CRP levels (SMD -0.3 mg/L; 95% CI -0.45, -0.15) (76) and a dose-response relationship found a favourable 17% decreased risk of breast cancer for every 3000 µg/day increase in lutein and zeaxanthin intake (RR 0.83; 95% CI 0.77, 0.89) (73). Dose-response relationships were not found for any other level of lutein or zeaxanthin intake (**Table S9**).

For lutein and zeaxanthin, no differences were found for the risk of gastric cancer (85), lung cancer (71), lung cancer or lung cancer mortality (71), pancreatic cancer (75), oral cavity and pharynx cancer (69), colon (74), rectal (74) or colorectal cancer (74), early aged macular degeneration (150), hip fracture (97) or IL-6 (76) (**Table S9**).

The strongest evidence for combined lutein and zeaxanthin was for decreased risk of bladder cancer (dose-response relationship, large to very large effect size, GRADE: low to high) and breast cancer (dose-response relationship, large effect size, GRADE: very low to low) (**Figure 2**).

Health effects of pale-yellow bioactive pigments in fruits and vegetables

The health effects of consuming pale yellow bioactive pigments from FV were reported by MA of flavonols (bioactive pigment subclass; n=17 SLRs reporting n=33 MAs), kaempferol (n=1 SLR reporting n=1 MA), myricetin (n=1 SLR reporting n=2 MA), and quercetin (n=10 SLRs reporting n=25 MAs) (**Table S5; S10**).

Flavonols

As a group, MAs of flavonols subclass were primarily based on cohort and/or case-control data (n=25 MAs with 2-28 years follow-up); although there was substantial cause-and-effect investigation via n=8 MAs of RCTs (14-84 days intervention duration). Over half (n=14 of 25) of the observational MAs measured flavonols from dietary sources alone (1-27 years follow-up), with the remaining n=11 MAs measuring flavonols from mixed sources (4-28 years follow-up) (**Table S10**). The doses of intake in the highest or lowest categories were not reported. Four of the observational MAs were dose-response, examining effects per 10 mg or 20 mg, and were based on cohort data. All the MAs based on RCTs tested the effect of flavonols delivered via supplementation from 14- to 90-days at doses of 6-1000 mg (**Table S10**).

When comparing the highest intake or levels with the lowest, flavonols were found to improve the risk of stroke (RR 0.86; 95% CI 0.75, 0.96), CVD (RR 0.85; 95% CI 0.79, 0.91), and CHD (RR 0.88; 95% CI, 0.79, 0.98), as well as CVD- (RR 0.79; 95% CI 0.63, 0.99) and CHD-related death (RR 0.80; 95% CI 0.69, 0.93) (108, 110, 157-159). High categories of flavonols were also associated with a reduced risk of T2DM (RR 0.92; 95% CI 0.85, 0.98) (160) and risk of breast (RR 0.88; 95% CI 0.80, 0.96), colorectal (RR 0.71; 95% CI 0.63, 0.81), gastric (OR 0.80; 95% CI 0.70, 0.91), ovarian (RR 0.68; 95% CI 0.58, 0.80), and smoking related cancer (OR 0.77; 95% CI 0.63, 0.95) (102, 104-106, 161). However, two other MAs found no association with breast cancer (101), one found no association with CHD (162), and no differences were found for effect on all-cause mortality (157), hypertension (109), nor other types of cancer including liver, lung, pancreatic, esophageal, or prostate (101),(103, 107) (**Table S10**).

In dose-response MAs, for each 20 mg/day increase in flavonols the risk of stroke decreased by 14% (RR 0.86; 95% CI 0.77, 0.96) (159), and for each 10mg/day increase in flavonols the risk of CVD mortality decreased by 13% (RR 0.87; 95% CI 0.76, 0.99) (157). MAs of RCTs examined chronic disease indicators, finding supplementation with flavonols improved systolic (MD -3.05 mmHg; 95% CI -4.83, -1.27) and diastolic (MD -2.63 mmHg; 95% CI -3.83, -1.42) blood pressure, HDL cholesterol (MD 0.05 mmol/L; 95% CI 0.02, 0.07), LDL cholesterol (MD -0.14 mmol/L; 95% CI -0.21, -0.07), and total cholesterol (MD -0.11 mmol/L; 95% CI -0.20, -0.02), blood glucose (MD -0.18 mmol/L; 95% CI -0.29, -0.08), and triglycerides (MD -0.11 mmol/L; 95% CI -0.18, -0.03) (163); however, there was no effect on waist circumference (164) (**Table S10**).

Kaempferol, quercetin and myricetin

One SLR reported on highest versus lowest dietary intake of kaempferol, quercetin, and myricetin using case-control data (duration not reported) (101); whereas the nine other SLRs reported on 30-1000 mg/day of supplemental quercetin via MA of RCTs (5-days to 12-weeks duration) (165-173). There were no dose-response MAs (**Table S10**).

When comparing the highest dietary intake with the lowest, kaempferol, but not myricetin or quercetin, reduced the risk of lung cancer by 23% (RR 0.77; 95% CI 0.62, 0.97) (101). Supplemental quercetin improved a range of CVD risk factors, including systolic (MD -3.09 mmHg; 95% CI -4.83, -1.27) and diastolic blood pressure (MD -2.86 mmHg; 95% CI -5.09, -0.63) (167), CRP (MD -0.33 mg/L; 95% CI -0.50, -0.16) (168), VO2 max (MD 1.94%; 95% CI 0.30, 3.59) (171), and exercise performance (MD 2.82%; 95% CI 2.05, 3.58) (173). RCT evidence for quercetin found no effect on blood lipids (165, 167), glycaemic or insulin metabolism (169), other measures of inflammation (170, 172), or adiposity (166) (**Table S10**).

The strongest evidence for the health effect of flavonols and flavonols sub-classes was for improved blood pressure (cause-and-effect relationship established, large effect size, GRADE: low to high), cholesterol (cause-and-effect relationship established, small effect size, GRADE: low to high), blood glucose (cause-and-effect relationship established, small effect size, GRADE: medium), and risk of CVD or CHD mortality (dose-response relationship, very large effect size, GRADE: medium) and stroke (dose-response relationship, moderate to large effect size, GRADE: very low) (**Figure 2**).

Health effects of white bioactive pigments in fruits and vegetables

The evidence for the health effects of white bioactive pigments were from MAs reporting on flavones. All n=19 MAs for flavones were based on cohort data (1-24 years duration) as measured via the diet (n=13 MAs) or mixed sources (n=6 MAs), and two MAs were dose-response analyses (**Table S5; S11**). The highest category of flavones was associated with a decreased risk of all-cause (RR 0.86; 95% CI 0.80, 0.93) and CVD mortality (RR 0.85; 95% CI 0.75, 0.96) (101), breast cancer (RR 0.81; 95% CI 0.68, 0.96) (101, 102), CHD (RR 0.94; 95% CI 0.89, 0.99) (108), esophageal cancer (OR 0.78; 95% CI 0.64, 0.95) (103), liver cancer (RR 0.49; 95% CI 0.30, 0.78) (101), and smoking-related cancer (OR 0.77; 95% CI 0.69, 0.85) (104) (**Table S11**). In dose-response MAs, for each 1 mg/day increase in flavones, the risk of CVD mortality decreased by 7% (RR 0.93; 95% CI 0.90, 0.97) (101). No differences were found for hypertension (109), risk of CVD (110), risk of T2DM, or risk of colorectal (105), lung (101, 106), ovarian (101), pancreatic (101), or prostate cancer (107) (**Table S11**).

The strongest evidence for the health effect of flavones was for decreased risk of all-cause and CVD mortality (dose-response relationship, moderate to large effect size, GRADE: very low to low), liver cancer (very large effect size, GRADE: medium), and smoking-related cancers (moderate effect size, GRADE: medium) (**Figure 2**).

Health effects of purple/blue bioactive pigments in fruits and vegetables

Purple/blue bioactive pigments were contributed to by anthocyanidins, anthocyanins, proanthocyanidins and proanthocyanins.

<u>Anthocyanidins</u>

All n=7 MAs examining anthocyanidins were based on cohort data derived from the diet (n=2 MAs, 4-20 years duration) or mixed sources (n=5 MAs, 4-16 years duration). The highest and lowest categories were not defined, but the single dose-response MA analysed effects per 10 mg/day (**Table S5; S12**).

Higher anthocyanidin serum levels were associated with an 11% decrease in both all-cause (RR 0.89; 95% CI 0.85, 0.94) and CVD mortality (RR 0.89; 95% CI 0.83, 0.95). In dose-response MAs, for each 10 mg/day increase in anthocyanidins the risk of CVD mortality improved by 6% (RR 0.94; 95% CI 0.88, 0.99) (157). Greater anthocyanidin intake was also associated with a 32% decreased risk of colorectal cancer (RR 0.68; 95% CI 0.56, 0.82) (105), 14% decreased risk of T2DM (HR 0.86; 95% CI 0.81, 0.91) (160), but a 12% increased risk of prostate cancer (RR 1.12; 95% CI 1.03, 1.21) (107) (**Table S12**). No association was found for smoking-related cancer (104).

<u>Anthocyanins</u>

Most anthocyanin research was based on RCTs (n=67 MAs) derived from diet (n=19 MAs of 3-days to 6-weeks duration; dose not reported), mixed sources (n=32 MAs of 4-hours to 6-months duration, dose 1.3-1025 mg/day), or supplementation (n=16 MAs of 1-96 weeks duration, dose 1.6-1323mg/day). The n=14 cohort MAs measured anthocyanins from the diet (n=11 MAs, 1-24 years duration, dose not reported) or mixed sources (n=3 MAs, 5-41 years, dose not reported) (**Table S12**).

The highest category of anthocyanin intake was associated with a decreased risk of CVD (RR 0.82; 95% CI 0.70, 0.96) (110), CHD (RR 0.90; 95% CI 0.83, 0.98) (108), CVD mortality (RR 0.92; 95% CI 0.87, 0.97) (174), hypertension (RR 0.92; 95% CI 0.88, 0.97) (109), and esophageal cancer (OR 0.60; 95% CI 0.49, 0.74) (103). However, no association was found with risk of stroke (174), or multiple cancers including breast, liver, lung, pancreatic, or gastric (101, 102, 175) (**Table S12**).

Thirty-three of the n=67 (49%) RCT MAs reported improved inflammatory, oxidative, lipid, or glycaemic markers (e.g., adiponectin, apolipoprotein A1/B, CRP, fasting glucose, HbA1c, HOMA-IR, LDL and HDL cholesterol, interleukin-6, TNF-alpha, triglycerides, see **Table S12** for full list) (140, 176-179), as well as vascular reactivity (SMD 0.77; 95% CI 0.37, 1.16) (180) and BMI (SMD -0.36 kg/m^2; 95% CI -0.58, -0.13) (141). No improvements were found for liver enzymes (181), uric acid, blood pressure (182), waist circumference (182), delayed onset muscle soreness (176) or vascular stiffness (180).

The strongest evidence for the health effect of anthocyanins and anthocyanidins was for improved inflammatory and oxidative stress biomarkers (cause-and-effect relationship established, small to large effect size, GRADE: very low to low), glycaemic and insulinemic biomarkers (cause-and-effect relationship established, small effect size, GRADE: medium), lipid profiles and vascular function (cause-and-effect relationship established, small to large effect size, GRADE: very low to medium), and adiposity (cause-and-effect relationship established, small effect size, GRADE: low to medium) (**Figure 2**).

Proanthocyanidins

There were n=11 MAs which reported on the effects of proanthocyanidins (n=4 RCT MAs, n=7 cohort MAs) (**Table S5**). Proanthocyanidin RCT MAs were all based on supplemental interventions of 100-400 mg/day delivered over 5 to 16 weeks. Cohort MAs were delivered over 4-16 years with unspecified categories of highest and lowest intakes, measured via diet (n=3 MAs) or mixed sources (n=4 MAs). One of the n=7 cohort MAs was a dose-response analyses examining effects per 100 mg/day (**Table S12**).

The highest serum levels of proanthocyanidin compared with the lowest was associated with a 11% improvement in CVD mortality risk (RR 0.89; 95% CI 0.81, 0.97), but this was not significant in a dose-response analysis (101). Higher status was also associated with a 28% decreased risk of colorectal cancer (RR 0.72; 95% CI 0.61, 0.85) (105). No differences were found with risk of all cause-mortality, T2DM, breast cancer, or esophageal cancer (103, 157, 160). MAs of RCT evidence showed that supplemental proanthocyanidin (100-400 mg for 5-16 weeks) improved systolic (MD -4.60 mmHg; 95% CI -8.04, -1.16) and diastolic (MD -2.75 mmHg; 95% CI -5.09, -0.41) blood pressure, and mean arterial pressure (MD -3.37 mmHg; 95% CI -6.72, -0.01), but not pulse pressure (183) (**Table S12**).

Proanthocyanins

The two MAs of proanthocyanins were based on cohort data and measured the highest dietary intakes compared with the lowest for up to 16 years, and found an inverse association with risk of CVD (RR 0.83; 95% CI 0.73, 0.95) (110) and CHD (RR 0.78; 95%CI 0.65, 0.94) (108) (**Table S12**).

The strongest evidence for the health effect of proanthocyanidins and proanthocyanins was for decreased blood and arterial pressure (large effect size, GRADE: high) (**Figure 2**).

Health effects of green bioactive pigments in fruits and vegetables

The health effects of consuming green bioactive pigments from FV were reported by single RCT and cohort evidence for chlorophyll. Ten of the 17 health outcome measures reported for chlorophyll were based on RCT data (Sweden and Japan, 8-12 weeks of 0.7-3000 mg supplementation/day); with the remaining seven from cohort data (Netherlands, 9-years duration, highest undefined quintile) (**Table S13**). One RCT reported chlorophyll supplementation improved seasonal allergic rhinitis rescue medication scores (MD -3.09; 95% CI -5.96, -0.22) (113) and 3000 mg supplementation per day trended towards 1.5 kg weight loss; however, this appeared underpowered ($p=0.06$, $n=36$ participants) (111). RCT evidence reported no effect on other measures of body composition or levels of insulin, glucose, or leptin (111). Analysis of cohort data found no association between the highest intakes of chlorophyll and colorectal, colon, or rectal cancer (112) (**Table S13**).

Health effects unique to each bioactive pigment

Many health outcomes were improved by three or more bioactive pigments, such as a decreased risk of all-cause mortality with the highest intakes of lycopene, beta-cryptoxanthin, beta-carotene, alpha-carotene, lutein and zeaxanthin, flavones, and anthocyanin/anthocyanidin (**Figure 2**). Other improved health outcomes which were associated with three or more bioactive pigment colours were body weight; total cholesterol/lipid profiles; inflammatory biomarkers; CVD, CHD, CVD mortality; stroke; T2DM; and multiple cancers including breast, oral, lung, prostate, bladder, colorectal/colon/rectal, and gastric (**Figure 2; Table S6-13**).

Some health effects were unique to only one or two bioactive pigments or colours. Every FV bioactive pigment colour had a single highly unique health effect which was not associated with any other pigment colour, except red and yellow (**Table 3**). For example, only red bioactive pigments were associated with a decreased risk of pancreatic and laryngeal cancer, and only pale yellow pigments were associated with improved exercise performance. All bioactive pigment colours also had other unique health effects that were associated with only two bioactive pigment colours. For example, decreased risk of cervical cancer was associated with only red and orange bioactive pigments, and decreased risk of esophageal cancer was only associated with white and blue/purple bioactive pigments (**Table 3**).

Of the highly unique health effects (i.e., significant effect in a single colour of FV), only four outcomes have been confirmed as being truly unique by being tested for association with three or more different bioactive pigments. Waist circumference, unique to carotenoids, was found not to be affected by anthocyanins nor flavonols; risk of hypertension, unique to anthocyanins, was found to have no association with flavones nor flavonols; risk of preeclampsia, unique to beta-carotene, was found to have no association with alpha-carotene, lutein, nor lycopene; and risk of liver cancer, unique to flavones, was found to have no association with anthocyanins nor flavanols (**Table 3; S6-13)**. The remaining highly unique health effects reported in **Table 3** were only tested for association with one or two bioactive pigments, and it is therefore unknown if they may be improved by other bioactive pigments also.

Table 3. Unique health effects of bioactive pigment colours sourced from fruit or vegetables.

BIOACTIVE PIGMENT	HIGHLY UNIQUE HEALTH EFFECTS [a,c]	UNIQUE HEALTH EFFECTS [b,c]
Red/orange/ yellow	↑ cognitive function (GRADE: medium) ↓ risk of IHD (GRADE: very low) ↑ HDL cholesterol (GRADE: high) ↓ waist circumference (GRADE: low to medium)	
Red		↓ risk of cervical cancer (GRADE: very low) ↓ risk of lung cancer (GRADE: very low) ↓ risk of pancreatic cancer (GRADE: very low) ↓ risk of pharyngeal cancer (GRADE: very low to medium) ↓ risk of hip fracture (GRADE: very low) ↓ risk of laryngeal cancer (GRADE: very low to medium)
Orange	↓ risk of preeclampsia (GRADE: very low) ↓ risk of total fracture (GRADE: very low) ↓ endometrial cancer (GRADE: very low)	↓ risk of non-Hodgkin lymphoma (GRADE: very low) ↓ risk of ovarian cancer (GRADE: very low) ↓ risk of cervical cancer (GRADE: very low) ↓ risk of pancreatic cancer (GRADE: very low) ↓ risk of cataract (GRADE: very low) ↓ risk of hip fracture (GRADE: very low) ↓ risk of laryngeal cancer (GRADE: very low to medium)
Yellow		↓ risk of non-Hodgkin lymphoma (GRADE: very low) ↓ risk of cataract (GRADE: very low) ↓ risk of pharyngeal cancer (GRADE: very low)
Pale yellow	↑ exercise performance (GRADE: very low)	↓ risk of ovarian cancer (GRADE: low) ↓ risk of cervical cancer (GRADE: very low)

		↓ blood pressure (GRADE: low to high) ↓ glycaemic biomarkers (GRADE: medium) ↓ risk of smoking-related cancers (GRADE: very low)
White	↓ risk of liver cancer (GRADE: medium)	↓ risk of smoking-related cancers (GRADE: medium) ↓ risk of esophageal cancers (GRADE: very low)
Blue/purple	↓ risk of hypertension (GRADE: very low) ↓ oxidative stress biomarkers (GRADE: very low to low) ↓ insulinemic biomarkers (GRADE: medium) ↓ vascular function (GRADE: very low to medium) ↓ arterial pressure (GRADE: high)	↓ glycaemic biomarkers (GRADE: medium) ↓ risk of esophageal cancers (GRADE: very low) ↓ blood pressure (GRADE: high)
Green	↓ seasonal rhinitis (GRADE: N/A)	

a. A health effect was considered highly unique if it was found to be associated with a single bioactive pigment colour.
b. A health effect was considered unique if it was found to be associated with only two bioactive pigment colours.
c. GRADE working groups of evidence: high = further research is unlikely to change our confidence in the estimated effect; medium = further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate; low = further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate; very low = we are very uncertain about the estimate.

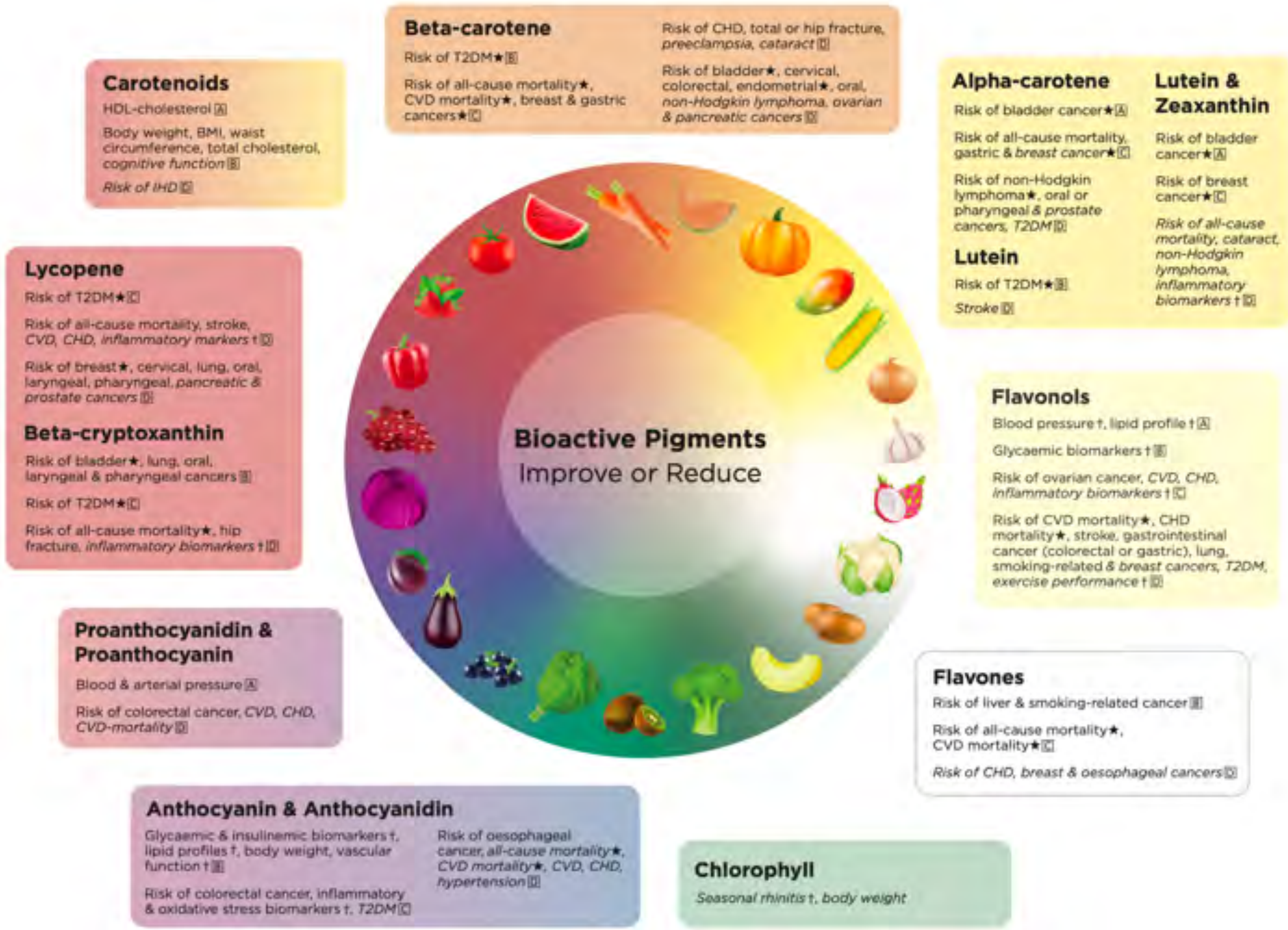


Figure 2. The health promoting effects of bioactive pigments by colour in fruits and vegetables.

GRADE working groups of evidence: A = high quality, further research is unlikely to change our confidence in the estimated effect; B = medium quality, further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate; C = low quality, further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate; D = very low quality, we are very uncertain about the estimate. = dose-response established. † = cause and effect established. Health effects in italics are those with small effect sizes. BMI, body mass index. CVD, cardiovascular disease. CHD, coronary heart disease. IHD, ischemic heart disease. T2DM, type 2 diabetes.

Discussion

This umbrella review synthesised an extensive body of evidence of the health effects of bioactive pigments from FV, representing 83 SLRS, 2,847 original research studies (cohorts and RCTs), and data from over 37 million participants. This review found that many health outcomes were improved by consuming three or more bioactive pigments classes or subclasses, reinforcing the importance of total FV in the diet, irrespective of colour (184, 185). However, this review found that colour-associated variety in FV may confer additional health benefits beyond total FV intake. This finding is strengthened by the 2020 umbrella review by Wallace et al., which reported a non-linear relationship between higher total intake of FV and lower risk of chronic disease, with a threshold of about 5 serves or 800g, beyond which further benefits were not observed (114). Wallace et al., also reported additional benefits of certain types of vegetables which tended to have greater or more unique health effects, such as dark-green leafy vegetables and dark-coloured berries. Whilst most dietary guidelines worldwide recommend consuming a variety of healthy food or a variety of FV specifically, only a limited number of national dietary guidelines specifically recommend FV should consumed in a variety of colours, including the Australian, Gabon, Polish, and several South and Central American countries (Argentina, Chile, Costa Rica, Dominican Republic, Grenada, Panama) (186). This umbrella review provides novel evidence to support the revision of dietary guidelines internationally regarding optimal FV intake for population health.

Despite the magnitude of the data presented, the health benefits of bioactive pigments may extend beyond the current findings as treatment effects and outcomes not relevant to population health were excluded, and many unique health outcomes have not yet been tested via MA with any bioactive pigment, including dementia, depression and anxiety, and infectious disease. Some of the unique health effects were anticipated due to an understanding of the physiological actions, such as carotenoids which have a structural and functional role in vision (187). There is emerging evidence that some health effects may be mediated through protein-flavonoid interactions (188, 189), which may result in changes to enzyme activity, receptors, antibodies and transcription factors such as inhibition of xanthine oxidase (188, 189). As flavonoids include all colours of FV, further research on the flavonoid subclasses and minor subclasses is required to understand their mechanisms of action. Two-way interactions between polyphenols and microbiota may mediate some health effects through improvements in gastrointestinal barrier function, butyrate production and down regulation of genes associated with inflammation (190). Although mechanisms of action for unique health effects beyond vision are less understood, the anti-inflammatory and antioxidant behaviour of bioactive pigments are known to play a mechanistic role for many health outcomes (113, 191, 192). Considering that all bioactive pigments demonstrate anti-inflammatory and antioxidant behaviour, investigation into the mechanisms of action of the truly unique health effects of specific pigments is required.

Most outcomes presented had limited certainty that the pooled estimates represented the true effects (91% had a GRADE rating of very low or low), with the principal reason for downgrading confidence being observational study design. Although observational data provide a lower certainty in the evidence according to the GRADE system and do not imply causality, many dietary guidelines worldwide are underpinned by observational evidence, and the observational nature strengthens translation. Observational data are based on the usual intakes and behaviours of sample populations, thereby showing that the level of bioactive pigments required to have a significant health effect are achievable using existing food environments and systems. However, it must be acknowledged that many factors related to health, social, and economic equity also determine the ability of an individual or population to consume the required bioactive pigment doses for a health effect (193, 194). This supposition is reinforced by the majority of included RCTs using supplemental bioactive pigments for intervention delivery, usually at doses unachievable through usual dietary intake, and are therefore unrealistic for translation to public health policy and health promotion activities. Observational data further strengthen the evidence by allowing the measurement of long-term outcomes such as disease incidence, which is often infeasible to measure in RCTs.

There were some outcomes in this review where a combination of both observational and RCT evidence allowed for stronger conclusions to be drawn. Specifically, observational research demonstrates implementation feasibility and impact on disease outcomes, where RCT evidence demonstrates causation via the measurement of related biomarkers. For example, RCT evidence demonstrated that anthocyanins improved the CVD biomarkers of cholesterol, inflammation, and blood glucose while cohort evidence confirmed a lower risk of CHD, hypertension, and CVD mortality. This alignment of observational and RCT data for anthocyanins is important; as other dietary strategies have a misalignment, for example, wholegrains are associated with decreased risk of CVD, yet RCT evidence is yet to confirm causality via association with related biomarkers (195). Finally, the downgrading of certainty in the evidence due to the observational nature of the data may underestimate the strength of some findings as prospective cohort data are recognised to be the highest level of evidence for prognostic outcomes such as disease incidence (196).

While this review identified substantial evidence for the beneficial effects of bioactive pigments from FV on many health outcomes, both divergent and negative health effects were also identified. Divergent findings were expected, due to both variations in dose, measurement type (dietary versus supplemental versus serum), follow-up duration, study design (e.g., cohort versus case-control versus RCT), power, and risk of bias, being reported within and across SLRs for a particular health effect. Additionally, other unreported sources of variation are also expected such as dataset quality, validity of the measurement tools, and sample characteristics. For example, n=3 MAs based on RCT data from n=3 different SLRs reported on the effect of anthocyanins on CRP; however, only one reported a significant effect. Differences between the three MAs possibly explaining the divergent findings include different measurement type, study duration, sample size, and dose. Of the n=449 included MAs, n=4 (<1%) reported negative health effects. Three of these negative health effects were based on the supplementation of beta-carotene and mortality (94, 95); and one was based on dietary anthocyanin intake and risk of prostate cancer (107). Due to the lack of a known and plausible mechanism, the negative effect of dietary anthocyanin intake on risk of prostate cancer is likely due to a type I error which is unable be addressed using the false discovery rate in an umbrella review study design. This explanation is supported by a small effect size and the p-value being higher than many other included significant findings (p=0.011, where 60% of significant p-values were <0.01). In contrast, the negative effect of beta-carotene supplementation on all-cause and CVD-mortality may not be subject to error. Whilst effect sizes were small, p-values were highly significant, and 95% CIs were precise. Further, there is a plausible mechanism of action as well as precedence. Supplemental versus dietary antioxidants are suggested to have differing bioavailability, biomechanics, and outcomes. For example, supplemental beta-carotene has been associated with pro-oxidation and increased risk of lung and stomach cancer (197, 198), whereas dietary sources had no effect on cancer risk (71).

Implications for future research and practice

This umbrella review provides a theoretical basis for improved health outcomes if colour-associated FV variety of is increased by populations, and presents the first high-level evidence to substantiate existing health promotional messages which recommend community members to “eat a rainbow” of FV (130, 199-201). Translational and interventional research is required to improve translation to policy and practice. Valid and reliable diet quality assessment tools are required to facilitate the measurement and quantification of colour associated FV variety and bioactive pigments from FV in both the clinical and research settings. Such tools will support the focus on colour-associated FV variety and bioactive pigments as well as allow for interventional and observational research to directly measure association with health outcomes. To further support translation to practice, increased measurement of bioactive pigments in diverse FV is required so that FV rich in a particular bioactive pigment relevant to an individuals’ health goals can be recommended. Agricultural methods should continue be explored to maximise the bioactive pigment concentrations in various FV, and modifications to agricultural practices which have other goals (e.g., improved sustainability or yield) should also consider their impact on bioactive pigment concentrations. Additionally, the reductionist approach utilised in many food systems to decrease the variety of FV available for the purposes of streamlining production should be addressed via reintroduction of FV varieties no longer or rarely commercially available, e.g., yellow watermelon, white tomatoes, purple cauliflower, or rainbow chard.

Limitations

The findings of this review have been strengthened by a strong study design and the utilisation of validated and best-practice methodology. However, inherent limitations must be acknowledged to ensure conclusions are drawn in context. The findings of this review do not represent the entirety of the evidence for the effect of bioactive pigments on population-relevant health outcomes, as data were extracted for only the highest level of evidence available. Although the CCA methodology was used to prevent overlap, some overlap remains. For example, although original studies have low levels of overlap, it is possible that multiple original studies in the included SLRs drew upon the same datasets for their analyses. Also, while data from more than 37 million participants were extracted, a single participant may have contributed to two or more of the individual MAs (e.g., participant A included in MAs for the effect of both lutein and alpha-carotene on risk of T2DM). Conclusions are also limited to adults as no studies were found for children or adolescents. Each finding should be interpreted in the context of its’ GRADE rating as well as the SLR characteristics including study type, measurement type, risk of bias, and length of follow-up.

Conclusion

A potential benefit to population health was found to be associated with eating a rainbow of FV. High consumption of FV, irrespective of colour or bioactive pigment concentration, was associated with many significant health improvements in adults; however, unique health benefits were found to be associated with individual bioactive pigments. Research to support both the measurement and recommendation of colour-associated FV variety and specific bioactive pigments is needed to support translation to policy and practice.

Appendix 3. Summary of health benefits associated with Australian watermelon.

Table A2. Summary of health benefits associated with the consumption of Australian watermelon.

HEALTH OUTCOME	TYPE OF EVIDENCE	DOSE RANGE	SUMMARY OF FINDINGS	SUGGESTED MECHANISMS	LEVEL OF EVIDENCE
Cardiovascular health	RCT, 4; non-randomised controlled trial, 1; non-controlled intervention study, 1; pre-clinical, 2.	300 g-1.04 kg fruit daily 500-710 mL juice daily	**Beneficial effect.** ↓ TC, LDL-C, TG, SBP; ↔ HDL-C, vLDL-C, CRP, FMD. **Beneficial effect.** ↑ FMD, MVBF, StO_2; ↓ SBP; ↔ DBP.	Presence of: • Citrulline and arginine: vasodilatory activity • Lycopene and beta-carotene: antioxidant and anti-inflammatory activity	Moderate. Highest quantity of human evidence.
Metabolic health	RCT, 1; pre-clinical, 9.	300 g fruit daily Normal human intake of juice	**Beneficial effect.** ↑ subjective satiety, TAC ↓ BW, BMI, WHR, %BF, oxidative stress; ↔ bGlc, insulin, CRP, liver function markers. **Beneficial effect.** ↓ bGlc, blood lipids, sugar metabolism, inflammation, oxidative stress; ↔ insulin.	Presence of: • Arginine: glucose and lipid metabolism; • Citrulline and arginine: reduction of oxidative stress via NO production • Lycopene, beta-carotene, vitamin C: antioxidant and anti-inflammatory activity	Low to moderate. Limited quantity of human evidence.
Exercise performance	RCT, 4.	980 mL fruit puree daily	**Potential beneficial effect.** ↑ TAC, blood L-cit, L-arg, NO, RPE	Presence of: • Citrulline: vasodilatory activity	Moderate to high. Moderate quantity of human evidence.

HEALTH OUTCOME	TYPE OF EVIDENCE	DOSE RANGE	SUMMARY OF FINDINGS	SUGGESTED MECHANISMS	LEVEL OF EVIDENCE
		355 mL juice	↔ exercise performance, inflammation, immune function. **Potential beneficial effect.** ↓ SBP, DBP (females only) ↔ recovery time, lactic acid, muscle soreness.	• Lycopene and beta-carotene: antioxidant and anti-inflammatory activity	
		> 1 kg fruit equivalent	**Beneficial effect.** ↑ peak force ↓ RPE, muscle damage, muscle soreness, lactic acid.		
Cognitive health	RCT, 1.	720 mL juice daily	**No effect.** ↑ blood lycopene ↔ cognitive function, inflammation, oxidative stress.	Presence of: • Lycopene: antioxidant and anti-inflammatory activity	Moderate to high. Limited quantity of human evidence.
Migraine	Cross-sectional, 1.	NR	**Adverse effect.** ↑ migraine headache	Presence of: • Citrulline: vasodilatory activity, blood flow, pain response.	Low to moderate. Limited quantity of human evidence.

bGlc, blood glucose; BMI, body mass index; BW, bodyweight; CRP, C-reactive protein; DBP, diastolic blood pressure; FMD, flow-mediated dilation; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; L-arg, L-arginine; L-cit, L-citrulline; MVBF, microvascular blood flow; NO, nitric oxide; RCT, randomised controlled trial; RPE, rating of perceived exertion; SBP, systolic blood pressure; StO_2, tissue oxygen saturation; TAC, total antioxidant capacity; TC, total cholesterol; TG, triglycerides; vLDL-C, very low-density lipoprotein cholesterol; WHR, waist-to-hip ratio; %BF, body fat percentage; ↑, increase; ↓, decrease; ↔, no change.

Appendix 4. Summary of health benefits associated with Australian melon by-products.

Table A3. Summary of health benefits associated with the consumption of Australian melon rind/peel and seeds.

HEALTH OUTCOME	TYPE OF EVIDENCE	DOSE RANGE	SUMMARY OF FINDINGS	SUGGESTED MECHANISMS	LEVEL OF EVIDENCE
Watermelon rind/peel					
Cardiovascular health	RCT, 1 Pre-clinical, 2.	100 kcal 0.2-1.0 mg/mL polysaccharide extract (solution) 10% (of diet, rats) for 8 weeks	**No effect.** ↔ endothelial function. **Beneficial effect.** ↓ ACE activity (dose-dependent; up to 93% reduction). ↓ TC, LDL-C.	Presence of: • Citrulline and arginine: vasodilatory activity. • Bioactive polysaccharides with ACE inhibitory activity.	Low to moderate. Limited quantity of human evidence.
Cancer	Pre-clinical, 1.	2.5 – 10 µg/mL polysaccharide extract (cells)	**Beneficial effect.** ↓ growth of laryngeal carcinoma cells (dose dependent, up to 65% reduction).	Presence of: • Bioactive polysaccharides with anti-tumour activity.	Very low. No human evidence. Limited total evidence.
Metabolic health	Pre-clinical, 4.	1-2.25% (of diet, diabetic/obese mice) for 4-10 weeks	**Inconsistent effect.** ↓ ↔ bGlc; ↑↓ insulin ↓ HOMA-IR	Presence of: • Citrulline and arginine: vasodilatory and anti-diabetic activity; • Fibre;	Low. No human evidence.

HEALTH OUTCOME	TYPE OF EVIDENCE	DOSE RANGE	SUMMARY OF FINDINGS	SUGGESTED MECHANISMS	LEVEL OF EVIDENCE
		60 mg/mL extract.	↑ expression genes associated with liver lipid metabolism; ↔ bodyweight. **Beneficial effect.** ↓ α-glucosidase activity (40-45% reduction).	• Bioactives with antioxidant activity.	
Reproductive health	Pre-clinical, 1.	500 mg/kg bw/day extract (rats, 42 days)	**Inconsistent effect.** ↑ sperm count, testosterone, LH, FSH, abnormal sperm; ↓ oxidative stress in testes due to nicotine, sperm motility.	Presence of: • Bioactives with antioxidant activity, including flavonoids, vitamin E, and vitamin C.	Very low. No human evidence. Limited total evidence.
Gut microbiota	Pre-clinical, 1.	2.25% (of diet, obese mice) for 10 weeks	**Beneficial effect.** ↑ Bacteriodes; reversal to match low fat mice.	Presence of: • Fibre and bioactives with prebiotic activity.	Very low. No human evidence. Limited total evidence.
Infection	Pre-clinical, 1.	500 mg/mL extract (bacterial cells)	**Beneficial effect.** ↓ *Staphylococcus albus, Micrococcus luteus, E.coli* (comparable to chloramphenicol).	Presence of: • Bioactives with antimicrobial activity.	Very low. No human evidence. Limited total evidence.
Watermelon seeds					
Cardiovascular health	RCT, 1 Pre-clinical, 2.	100 kcal 2 and 5 mL/kg bw/day seed oil or 9	**No effect.** ↔ endothelial function. **Inconsistent effect.** ↓ TG, LDL-C;	Presence of: • Citrulline and arginine: vasodilatory activity. • High proportion of linoleic acid; UFA:SFA is 5.2:1.	Low to moderate. Limited quantity of human evidence.

HEALTH OUTCOME	TYPE OF EVIDENCE	DOSE RANGE	SUMMARY OF FINDINGS	SUGGESTED MECHANISMS	LEVEL OF EVIDENCE
		g/day seed kernels for 28 days (rats)	↓↔ TC ↑↓VLDL-C; ↑HLD-C.		
Metabolic health	Pre-clinical, 4.	2 and 5 mL/kg bw/day seed oil or 9 g/day seed kernels for 28 days (rats); 60 mg/mL seed extract; 2.25% (of diet, obese mice) for 4-10 weeks; 9 g/day seed kernels for 28 days (rats)	**Beneficial effect.** ↓ BW, bGlc, liver glycogen. ↑ glucose tolerance; ↓ α-glucosidase activity (40-45% reduction). ↑ expression genes associated with liver lipid metabolism.	Presence of: • High proportion of linoleic acid; UFA:SFA is 5.2:1. • Bioactives, including citrulline, with hypoglycemic effects.	Low. No human evidence.
Oxidative stress	Pre-clinical, 3.	2 and 5 mL/kg bw/day seed for 28 days (rats); 500 or 1000 mg/kg bw/day for 65 days (rats) 50 µL purified seed protein peptides (liver cells treated with H_2O_2)	**Beneficial effect.** ↑ SOD, GSH-Px, catalase activity; ↓ lipid peroxidation, liver damage. **Beneficial effect.** ↑ cell viability; ↓ ROS, MDA ↑ SOD, GSH-Px, catalase activity, antioxidant signaling.	Presence of: • Bioactives with antioxidant activity • Antioxidant peptides	Low. No human evidence.
Infection	Pre-clinical, 1.	1% seed mixture (diet, *Toxoplasma gondii* infected mice)	**Beneficial effect.** ↑ survival; rate of cure.	Presence of: • Bioactives with antimicrobial activity.	Very low. No human evidence. Limited total evidence.

HEALTH OUTCOME	TYPE OF EVIDENCE	DOSE RANGE	SUMMARY OF FINDINGS	SUGGESTED MECHANISMS	LEVEL OF EVIDENCE
Liver health	Pre-clinical, 1.	100, 200, 400, and 800 mg/kg for 8 weeks (mice with hepatic fibrosis)	**Beneficial effect.** ↓ liver damage, lesions, necrosis, MDA. ↑ SOD, GSH-Px activity.	Presence of: • Bioactives with antioxidant activity and ability to stimulate liver detoxification pathways.	Very low. No human evidence. Limited total evidence.
Rockmelon seeds and peel					
Cancer	Pre-clinical, 1.	0.1 to 1 mg/mL extract (cancer cells)	↓ cell growth (>50%)	Presence of: • Bioactives with anti-tumour activity	Very low. No human evidence. Limited total evidence.
Honeydew melon seeds					
Cancer	Pre-clinical, 1.	50 to 450 µg/mL seed extract (cancer cells)	↓ cell growth	Presence of: • Bioactives with anti-tumour activity	Very low. No human evidence. Limited total evidence.

ACE, angiotension converting enzyme; bGlc, blood glucose; BW, bodyweight; FMD, flow-mediated dilation; FSH, follicle stimulating hormone; GSH-Px, glutathione peroxidase, HDL-C, high-density lipoprotein cholesterol; HOMA-IR, Homeostatic Model Assessment for Insulin Resistance; kcal, kilocalories; kg bw, kilograms of body weight; LDL-C, low-density lipoprotein cholesterol; LH, lutenising hormone; MDA, malondialdehyde; mg, milligram; mL, millilitre; RCT, randomised controlled trial; ROS, reactive oxygen species; SOD, supeoxide disumutase; TC, total cholesterol; TG, triglycerides; UFA:SFA, ratio of unsaturated to saturated fatty acids; VLDL-C, very low-density lipoprotein cholesterol; µg, microgram; ↑, increase; ↓, decrease; ↔, no change.

Appendix 5. Summary of bioactives present in Australian melons

Table A4. Bioactives present in the flesh of Australian melons[1], including colour-associated bioactive pigments and other bioactives.

BIOACTIVE	WATERMELON				HONEYDEW		ROCKMELON	PIEL DE SAPO
	RED/PINK	ORANGE	YELLOW	JUICE	ORANGE	GREEN		
Colour-associated bioactive pigments								
Carotenoids								
Total carotenoids	4.9 - 8.06 mg/100 g (47)						4.5 mg/100 g (62)	
Beta-cryptoxanthin	78 µg /100g (49)						1 µg /100 g (49)	
Lycopene	1.0 - 6.8 mg/100g (26, 47-49)	0.6 - 0.9 mg/100g (23)		2.0 - 11.34 mg/100 mL (10, 11, 24, 28)				
Beta-carotene	0.30 mg/100 g (49)			0.29 mg/100 mL (10)	0.9 - 2.7 mg/100 g (56, 59)	0.03 mg/100 g (49)	1.3 - 2.7 mg/100 g (49, 59, 60, 62, 63)	
Alpha-carotene							16 µg /100 g (49)	
Vitamin A retinol equivalents[2]	48 µg/100 g (50)				9 µg/100 g (50)	9 µg/100 g (50)	130 µg/100 g (50)	
Lutein and zeaxanthin	8 µg /100 g (49)					27 µg/100 g (49)	0.03 – 1.3 mg/100 g (49, 60)	
Flavonoids								
Flavones	1.84 mg/100 g (51)						2.58 mg/100 g (51)	
Chlorophylls								
Chlorophyll						0.17 - 0.2 mg/100 g (60)		0.161 mg/100 g (65)

BIOACTIVE	WATERMELON				HONEYDEW		ROCKMELON	PIEL DE SAPO
	RED/PINK	ORANGE	YELLOW	JUICE	ORANGE	GREEN		
Other bioactive pigments								
Total polyphenols				16.94 - 20.23 mg/100 mL (24, 48)	59.33 mg/100 g (51)	59.33 mg/100 g (51)		22.1 mg/100 g (65)
Other bioactives								
Citrulline	10 - 350 mg/100 g (13, 23-26)	10 - 25 mg/100 g (23)		140.8 - 220 mg/100 mL (10, 11, 20)				
Arginine	47.4 - 52.6 mg/100 g (13, 26)							
Vitamin C	0.4 - 8.6 mg/100 g (26, 48-50)		5.2 mg/100 g (48)	9.1 - 12.31 mg/100 mL (24)	7 - 34 mg/100 g (50, 56, 57)	12 - 34 mg/100 g (49, 50, 60)	16 - 36.7 mg/100 g (49, 50, 60)	18.7 mg/100 g (65)

[1] All amounts per 100 g fresh weight or fresh weight equivalent.

[2] Including but not limited to retinol equivalents as beta-cryptoxanthin, beta-carotene, and alpha-carotene.

Appendix 6. Summary of bioactives present in Australian melon by-products

Table A5. Bioactives present in the rind/skin/peel and seeds of Australian melons, including colour-associated bioactive pigments and other bioactives.

BIOACTIVE	WATERMELON RIND/SKIN/PEEL	WATERMELON SEEDS	ROCKMELON PEEL	ROCKMELON SEEDS	HONEYDEW PEEL	HONEYDEW SEEDS
Colour-associated bioactive pigments						
Carotenoids						
Beta-carotene	0.12 - 0.23 mg/100 g ex (37, 52)	0.207 mg/100 g ex (37)				
Lutein	1.12 mg/100 g ex (37)	127.3 mg/100 g ex (37)				
Flavonoids						
Total flavonoids		1.9 mg/100 g gs (31, 40)	151.9 – 262.0 mg/100 g ex (45, 64)	7.4 mg/100 g ex (64)		
Tannins		0.4 mg/100 g gs (Eke)	118.3 mg/100 g ex (64)	9.2 mg/100 g ex (64)		
Rutin						191.6 mg/100 g ex (46)
Chlorophylls						
Chlorophyll	2.64 mg/100 g ex (37)	788.0 mg/100 g ex (37)				
Other bioactive pigments						
Total polyphenols			254.8 mg/100 g ex (64)	15.0 mg/100 g ex (64)		
Melanin		Present, ANS (40)				
Other bioactives						
Total phenols	0.26 - 0.87 mg/100 g ex (31)	0.42 mg/100 g ex (31)	9 to 14.2 mg/100 g pd (45, 61)		9.6 mg/100 g pd (61)	
Ortho-diphenols			178.6 mg/100 g ex (64)	9.2 mg/100 g ex (64)		
Saponins	Present, ANS (31)	2.1 mg/100 g gs (40)				
Alkaloids	Present, ANS (31)	Present, ANS (31); 1 mg/100 g gs (40)				
Triterpenoids	Present, ANS (31)	Present, ANS (31)				

BIOACTIVE	WATERMELON RIND/SKIN/PEEL	WATERMELON SEEDS	ROCKMELON PEEL	ROCKMELON SEEDS	HONEYDEW PEEL	HONEYDEW SEEDS
Citrulline	13 mg/100 g fw (53); 387.4 mg/100 kcal (13, 54); 101.71 mg/100 g ex (37)	231.3 mg/100 kcal (13, 54); 310.1 mg/100 g ex (37)				
Arginine	75.3 mg/100 kcal (13, 54)	69.3 mg/100 kcal (13, 54)				
Vitamin C	5.35 mg/100 g fw (52); 7.23 mg/100 g ex (55)	6.8 mg/100 g ex (55)				

ANS, amount not specified; ex, extract; fw fresh weight; g, grams; gs, ground seeds; kcal, calories; mg, milligrams; pd, powder.

Appendix 7. Summary of health benefits associated with the colour-associated bioactive pigments present in Australian melons.

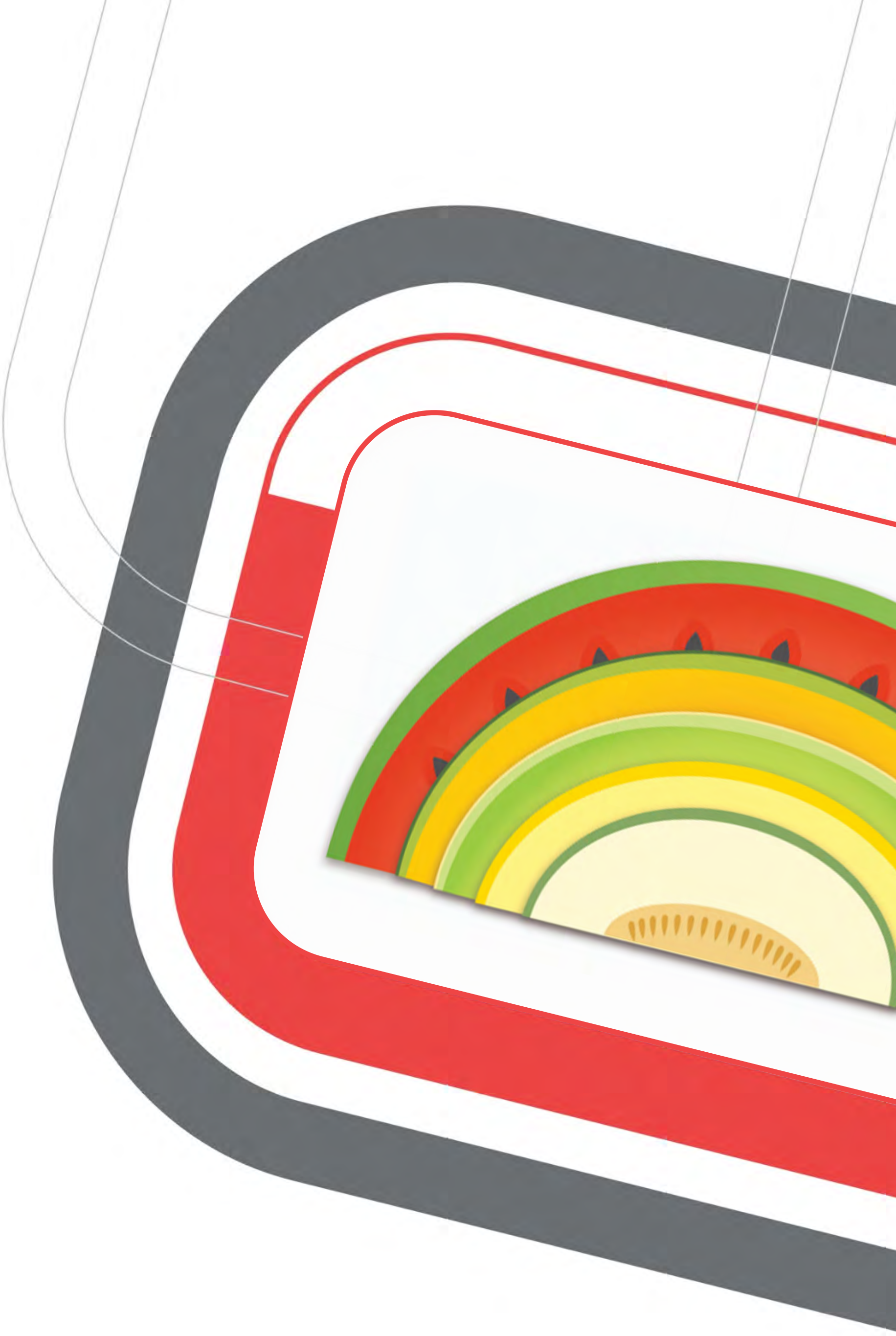
Table A6. Health benefits identified to be associated with the colour-associated bioactive pigments present in Australian melons.

COLOUR-ASSOCIATED BIOACTIVE PIGMENT	DOSE RANGE	TIME PERIOD OF CONSUMPTION	HEALTH EFFECTS
Total carotenoids	1.2 – 60 mg/day; H vs L intake	12 – 16 w	↓ Obesity and T2DM, CVD;
	0.5 – 50 mg/day	2 m – 18 y	↑ Cognitive function
Beta-cryptoxanthin	>56-371 µg/1000 kcal/day vs <5-<46 µg/1000 kcal/day; H vs L	6 -25 y	↓ Cancer
	6 mg/day	12 w	↓ CVD
	H vs L; Per 0.1 µmol/L (blood)	2-26 y	↓ Mortality
	H vs L	NR	↑ Bone health
	Per 0.5 µmol/L (blood)	8-10 y	↓ Obesity and T2DM
Lycopene	2 to 18.2 mg/day	1-25 y	↓ Cancer
	H vs L	2-26 y	↓ Mortality
	H vs L	4-13 y	↓ CVD
	Per 0.5 µmol/L (blood)	8-10 y	↓ Obesity and T2DM
Beta-carotene	2-7 mg/day; 1 mg/1000 kcal/day	1-5 y	↓ Cancer
	H vs L	NR	↓ CVD
	H vs L; Per 1 mg/day	2-26 y	↓ Mortality
	15-50 mg/day[1]	2-16 y	↑ Mortality
	Per 0.5 µmol/L (blood)	7-10 y	↓ Obesity and T2DM
	H vs L	NR	↑ Bone health
	H vs L	9 m	↑ Pregnancy health
	H vs L	5-15 y	↑ Eye health

Alpha-carotene	0.5 to 2 mg/day; H vs L	1-14 y	↓ Cancer
	H vs L	10-23 y	↓ Obesity and T2DM
	Per 0.1 µmol/L (blood); H vs L	2-26 y	↓ Mortality
Lutein and zeaxanthin	H vs L; Per 3000 µg/d	NR	↓ Cancer
	H vs L (blood)	2-26 y	↓ Mortality
	8-20 mg	8-32 w	↓ CVD
Lutein[2]	Per 0.2 µmol/L (blood); H vs L (blood)	8-10 y	↓ Obesity and T2DM
	H vs L	6-13 y	↓ CVD
Flavones	H vs L	1-3 y; NR	↓ Cancer
	H vs L; Per 1 mg/day	4-21 y	↓ CVD
	H vs L	5-16 y	↓ Mortality
Chlorophyll	0.7 mg/day	8 w	↓ Seasonal Allergic Rhinitis

[1] Supplemental beta-carotene only.
[2] Lutein studied in isolation.
CVD, cardiovascular disease; H vs L, higher dietary intake or blood levels compared to lower dietary intake or blood levels; m, month; NR, dose information not reported; T2DM, type 2 diabetes mellitus; w, week; y, year; ↑, increase; ↓, decrease.

APPENDIX 5



VM20003: Melons Matrix: a gaps analysis report

Prepared for:

Hort Innovation

July 2022

Prepared by:

Nutrition Research Australia Pty Ltd

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Background

Nutrition Research Australia (NRAUS) is the delivering the Hort Innovation and levy funded project VM20003 Educating Health Care Professionals on Australian Melons. This 3-year project aims to establish Australian melons as a fruit which can provide a range of colour-associated nutrients and bioactives required to achieve optimal health and wellbeing.

Despite fruit being accessible and affordable, only about half of Australians consume the recommended 2-serves of fruit per day[1]. Fruits are rich in vitamins, minerals, and dietary fibre; as well as non-nutritive bioactives that confer additional health benefits including; decreased inflammation, oxidative stress, and atherosclerosis [2, 3]. Not only is the Australian diet lacking in fruit, research shows it is also lacking in variety [4]. Food variety is vital for people to access the full range of nutrients and bioactives available for health and wellbeing. In fact, it is the nutrients and bioactives that give fruits and vegetables their colour, leading Australian state governments to not only recommend *Go for 2&5* (2-serves of fruit, 5-serves of vegetables) [5], but to *Eat a Rainbow* (a range of fruit and vegetable colours) [6-8]. Melons are unique amongst all fruit because they represent the full spectrum of colour across their varieties, providing a range of colour-associated nutrients and bioactives.

Current data on the composition of nutrients and bioactives in Australian melons are limited. Much of the data in our reference national database, the Australian Food Composition Database (AFCD), were derived from Australians melons in the 1980s, and may require updated testing due to changes in analytical methods after this time. Exploring overseas food composition databases may offer new or updated information on the nutrient and bioactive content of melon varieties and provide direction for new analyses of Australian melons. Additionally, data available in published scientific work may highlight colour-associated nutrients and bioactives that are found in melons, but not currently included in reference databases. Further, Hort Innovation has funded another project being conducted by Curtin University (ST19036), which has updated nutritional analysis for melons including macronutrients, minerals, vitamins, total polyphenols, and total flavoinoids.

The purpose of this report is to: (i) compile a dataset of the nutrient and bioactive composition of Australian melons and comparable melon varieties, and (ii) identify any gaps in data that may exist for additional nutrient testing (the melon matrix). Data were obtained from a desktop audit of food composition databases, published scientific evidence on the composition of melons, and nutritional analysis data for melons generated in ST19036. This melon matrix provides comprehensive insight into the nutritional composition of Australian melons which can be used to update data in the AFCD, inform the education campaign, and be used in future scientific studies.

Research Question

What is the nutrient and bioactive composition of Australian Melons?

Project Deliverables

1. Melon matrix: a gaps analysis report and recommendations for additional nutritional and bioactive testing to be performed.
2. Dataset of the nutrient and bioactive analysis of Australian melons that can be submitted to FSANZ to update the AFCD or published in the Dryad data repository (https://datadryad.org/).

Methods

Nutrient and bioactive data available for four melon types readily grown and available in Australia were obtained; watermelon, rockmelon, honeydew (yellow/gold rind or green rind) and Piel de Sapo. Information available for these fruits (peeled, flesh only) as well as their components (e.g., watermelon seeds) was collated via three sources:

1. Australian and international nutrient composition databases,
2. Published scientific literature, and
3. Primary nutrient and bioactive analyses conducted by researchers at Curtin University as part of ST19036.

1) Nutritional databases

Nutrient and bioactive composition data for melons and their components were sourced and collated from five databases:

1. Australian Food Composition Database (AFCD)
2. United States Department of Agriculture (USDA) FoodData Central
3. United Kingdom (UK) Composition of Foods (CoFID)
4. Phenol-Explorer
5. USDA Database for the Flavonoid Content of Selected Foods

Nutrient composition data were sourced from the AFCD, Australia's most comprehensive and up-to-date nutritional dataset containing data for 1,616 Australian foods and up to 256 nutrients per food [9]. Data were also collated from major USA databases (USDA FoodData Central [10]) and UK (UK CoFID [11]), to assess differences in data reported in Australian, USA and UK nutritional databases.

Phenol-Explorer [12-14] and the USDA Database for the Flavonoid Content of Selected Foods [15] were further used to identify literature sources that report on the bioactive content of melon and melon components. Literature reported in these two databases were further screened and reported as literature-sourced data in this report.

2) Scientific literature

Nutrient and bioactive data for melon and melon components were collated from published scientific literature. The electronic database PubMed was searched using the search terms; ‘honeydew’ OR ‘cantaloupe’ OR ‘rockmelon’ OR ‘muskmelon’ OR ‘*cucumis melo*’ OR ‘watermelon’ OR *‘citrullus lanatus*’ OR ‘Piel de Sapo’ OR ‘santa claus melon’ OR ‘christmas melon’ AND ‘nutri*’ OR ‘bioactive’ OR ‘phytochem*’ OR ‘flavon*’ OR ‘polyphen*’. A secondary search of Google Scholar was conducted to capture articles not listed in PubMed and to uncover relevant grey literature. A total of 45 studies were included in this project.

3) Primary nutrient and bioactive analysis

Researchers from the Curtin University (Perth, Australia) provided Hort Innovation and NRAUS with data for composite samples of Australian watermelons (peeled), rockmelons (peeled) and honeydew melons (green, peeled) analysed in 2021, as part of the Hort Innovation and levy funded project ST19036. The ST19036 project aimed to provide up to date nutritional composition data for many horticulture commodities (watermelon, honeydew, rockmelon, strawberry, cucumber, banana, sun muskat) and provided data for 58 select nutrients and bioactives (macronutrients, minerals, vitamins, total polyphenols, total flavoinoids).

Notes on data reporting

1. Unless otherwise stated in table rows, presented data are for the flesh component of melons.
2. All included studies and datasets represent analyses that were repeated and/or conducted on composite melon samples, with mean values presented.
3. Values less than 0 were reported to two decimal places, with values over 1 reported to one decimal places. Values over 10 were reported to the nearest whole number.
4. The country of origin and analysis dates were noted for all reported melon and melon product values, with **Australian data bolded** in reported results.
5. Where data were not identified or reported in databases, they were reported as NR (not reported).
6. Nutrient and bioactive data were assessed as ‘requires Australian testing’ if values were sourced from international food composition databases or published scientific literature for melons grown outside of Australia.
7. Nutrient and bioactive data were considered as ‘requires updated testing’ if values were derived from melons or melon components before the year 2000. Analytical methods have changed since 2000, which can impact the accuracy of the nutrient or bioactive composition. For example, separation techniques were largely used at the end of the 20th century, but have since reduced in use during the 21st century in favour of more accurate spectroscopic methods as they are able detect a greater range of food components [16].

Updating melon data in Australia

As part of this project, NRAUS consulted with Food Standards of Australia and New Zealand (FSANZ) on the current process to update nutrient data for melons in the Australian Food Composition Database. FSANZ has published a guide to designing nutrient analysis programs for submitting nutrient data to FSANZ, which can be downloaded in full here. We outline the process below and refer to this when summarising the melon matrix and when recommending additional testing to be performed.

Key points:

- FSANZ welcomes nutrient data from external bodies, such as universities, food and health organisations and the food industry, at any time.
- A minimum set of nutrients is not required for submitting data. However, analysis of moisture content is recommended so that submitted data can be effectively validated by FSANZ and compared to previous analyses and international data.
- Data for nutrients not currently covered in the Australian Food Composition Database is accepted.
- FSANZ has developed a spreadsheet template that can be used as a guide for providing nutrient data (see here). This template covers the submission of meta-data (information on how and when foods were sampled, prepared, and analysed) as well as analytical nutrient data.
- There are no streams to submit nutrient data sourced from secondary sources (literature or international databases). FSANZ recommends generating primary analytical data on Australian melons, using the template above, as generated data will be representative of our produce and can be easily validated for use in their nutrient databases.
- FSANZ reviews all provided data and will consult with providers to obtain further information if required. From here, data will be made available as a short report on the 'Data provided by food companies and organisations' page in the Australian Food Composition Database section of the FSANZ website, and for use in Australian Food Composition Database on the timing of next dataset release. There is currently no set date for the next AFCD release. Historically, our nutrient reference database is updated every 3-4 years, with the last releases of the Australian Food Composition database in 2019 and again in 2021-22.
- How FSANZ incorporates provided data into nutrient databases will depend on what data are provided and what data already exist. If a food has existing data in the database (e.g., honeydew, rockmelon and watermelon), FSANZ may combine both data sets and publish an average profile. If data are provided for a food with no existing analytical data (e.g., Piel de Sapo melon), FSANZ may create a new food record. It is unlikely that FSANZ will do this if data for a limited range of nutrients is provided for a new food.

Results

Nutrient composition data for 62 melon records were collated, including 15 records for honeydew, 28 for rockmelon, 14 for watermelon and 5 records for Piel de Sapo melon (**Figure 1**). Gathered data includes:

- 17 melon records from nutritional databases
- 3 melon records from Curtin University (ST19036 project)
- 45 melon records from published scientific literature

12 of the 62 melon records (~20%) were obtained from Australian sources.

Combined, data were obtained for 163 nutrients and/or bioactive compounds found in melons. This report covers the key nutrients (energy, macronutrients, vitamins, minerals), bioactive pigments and organic acids present in notable quantities in melons. The complete dataset is provided as an excel datafile for any future submission to FSANZ or publication in the Dryad data repository.

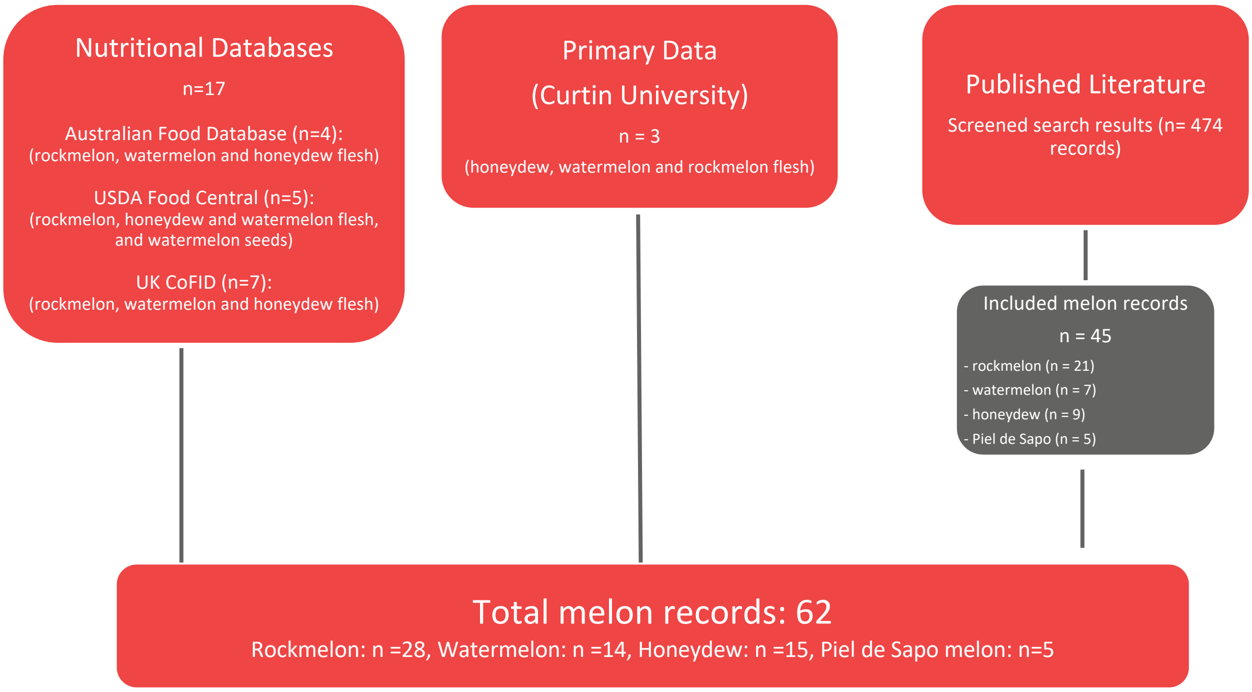

Figure 1. Flowchart of data collection

Melon matrix

Table 1. Energy and macronutrient composition of melons

		PER 100G					
MELON (COUNTRY)	SOURCE (YEAR)	ENERGY (kJ)[2]	PROTEIN (g)	CARBS (g)	TOTAL SUGARS (g)	DIETARY FIBRE (g)	TOTAL FATS (g)
Honeydew (Australia)[1]	AFCD (1983-84)	128	0.75	5.8	5.8	0.30	0.95
Honeydew (Australia)	CU (2021)	126	0.40	6.9	6.9	<0.20	0.80
Honeydew (UK)	UK-CoFID (1985-2013)	72	0.30	4.2	4.2	0.10	0.40
Honeydew (US)	USDA (2000-19)	150	0.54	9.1	8.1	0.14	0.80
Rockmelon (Australia)	AFCD (1983-84)	99	0.50	4.7	4.7	0.10	1.0
Rockmelon (Australia)	CU (2021)	100	0.70	4.9	4.9	<0.20	1.1
Rockmelon (UK)	UK-CoFID (1985-2013)	62	0.50	3.2	3.2	0.10	1.4
Rockmelon (US)	USDA (2000-19)	150	0.83	8.2	7.9	0.19	0.85
Watermelon (Australia)	AFCD (1983-84)	130	0.60	7.3	7.0	0.00	0.40
Watermelon (Australia)	CU (2021)	125	NR	6.9	6.6	NR	NR
Watermelon (UK)	UK-CoFID (1985-2013)	105	0.40	5.6	5.6	0.25	NR
Watermelon (US)	USDA (2000-19)	127	0.61	7.6	6.2	0.15	0.40
Watermelon Seeds (US)	USDA (2000-19)	2330	28	15	NR	47	NR

Table 1 footnotes:
Bolded entries represent data collected for Australian melons. If not otherwise stated, the nutrient data are for the flesh component of melons. Added data available for individual melons and nutrients in Melon Matrix excel file.
1: Average of two records from the same source and for the same melon type shown.
2: energy reported as energy with fibre or energy with fibre otherwise not stated.
Abbreviations: AFCD: Australian Food Composition Database, CU: Curtin University (ST19036 project), USDA: United States Department of Agriculture Food Central, UK-CoFID: UK Composition of Foods Integrated Dataset, UK: United Kingdom, US: United States, NR: Data not reported.

Summary of energy and macronutrient data

Review of current data:

- Collated data show that honeydew, rockmelon, and watermelon varieties have comparable energy and macronutrient profiles. These melon types are very low in kilojoules (<150kj per 100g), with the energy content mostly provided by carbohydrates.
- No energy or macronutrient data are available for Piel de Sapo melons from Australian or searched international sources.
- Data in the AFCD is old for honeydew, rockmelon and watermelon. They were generated from samples purchased in Sydney during 1983-84.
- Updated energy and macronutrient values were generated for Australian honeydew, rockmelon, and watermelon in the ST19036 project (Curtin University: 2021), except for total fats for watermelon, which was not analysed.
- The energy and macronutrient profiles recorded on AFCD reflect current commercially available rockmelon, watermelon, and honeydew melon varieties. When comparing AFCD data to more recent data (i.e., Curtin University: 2021, USDA: 2000-19, UK-CoFID), similar energy and macronutrient profiles were found, with minor differences in values explained by natural variation and/or differences in the moisture content of melons.
- **Other relevant findings:** USDA reports on the nutrient composition of watermelon seeds. This may be of interest as watermelon seeds are increasingly explored in the literature as good sources of protein and healthy fats, which may be processed into flours and oils to use as functional foods [17-20].

Recommendations:

- Analyse Piel de Sapo melon for energy and macronutrients.
- Submit the data provided by Curtin University (ST19036 project) to FSANZ to update the energy and macronutrient values reported in the AFCD for honeydew, rockmelon, and watermelon.

Table 2. Macronutrient composition of melons and melon components

MELON (COUNTRY)	SOURCE (YEAR)	SUGARS (G/100G)			FA (G/100G)			AMINO ACIDS (G/100G)										
		FRUCTOSE	GLUCOSE	SUCROSE	SFA	MUFA	PUFA	ALANINE	ARGININE	ASPARTATE	CYSTINE	GLUTAMATE	GLYCINE	HISTIDINE	ISOLEUCINE	LEUCINE	LYSINE	METHIONINE
Honeydew (Australia)[1]	AFCD (1983-84)	1.9	1.4	2.5	0.0	0.0	0.0	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Honeydew (Australia)	CU (2021)	0.8	0.8	0.8	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Honeydew (Australia)	Literature (2022)[21]	NR	NR	NR	NR	NR	NR	NR	0.2	NR	NR	NR	NR	NR	NR	NR	NR	NR
Honeydew Rind (Australia)	Literature (2022)[21]	NR	NR	NR	NR	NR	NR	NR	0.1	NR	NR	NR	NR	NR	NR	NR	NR	NR
Honeydew (UK)	UK-CoFID (1985-2013)	1.6	1.1	1.6	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Honeydew (US)	USDA (2000-19)	3.0	2.7	2.5	.04	0.0	.07	.04	.01	.09	.01	.15	.02	.01	.01	.01	.02	.01
Rockmelon (Australia)	AFCD (1983-84)	2.2	1.3	1.2	0.0	0.0	0.0	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Rockmelon (Australia)	CU (2021)	1.1	1.1	1.1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

MELON (COUNTRY)	SOURCE (YEAR)	SUGARS (G/100G)			FA (G/100G)			AMINO ACIDS (G/100G)										
		FRUCTOSE	GLUCOSE	SUCROSE	SFA	MUFA	PUFA	ALANINE	ARGININE	ASPARTATE	CYSTINE	GLUTAMATE	GLYCINE	HISTIDINE	ISOLEUCINE	LEUCINE	LYSINE	METHIONINE
Rockmelon (Australia)	Literature (2022)[21]	NR	NR	NR	NR	NR	NR	NR	.01	NR	NR	NR	NR	NR	NR	NR	NR	NR
Rockmelon (UK)	UK-CoFID (1985-2013)	1.7	1.4	0.1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Rockmelon (US)	USDA (2000-19)	2.1	1.8	3.9	.05	0.0	.08	.09	.03	0.1	.09	.19	.02	.01	.02	.03	.03	.01
Watermelon (Australia)	AFCD (1983-84)	3.2	1.2	2.6	0.0	0.0	0.0	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Watermelon (Australia)	CU (2021)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Watermelon (Australia)	Literature (2022)[21]	NR	NR	NR	NR	NR	NR	NR	.01	NR	NR	NR	NR	NR	NR	NR	NR	NR
Watermelon (UK)	UK-CoFID (1985-2013)	1.8	1.0	2.7	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Watermelon (US)	USDA (2000-19)	3.4	1.6	1.2	.02	.04	.05	.02	.06	.04	.00	.06	.01	.01	.02	.02	.06	.01
Watermelon Seeds (US)	USDA (2000-19)	NR	NR	NR	9.8	7.4	28	1.5	4.9	2.8	0.4	5.7	1.7	0.8	2.2	0.9	0.8	0.8

MELON (COUNTRY)	SOURCE (YEAR)	SUGARS (G/100G)			FA (G/100G)			AMINO ACIDS (G/100G)											
		FRUCTOSE	GLUCOSE	SUCROSE	SFA	MUFA	PUFA	ALANINE	ARGININE	ASPARTATE	CYSTINE	GLUTAMATE	GLYCINE	HISTIDINE	ISOLEUCINE	LEUCINE	LYSINE	METHIONINE
Piel de Sapo (Australia)	Literature (2022)[21]	NR	NR	NR	NR	NR	NR	NR	.01	NR	NR	NR	NR	NR	NR	NR	NR	NR

Table 2 footnotes:
Bolded entries represent data collected for Australian melons. If not otherwise stated, the nutrient data are for the flesh compon
1: Average of two records from the same source and for the same melon type shown
Abbreviations: SFA: saturated fats, MUFA: monounsaturated fats, PUFA: polyunsaturated fats, AFCD: Australian Food Compositio
(ST19036 project), USDA: United States Department of Agriculture Food Central, UK-CoFID: UK Composition of Foods Integrated I
States, NR: Data not reported.
Added data available for individual melons and minerals in provided Melon Matrix excel file.

Summary of macronutrient composition data

Review of current data:

- The ACFD data are old and was generated in 1983-84. The ACFD reports on the composition of sugars in melons, but does not report on amino acids and fatty acids (tryptophan values, an amino acid, were borrowed from USDA).
- Only one published paper was found on Australian-grown Piel de Sapo, which reported it as good source of the amino acid alanine and citrulline.
- Updated values for sugars and the amino acid tryptophan were generated for Australian honeydew, rockmelon, and watermelon by Curtin University in 2021 (ST19036)
- Similar sugars values were found when comparing AFCD data to more recent data (i.e., Curtin University: 2021, USDA: 2000-19, UK-CoFID),
- Honeydew, rockmelon, and watermelon are a good dietary source of a wide range of amino acids, particularly citrulline, arginine, alanine, cystine, aspartate, lysine, and glutamate- supported by data collated from international sources (USDA) and Australian literature.
- **Other relevant findings:** USDA data show that watermelon seeds are rich sources of polyunsaturated fats and amino acids.

Recommendations:

- Submit the data provided by Curtin University (ST19036 project) to FSANZ to update sugar data in AFCD for honeydew, rockmelon, and watermelon.
- Undertake further sugar analyses for the Piel de Sapo melon.
- Perform amino acid testing in melons to update the ACFD and showcase melons as a good dietary source of amino acids.

Table 3. Vitamin composition of melons and melon components

MELON (COUNTRY)	SOURCE (YEAR)	A (ug)	C (mg)	D (ug)	E (mg)	K1 (ug)	B1 (mg)	B2 (mg)	B3 (mg)	B5 (mg)
Honeydew (Australia)[1]	AFCD (1983-84)	7.0	16	0.00	0.02	NR	0.02	0.02	0.32	NR
Honeydew (Australia)	CU (2021)	10	11	NR	0.20	NR	0.02	<0.02	0.12	0.04
Honeydew (UK)[1]	UK-CoFID (1985-2013)	1.0	5.5	0.00	0.04	NR	0.04	0.01	0.35	0.15
Honeydew (US)	USDA (2000-19)	3.0	18	0.00	2.9	NR	0.04	0.01	0.42	0.16
Rockmelon (Australia)	AFCD (1983-84)	130	34	0.00	0.00	NR	0.02	0.02	0.22	0.00
Rockmelon (Australia)	CU (2021)	450	13	NR	0.2	NR	0.02	<0.02	0.41	0.04
Rockmelon (UK)[2]	UK-CoFID (1985-2013)	221	19	0.00	0.09	NR	0.03	0.01	0.43	0.10
Rockmelon (US)[1]	USDA (2000-19)	201	24	0.00	NR	2.6	0.05	0.02	NR	0.10
Watermelon (Australia)	AFCD (1983-84)	48	4.0	NR	0.00	NR	0.02	0.00	0.08	0.09
Watermelon (Australia)	CU (2021)	43	4.0	NR	0.00	NR	NR	NR	0.08	NR

MELON (COUNTRY)	SOURCE (YEAR)	A (ug)	C (mg)	D (ug)	E (mg)	K1 (ug)	B1 (mg)	B2 (mg)	B3 (mg)	B5 (mg)	(r
Watermelon (UK)[1]	UK-CoFID (1985-2013)	15	6.5	0.00	0.08	0.30	0.04	0.01	0.10	0.17	(
Watermelon (US)	USDA (2000-19)	28	8.1	0.00	NR	0.10	0.03	0.02	0.18	0.22	(
Watermelon, Seeds (US)	USDA (2000-19)	0.00	0.00	0.00	NR	NR	0.19	0.15	3.6	0.35	(
Piel de Sapo, Pulp (Portugal)	Literature (2020)[22]	NR	37.2	NR	NR	NR	NR	NR	NR	NR	
Piel de Sapo, Peel (Portugal)	Literature (2020)[22]	NR	33.4	NR	NR	NR	NR	NR	NR	NR	
Piel de Sapo, Seeds (Portugal)	Literature (2020)[22]	NR	32.0	NR	NR	NR	NR	NR	NR	NR	

Table 4 footnotes:

Bolded entries represent data collected for Australian melons. If not otherwise stated, the nutrient data are for the flesh compon
1: Average of two records from the same source and for the same melon type shown
2: Average of three records from the same source and for the same melon type shown
Abbreviations: A: vitamin A (reported as vitamin A retinol equivalents), C: vitamin C (ascorbic acid), D: vitamin D, E: vitamin E, K1:
riboflavin, B3: niacin (reported as niacin derived equivalents), B5: pantothenic acid: B6: pyridoxine, B7: biotin, B9: folate (reporte
cobalamin, AFCD: Australian Food Composition Database, CU: Curtin University (ST19036 project), USDA: United States Departme
UK Composition of Foods Integrated Dataset, UK: United Kingdom, US: United States, NR: Data not reported.
Added data available for individual melons and minerals in provided Melon Matrix excel file.

Summary of vitamin data

Review of current data:

- The ACFD data is old (1983-84) and reports on the content of several vitamins (vitamins A, C, D, E, B1, B2, B3, B5, B6, B7, B9 (folate) and B12) in honeydew, rockmelon, and watermelon (exceptions: B5 and B7 not reported for honeydew, vitamin D not reported for watermelon).
- Data were not available in the ACFD for the Piel de Sapo, but does exist for vitamin C from international sources.
- ACFD data were not available for Vitamin K. Data from international sources (USDA: 2000-19) suggests that melons are a good dietary source vitamin K, with rockmelon in particularly providing 4-5% the recommended dietary intake of vitamin K per 100g.
- Updated values for several vitamins in honeydew and rockmelon (A, C, E, B1, B2, B3, B5, B6, B7, and B9) were generated by Curtin University in 2021. Data for select vitamins were also generated for watermelon (A, C, E, B5 and B7) by Curtin University (2021), with international sources suggesting watermelon is a source of other B vitamins: B1, B2, B6, and B9.
- The ST19036 project also provides data for vitamins not covered in the ACFD for honeydew (B5 and B7). Vitamin D was not assessed in the ST19036 project, however Australian and international data indicate this nutrient is not detected in honeydew, rockmelon or watermelon.
- Similar vitamin profiles were fond when comparing ACFD data to most recent data (i.e., Curtin University: 2021, USDA: 2000-19, UK-CoFID).
- Collated data show that melons are a rich source of vitamins, particularly vitamin A and C.

Recommendations:

- Submit the available data provided by Curtin University (ST19036 project) to FSANZ to update the vitamin data for honeydew, rockmelon and watermelon in the AFCD.
- Complete vitamin K analysis for all melons including Piel de Sapos.
- Complete analyses for B vitamins (B1, B2, B6, and B9) in watermelon.
- Undertake vitamin analyses for the Piel de Sapo melon.

Table 4. Mineral composition of melons and melon components

MELON (COUNTRY)	SOURCE (YEAR)	PER 100G Ca (mg)	Fe (mg)	I (ug)	Mg (mg)	P (mg)	K (mg)	Se (ug)	Na (mg)	Zn (mg)
Honeydew (Australia)[1]	AFCD (1983-84)	38.5	0.00	0.35	13	11	155	0.70	42	0.15
Honeydew (Australia)	CU (2021)	9.6	0.72	NR	12	10	160	<0.1	24	0.07
Honeydew (UK)[1]	UK-CoFID (1985-2013)	3.5	0.11	NR	4.0	4.0	108	NR	6.5	NR
Honeydew (US)[2]	USDA (2000-19)	6.0	0.17	NR	10.0	11	228	0.7	18	0.09
Rockmelon (Australia)	AFCD (1983-84)	7.0	0.24	0.00	8.0	14	215	0.0	14	0.12
Rockmelon (Australia)	CU (2021)	11	0.28	0.00	15	18	240	<1.0	19	0.16
Rockmelon (UK)[2]	UK-CoFID (1985-2013)	15	0.23	3.0	8.0	10	157	NR	6.0	0.1
Rockmelon (US)[1]	USDA (2000-19)	9.0	0.30	NR	12.5	16	212	1.1	23	0.31
Watermelon (Australia)	AFCD (1983-84)	5.0	0.1	0.1	12	14	122	0.1	3	0.06

MELON (COUNTRY)	SOURCE (YEAR)	PER 100G								
		Ca (mg)	Fe (mg)	I (ug)	Mg (mg)	P (mg)	K (mg)	Se (ug)	Na (mg)	Zn (mg)
Watermelon (UK)[1]	UK-CoFID (1985-2013)	5.5	0.25	0.1	6.5	7.0	79	NR	1.5	0.15
Watermelon (US)	USDA (2000-19)	7.0	0.24	NR	10	11	112	0.4	1 (0-5)	0.1
Watermelon, Seeds (US)	USDA (2000-19)	54	7.28	NR	515	755	648	NR	99	10.2
Piel de Sapo, Pulp (Portugal)	Literature (2020)[22]	NR	NR	NR	NR	NR	290	NR	NR	NR
Piel de Sapo, Peel (Portugal)	Literature (2020)[22]	NR	NR	NR	NR	NR	329	NR	NR	NR
Piel de Sapo, Seeds (Portugal)	Literature (2020)[22]	NR	NR	NR	NR	NR	793	NR	NR	NR

Table 3 footnotes:
Bolded entries represent data collected for Australian melons. If not otherwise stated, the nutrient data are for the flesh compon
1: Average of two records from the same source and for the same melon type shown
2: Average of three records from the same source and for the same melon type shown
Abbreviations: Ca: Calcium, Fe: Iron, I: Iodine, Mg: Magnesium, P: Phosphorus, K: Potassium, Se: Selenium, Na: Sodium, Zn: Zinc, (
Mo: Molybdenum, Cl: Chloride, AFCD: Australian Food Composition Database, CU: Curtin University (ST19036 project), USDA: Un
Food Central, UK-CoFID: UK Composition of Foods Integrated Dataset, UK: United Kingdom, US: United States, NR: Data not reporte
Added data available for individual melons and minerals in provided Melon Matrix excel file.

Summary of mineral data

Review of current data:

- The ACFD data are old; generated in 1983-4. It includes the minerals calcium, iron, iodine, manganese, potassium, sodium, and zinc of Australian honeydew, rockmelon, and watermelon varieties.
- The AFCD also contains borrowed data on selenium and phosphorus content for honeydew, rockmelon, and watermelon, from the USDA database.
- Updated values were generated for honeydew and rockmelon (but not watermelon) by Curtin University (2021) for calcium, iron, manganese, potassium, sodium, phosphorus, iodine, selenium, and zinc. The ST19036 project also provided data for minerals not currently reported in the ACFD for melons (copper, manganese, and molybdenum).
- The ST19036 project did not cover mineral analyses for watermelon. ST19036 data were also not generated for select minerals in honeydew (Iodine, chloride), and rockmelon (fluoride, chloride), with Australian and international sources indicating that these melons are sources of these minerals.
- Considerable variations were found for minerals calcium, iron and sodium when comparing ACFD data to most recent data (i.e., Curtin University: 2021, USDA: 2000-19, UK-CoFID). These variations are likely explained by changes in mineral content of soils across different areas and time periods.
- One literature source found that Australian-grown Piel de Sapo pulp, peel and seeds are good sources of potassium (highest content in seeds).

<u>Recommendations:</u>

- Submit the available data provided by Curtin University (ST19036 project) to FSANZ to update the mineral values reported in the AFCD for honeydew and rockmelon.
- Conduct mineral analyses for watermelon and for the Piel de Sapo melon, to provide FSANZ with data of the mineral composition of these melon varieties.
- Conduct analyses of select minerals in honeydew (Iodine, chloride), and rockmelon (fluoride, chloride) to update the AFCD.

Table 5. Bioactive and polyphenol composition of melons and melon components

MELON (COUNTRY)	SOURCE (YEAR)	CHLOROPHYLLS (PER 100G)	CAROTENOIDS (PER 100G)					PO (PE
		TOTAL CHLOROPHYLLS (ug)	LUTEIN (ug)	α-CAROTENE (ug)	β-CAROTENE (ug)	β-CRYPTOX (ug)	LYCOPENE (ug)	FL
Honeydew (Australia)[1]	AFCD (1983-84)	NR	NR	5.0	40	0.00	NR	
Honeydew (Australia)	CU (2021)	NR	NR	<5.0	58	NR	NR	
Honeydew (UK)	UK-CoFID (1985-2013)	NR	NR	4.0	NR	NR	NR	
Honeydew (US)	USDA (2000-19)	NR	27*	0.00	30	0.00	0.00	
Honeydew (Mixed)[3]	Literature (2001- 2021) [23-28]	NR	NR	NR	NR	NR	NR	
Rockmelon (Australia)	AFCD (1983-84)	NR	NR	5.0	770	20	NR	
Rockmelon (Australia)	CU (2021)	NR	9.7	<5.0	2700	3.0	NR	
Rockmelon (UK)[2]	UK-CoFID (1985-2013)	NR	0.00	15	1395	NR	NR	
Rockmelon (US)	USDA (2000-19)	NR	26*	16	2020	1.0	0.00	

MELON (COUNTRY)	SOURCE (YEAR)	CHLOROPHYLLS (PER 100G)	CAROTENOIDS (PER 100G)					PO (PE
		TOTAL CHLOROPHYLLS (ug)	LUTEIN (ug)	α-CAROTENE (ug)	β-CAROTENE (ug)	β-CRYPTOX (ug)	LYCOPENE (ug)	FL
Rockmelon (Mixed)[3]	Literature (2001-2021) [23, 25, 27, 29, 30]	NR	NR	NR	NR	NR	NR	
Watermelon (Australia)	AFCD (1983-84)	NR	NR	0.0	290	0.0	NR	
Watermelon (Australia)	CU (2021)	NR	0.0	0.0	116	0.0	4763	
Watermelon (UK)[1]	UK-CoFID (1985-2013)	NR	0.0	0.0	91	0.0	3739	
Watermelon (US)	USDA (2000-19)	NR	8.0*	0.0	303	78	4530	
Watermelon (Mixed)[3]	Literature (2001-2021) [24-27, 30-32]	NR	NR	NR	NR	NR	NR	
Piel de Sapo, Pulp (Portugal)	Literature (2020)[22]	1.61	NR	NR	NR	NR	NR	
Piel de Sapo, Peel (Portugal)	Literature (2020)[22]	87.9	NR	NR	NR	NR	NR	
Piel de Sapo Seeds (Portugal)	Literature (2020)[22]	4.8	NR	NR	NR	NR	NR	

Table 5 footnotes:

Majority of included compounds are bioactive pigments in fruits and are coloured appropriately. Note: Total flavonoids cover a g yellow or ivory-coloured pigments. Total phenolics cover another group of polyphenols, with the major phenolic (gallid acid) yello colourless.

Bolded entries represent data collected for Australian melons. If not otherwise stated, the nutrient data are for the flesh compon

1: Average of two records from the same source and for the same melon type shown

2: Average of three records from the same source and for the same melon type shown

3: Average of six to seven literature sources

*combined lutein and zeathin content reported

Abbreviations: β-cryptox: β-crytptoxanthin, AFCD: Australian Food Composition Database, CU: Curtin University (ST19036 project Agriculture Food Central, UK-CoFID: UK Composition of Foods Integrated Dataset, UK: United Kingdom, US: United States, NR: Da

Added data available for individual melons and minerals in provided Melon Matrix excel file.

Summary of bioactive data

Review of current data:

- The ACFD contains old data (1983-84) for select carotenoids (α-carotene, β-carotene and β cryptoxanthin) and organic acids (citric and malic acid) found in honeydew, rockmelon, and watermelon.
- AFCD data are comparable to more recent data (i.e., Curtin University: 2021, USDA: 2000-19, UK-CoFID).
- The ACFD does not contain data for the carotenoids, lycopene, lutein, and zeaxanthin, as well as the bioactives chlorophyll, flavonoids and phenolics.
- No data was available for Piel de Sapo melon, with collated literature sources finding Piel de Sapo is a good dietary source of polyphenols and chlorophyll (highest contents in the peel).
- The ST19036 project (Curtin University: 2021) provides data for the α- and β-carotene content of Australian honeydew, rockmelon, and watermelon.
- The ST19036 project also provides values for lycopene, lutein (not available for honeydew), total phenolics and total flavonoids, which are not currently reported in the ACFD for these melons.
- No data were sourced for the chlorophyll of honeydew, rockmelon and watermelon; however we can be confident that this bioactive is present in considerable amounts in honeydew, as chlorophylls provide the green colour found in fruits [2].

Recommendations:

- Submit data available for carotenoid, polyphenol and organic acids generated from by Curtin University for honeydew, rockmelon, and watermelon.
- Perform analyses for chlorophyll for honeydew.
- Perform analyses for bioactives that are colourless or contribute ivory, pale-yellow, or pale-green pigments (chlorophyll, total phenolics, lutein, α-carotene, total flavonoids and organic acids) for Piel de Sapo, to submit to FSANZ for inclusion in the AFCD.

Summary and recommendations

- Energy, macronutrient, vitamins, minerals and bioactive pigments need to be analysed for Piel de Sapo.
- Energy, macronutrient, vitamins, bioactive pigments can be updated using data from ST19036 for honeydew, rockmelon and watermelon. Macronutrient composition (i.e., amino acids) need to be performed for all melon varieties.
- Analyses for select vitamins need to be performed for melon varieties: vitamin K (all melons) and B vitamins (B1, B2, B6 and B9) in watermelon.
- Mineral analyses need to be performed for watermelon.
- Select minerals need to be analysed for honeydew (Iodine, chloride) and rockmelon (fluoride, chloride).
- Analyses for the bioactive pigment chlorophyll need to be performed for honeydew.

Table 6. Summary of recommendations to update the Australian Food Composition Database for Australian melons

<table>
<tr><th>MELON</th><th>ENERGY & MACRO-NUTRIENTS</th><th>MACRO-NUTRIENT COMPOSITION</th><th>MINERALS</th><th>VITAMINS</th><th>BIOACTIVES</th></tr>
<tr><td>Honeydew</td><td rowspan="3">Update ACFD with available data (ST19036 project)</td><td rowspan="3">Update ACFD available sugars profiles from the ST19036 project + Conduct additional amino acid analyses</td><td rowspan="2">Update ACFD with ST19036 project data</td><td rowspan="3">Update ACFD with available data (ST19036 project) + Conduct additional vitamin analyses</td><td>Conduct additional analyses for chlorophyll</td></tr>
<tr><td>Rockmelon</td><td rowspan="2">Update ACFD with available data (ST19036 project)</td></tr>
<tr><td>Watermelon</td><td>Conduct updated mineral analyses</td></tr>
<tr><td>Piel de Sapo</td><td colspan="5">Analyse Australian Piel de Sapo melons</td></tr>
</table>

Key:

- Little to no Australian data, requires first-hand testing
- Missing some data, requires updating with available data (ST19036 project) and some additional Australian testing
- Testing was performed 20+ years ago, data require updating with those data generated in the ST19036 project

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Appendices

This report is accompanied by a Microsoft Excel file of the melon data tables. This datafile is designed for submission to FSANZ to update the AFCD or publication in Dryad data repository.

APPENDIX 6

NRAUS

VM20003 Melons Website Copy

Prepared for:

Melons Australia

November 2022

Prepared by:

Nutrition Research Australia Pty Ltd

Background

Melons Australia commissioned Nutrition Research Australia (NRAUS) to provide copy for an updated website, translating the nutritional properties and health benefits of Australian melons. The audience includes both health-care professionals (HCPs) and consumers.

The website content delivers key messages to:

- Increase HCP's knowledge and awareness of the nutrition and health benefits of melons and empower them to recommend them to their clients.
- Provide evidence-based messages to support consumer awareness and knowledge around the nutrition and health benefits of melons.

This report provides nutrition and health content on Australian melons that can be utilised specifically for 1) consumers, and 2) HCPs, as well as 3) fun facts that can be utilised in any location. Suggestions are also given for design layout and direction.

Regulatory considerations

The Australia New Zealand Food Standards Code is a collection of standards that set the legal requirements for foods and beverages in Australia and New Zealand. Standard 1.2.7 (Nutrition, Health and Related claims) specifies the nutrition and health claims that can be made on advertisement or the labelling of foods. Copy provided on the Australian Melons' website has been written for educational purposes only. It is not to be used for advertisement or labelling.

Consumer messaging

Overview

The consumer messaging is designed to provide educational content about the health benefits of Australian melons that is easy to access and digest by consumers. This section brings the "goodness in every colour" story to life and provides practical tips on melon usage and safety.

Goodness in every colour

Content aims to highlight melons as:

- A hero fruit for the delivery of colour-associated nutrients and bioactives; and
- A solution to Australians not getting enough fruit nor colour variety in the diet.

Disclaimer

A disclaimer should be placed on the website relating to any nutrition and health information and appropriate copy is as below:

The content on this website is for educational purposes only.

Website copy

Eat a rainbow: Maximising the benefits of colour variety with melons.

Have you ever heard of the advice to "Eat a rainbow?"
Have you ever wondered what it means? "Eat a rainbow" simply means to eat a variety of different-coloured fruits and vegetables. Fruits and vegetables come in many colours: red, orange, yellow, green, blue, purple, and white, similar to the colours of a rainbow. These colours are the result of the special bioactive pigments they contain, which are linked to beneficial health effects.

Why "Eat a rainbow" of colours?

A world-first study shows that eating a variety of colours (from bioactive pigments) has health benefits [1]. The research showed that 6 of the 8 colours had unique health benefits associated with them, and that having a variety of colours provides extra health benefits compared to eating same-coloured fruits and vegetables every day.

Research also shows that around 8 in 10 people are not getting enough colour variety from fruits and vegetables [1], and therefore, are not getting their associated health benefits, increasing their risk for chronic diseases such as diabetes and cancer [1, 2].

Why melons?

Melons are not only juicy and delicious, but they also provide 5 different colours (red, orange, yellow, green and white), making them an excellent choice to help get more colour variety in the diet.

The bright colours of melons are due to the presence of different bioactive pigments produced by the fruit during the ripening process.

Melons contain goodness in every colour!

Each melon has its own blend of health-promoting colourful *bioactives* plus they have a range of essential nutrients that are needed as part of a healthy, balanced diet.

The different colours of melons:

Australian melons include watermelons, rockmelons, honeydew melons, and Piel de Sapo melons.

Watermelon contains RED, ORANGE, YELLOW, AND WHITE BIOACTIVES

- The typical red colour of watermelon comes from the presence of red pigments such as lycopene [3, 4] and beta-cryptoxanthin [4].
- Watermelon also contains orange and yellow pigments called total carotenoids [3], and white pigments called flavones [5].

Rockmelon contains ORANGE, RED, YELLOW, AND WHITE BIOACTIVES

- The typical orange colour of rockmelon comes from orange pigments such as beta-carotene [4, 6].
- Rockmelon also contains red, orange, and yellow pigments called total carotenoids [6], and white pigments called flavones [5].

Honeydew melon contains ORANGE or GREEN BIOACTIVES

- Honeydew melons can be orange or green.
- Like rockmelon, orange honeydew melon gets its colour orange pigments such as beta-carotene [7], but the colour of green honeydew melon comes from green pigments such as chlorophyll [8].

Piel de Sapo melon contains BIOACTIVES

- Like green honeydew melon, the Piel de Sapo melon contains the green pigment chlorophyll [9], which contributes to the light green colour of its flesh.

How do the colourful bioactives in melons benefit our health?

When consumed as part of a healthy, balanced diet, the colourful bioactive pigments in melons can support our health [1]:

Red lycopene can support:

- ✓ a healthy heart
- ✓ normal metabolism
- ✓ protection from some cancers
- ✓ a long life.

Red beta-cryptoxanthin can support:

- ✓ normal metabolism
- ✓ protection from some cancers
- ✓ a long life
- ✓ healthy bones

Orange beta-carotene can support:

- ✓ a healthy heart
- ✓ normal metabolism
- ✓ protection from some cancers
- ✓ a long life
- ✓ healthy bones

Red, orange, and yellow total carotenoids can support:

- ✓ a healthy heart
- ✓ normal metabolism

Green chlorophyll can help with:

- ✓ seasonal allergy symptoms.

White flavones can support:

- ✓ a healthy heart
- ✓ protection from some cancers
- ✓ a long life

To increase colour variety in your diet, just add melons.

Melons contain essential nutrients.

One serve of melons (150 g) provides essential nutrients as part of a healthy and balanced diet [9-11]:

- Watermelon, rockmelon, honeydew melon, and Piel de Sapo melon all contain Vitamin C to support immunity
- Rockmelon contains Vitamin A to support healthy vision
- Rockmelon and honeydew melon contain folate to support energy levels and growth and development
- Rockmelon, honeydew melon, and Piel de Sapo melon contain potassium to support electrolyte balance and muscle function.
- All melons contain water for hydration.

How can I add more melons to my diet?

It is easy, fun, and delicious to just add melons to your diet:

Make it EASY: When they're pre-prepared, you'll be more likely to eat them.

- CHOP THEM: Chop up a variety of melons of different colours into 2 cm cubes.
- STORE THEM: Store chopped melons in the fridge at eye level. Research shows that you can increase your fruit intake just by making it convenient and accessible [12].
- FREEZE THEM: Store chopped melons in the freezer to use as the base for cold summer snacks. This is a great way to help prevent food waste.

Make it FUN. Fun things become done things.

- **Melon cubes as fruit kebabs**. Create different shapes and sizes to make it fun to eat.
- **Summer snack**. Add as the base of smoothies, melon sorbets, or as ice cubes for drinks.
- **In a salad**. Try watermelon with feta, Piel de Sapo with chicken, rockmelon with prosciutto, or honeydew with cucumber.
- **Get inspired** – Check out **this link** for more delicious recipe ideas that bring colour into the kitchen. Did you know watermelon melon rind can be used to make a fabulous stir fry? [QR code with "scan for recipes"] www.melonsaustralia.org.au/recipes/ https://alicezaslavsky.com/recipe/watermelon-rind-san-choy-bao/

Make it SAFE: Take extra care.

How can I use melons safely?

Melons are a fresh, whole fruit with no preservatives or additives. This means that they need to be refrigerated and used within a certain time to keep from spoiling.

To ensure that melons remain safe to eat, follow these tips:

DO:

- Wash hands, chopping boards & knives before and after handling.
- Store in the fridge at 5°C or below.
- Consume within 4 days (cut melon), two weeks (whole melons), or one month (frozen melon).

AVOID:

- Melons with cracked, bruised, decayed or mouldy skin.
- Rockmelons if pregnant or immune-compromised [13].

Design and layout considerations

A suggestion for the strategic layout direction for the consumer-friendly content for the website is depicted in **Appendix 1** and includes:

- Pictures of the different Australian melons.
- The "goodness in every colour" logo.
- The "goodness in every colour" story to create impact.
- A colour theme made up of the key colours that melons provide to the diet: red, orange, yellow, green, and white.
- Practical tips section: How can I add more melons to my diet? with a link to additional inspiring melons recipes.
- A section on how to use melons safely.
- A link to the consumer-friendly brochure resource.

The references cited in the website content are outlined at the end of the Appendices.
Please note that any use of copy may alter the order of the references used; alignment between the numbering of citations throughout the copy and the listing of references used should be ensured.

HCP-specific messaging

Overview

Messaging provides more detailed educational content for healthcare professionals on the health benefits of eating a rainbow, and the nutrition and health benefits of each Australian melon, including:

- The importance of eating a rainbow.
- The colour-associated bioactive content of each melon.
- The specific health benefits associated with each colour-associated bioactive.
- The nutritional composition of each melon.
- Bioactive content and health benefits of the by-products (rind and seeds).
- Additional health benefits linked to consumption (where applicable).

Disclaimer

A disclaimer should be placed on the website relating to any nutrition and health information and appropriate copy is as below:

The content on this website was created for healthcare professionals and is for educational purposes only.

Website copy

Eat a rainbow: The benefits of maximising colour variety

The naturally occurring bioactive pigments (i.e., colour-associated phytonutrients) are responsible for the vibrant colour of fruits and vegetables, and provide significant benefits for health beyond the benefits associated with total fruit and vegetable intake [1].

A world-first umbrella review representing 83 systematic literature reviews (SLRS), 2847 original research studies (cohorts and randomised controlled trials), and containing data from over 37 million participants [1], shows that there are health benefits associated with each bioactive pigment. Further, that colour variety is just as important as total serves of fruit and vegetables consumed, supporting the message to **“eat a rainbow”** of colours from fruits and vegetables. While similar health benefits were found across the groups of bioactive pigments, there were unique health benefits found for six of the eight bioactive pigments [1]. This research suggests that while it is important to meet the recommended serves of fruits and vegetables, it is just as important to consider the colour-variety of the fruits and vegetables.

Key bioactive pigments found in the review to have health benefits:

Red Lycopene:

- Associated with a reduced risk for mortality, cardiovascular disease, a range of cancers, and type 2 diabetes mellitus [1].

Red Beta-cryptoxanthin:

- Associated with a reduced risk for mortality, a range of cancers, bone fractures, and type 2 diabetes mellitus [1].

Orange Beta-carotene:

- Associated with a reduced risk for a range of cancers, mortality, type 2 diabetes mellitus, bone fractures, and coronary heart disease [1].

Yellow Alpha-carotene, Lutein, & Zeaxanthin

- Associated with a decreased risk of bladder cancer, all-cause mortality, breast cancer, and type 2 diabetes mellitus [1].

Red, Orange, & Yellow Total Carotenoids:

- Improved HDL cholesterol and decreased risk factors for obesity and type 2 diabetes mellitus, including body weight, waist circumference, and total cholesterol [1].

Red, Purple, & Blue Anthocyanins and Anthocyanidins

- Associated with decreased risk of colorectal cancer, as well as improved biomarkers of inflammation, oxidative stress, and cardiometabolic health [1].

Red, Purple, Blue, & Brown Proanthocyanins and Proanthocyanidins

- Associated with a decreased risk of colorectal cancer and cardiovascular disease, as well as improved blood and arterial pressure [1].

Green Chlorophyll:

- Can relieve symptoms of seasonal allergic rhinitis [1].

White Flavones:

- Associated with a reduced risk for a range of cancers, as well as all-cause and cardiovascular disease mortality [1].

Just add melons to get the benefits of colour variety

Melons can contain red [3, 4, 6] orange [3, 4, 6, 7], yellow [3, 6], green [8, 9], and white [5] bioactive pigments, and having a variety of melons can make it easier to improve health by adding colour variety to the diet.

Watermelon

Provides red, orange, yellow, and white bioactive pigments:

- The red pigment lycopene [3, 4]: associated with reduced risk for cardiovascular disease, mortality, a range of cancers, and type 2 diabetes mellitus [1].
- The red pigment beta-cryptoxanthin [4]: associated with reduced risk for mortality, a range of cancers, hip fracture, and type 2 diabetes mellitus [1].
- Red, orange and yellow total carotenoids [3]: which are linked to decreased risk factors for obesity and type 2 diabetes, including reduced bodyweight and waist circumference, and improved cholesterol levels [1].
- White pigments called flavones [5]: associated with decreased risks for a range of cancers, mortality, and cardiovascular disease mortality [1].

Rockmelon

Provides orange, red, yellow, and white bioactive pigments:

- The orange pigment beta-carotene [4, 6]: associated with a reduced risk for a range of cancers, mortality, type 2 diabetes mellitus, and cardiovascular disease [1].
- Red, orange and yellow total carotenoids [6]: linked to decreased risk factors for obesity and type 2 diabetes, including reduced bodyweight and waist circumference, and improved cholesterol levels [1].
- White pigments called flavones [5]: associated with decreased risks for a range of cancers, mortality, and cardiovascular disease mortality [1].

Honeydew melon

Can provide orange and green bioactive pigments:

- Orange honeydew contains the orange pigment beta-carotene [7]: associated with a reduced risk for a range of cancers, mortality, type 2 diabetes mellitus, and cardiovascular disease [1].
- Green honeydew contains the green pigment chlorophyll [8]: can help to relieve seasonal allergy symptoms [1].

Piel de Sapo melon

Can provide green bioactive pigments:

- Contains the green pigment chlorophyll [9], which can help to relieve seasonal allergy symptoms [1].

Benefits of the whole melon

The rind and seeds of melons also contain bioactive pigments, including chlorophyll [14], lutein [14], and beta-carotene [14, 15].

- Emerging research with watermelon rind and seeds in cultured cells and animals has shown a link to improved markers of cardiovascular health, metabolic health, cancer, gut microbiota, liver health, oxidative stress, and infection [16-23].
- Emerging research with rockmelon rind/peel and seeds has shown possible benefits for cancer development, by inhibiting the growth of cultured human cancer cells [24].
- Emerging research with honeydew melon seeds has shown possible benefits for cancer development, by inhibiting the growth of cultured human cancer cells [25].

Additional health benefits of melons

Recent evidence has identified additional health benefits associated with the consumption of watermelon. Research investigating rockmelon, honeydew melon, and Piel de Sapo melon has not been performed.

Antioxidant potential

- ➢ Two serves of watermelon per day have been shown to reduce oxidative stress, which has been associated with a range of chronic diseases [26].
- ➢ High doses of watermelon (7 serves per day) were found to improve antioxidant capacity during exercise [27, 28].

Cardiovascular Health

- ➢ Watermelon contains citrulline [29-33] and arginine [32, 33], amino acids that support the production of nitric oxide, which functions as a vasodilator, increasing blood flow and reducing blood pressure [26, 34].
- ➢ Two serves of watermelon per day have been linked to improved markers of cardiovascular health, including blood lipids and blood pressure [26, 34-37].

Metabolic Health

- ➢ With 91% water and 10.5 g sugars per serve [10], watermelon has a low glycemic load, which is associated with improved glycemic control [38].
- ➢ Two serves of watermelon per day have been shown to improve markers of metabolic health such as bodyweight, and reduce appetite [26].

The nutritional composition of melons

Per 150g serve (for adult male based on an energy intake of 8700 kJ/day).

Watermelon [10, 11, 39]:

- 191 kJ energy, 2% RDI
- 10.4 g sugars
- 136.5 mL water, which is 5% AI for an adult male
- 59.5 µg and 8% RDI for vitamin A
- 4.5 µg and 2% RDI for folate
- 8 mg and 20% RDI for vitamin C
- 9 mg and 1% RDI for calcium
- 0.26 mg and 2% RDI for iron
- 16.5 mg and 5% RDI for magnesium
- 175.5 mg potassium, which is 5% AI for an adult male

Rockmelon [10, 11, 39]:

- 175 kJ energy, 2% RDI
- 8.8 g sugars
- 135 mL water, which is 5% AI for an adult male
- 435 µg and 58% RDI for vitamin A
- 35.5 µg and 18% RDI for folate
- 35.3 mg and 88% RDI for vitamin C
- 13.5 mg and 2% RDI for calcium
- 0.41 mg and 3% RDI for iron
- 17.8 mg and 6% RDI for magnesium
- 333.5 mg potassium, which is 9% AI for an adult male

Honeydew [10, 11, 39]:

- 202 kJ energy, 2% RDI
- 9.9 g sugars
- 135 mL water, which is 5% AI for an adult male
- 10 µg and 1% RDI for vitamin A
- 23.1 µg and 12% RDI for folate
- 22.5 mg and 56% RDI for vitamin C
- 36.1 mg and 5% RDI for calcium
- 0.45 mg and 4% RDI for iron
- 17.5 mg and 5% RDI for magnesium
- 271.5 mg potassium, which is 7% AI for an adult male

Piel de Sapo (per 150 g serve, adult male [9, 39]).

- 5% AI for water (as the average of other melons), which is 2% RDI (based on an energy intake of 8700 kJ/day)
- 41.9 mg and 105% RDI for vitamin C
- 435 mg potassium, which is 11% AI for an adult male

No information was available for energy, sugars, magnesium, iron, calcium, folate, or vitamin A levels for Piel de Sapo melon.

Watch this space! There is very limited research and nutrient composition information available for Piel de Sapo melon, highlighting a large research gap that needs to be filled.

Design and layout considerations

Two suggested strategic layout approaches (A and B) for the HCP-specific educational content are depicted in **Appendix 2 and 3.** Both include:

- An overview of the eat a rainbow manuscript.
- An overview section of the colour-associated health benefits of melons.
- The "goodness in every colour" logo.
- A build on the "goodness in every colour" story provided within consumer-friendly messaging.
- A colour theme made up of the key coloured pigments that melons provide to the diet: red, orange, yellow, green, and white.
- Messaging that melons are a way to obtain the health benefits of colour variety.
- Links to resources
  - The "Eat a Rainbow" umbrella review manuscript.
  - The two melons brochures (HCP and Consumer friendly).

The references cited in the website content are outlined at the end of the Appendices.

References: Please note that the order of the references may change when the copy is utilised for the website, resulting in misalignment between the reference numbers and the references throughout the copy. A thorough check of references needs to be performed and checked after use.

Approach A:

- Contains links to individual sections for each melon type: watermelon, honeydew melon, rockmelon, and Piel de Sapo; with each section detailing the nutritional composition (in table format), colour-associated bioactives, health benefits, as well as emerging research on melon by-products, if applicable, for that melon.

Approach B:

- Contains links to individual sections for each factor associated with the health benefits of melons: colour-associated bioactive pigments (in table format), nutritional composition (in table format), additional health benefits, and melon rind and seeds; with each section providing the relevant detail for all melons.

Fun facts about melons

Did you know...

- You only need one serve of melons per day, as part of the recommended fruit intake and a healthy, balanced diet! Adding one serve (150 g) per day of a mixture of different melon types can provide bioactives that are linked to health benefits [3-9].
- Melons have a low glycemic load [38], indicating that they have a low impact on your blood sugar after eating. A diet containing low glycemic load foods can help to support healthy blood sugar levels [40].
- The seeds and rind of melons can also contain healthy bioactive pigments. The rind can be cooked into a fabulous stir-fry, and the seeds are being used by food scientists to turn it into oil and flour [41, 42], reducing food waste while creating new food products.
- At around 90% water, melons provide 1/2 cup water per serve, meaning that melons are great for hydration [4]!
- Watermelon contains citrulline, which is a common supplement used by body builders to increase their “muscle pump”. This is because citrulline supports the production of nitric oxide, a compound which can increase blood flow to the muscles [34, 43].
- Melons are thought to have originated in South and Central America but are now grown all over Australia [44].
- In the US, July is National Watermelon Month [45]!
- The orange pigment beta-carotene, found in rockmelons and orange honeydew melons, contributes to the colour of our skin [46].
- The colour of melons changes throughout the growing process so that the ripe melons are the brightest, with the highest levels of many health-associated bioactive pigments [47]. Nature is smart!
- Melons belong to the Cucurbitaceae family, which also contains pumpkin, zucchini, and cucumber [48].

Design and layout considerations

A suggested strategic layout for the fun facts is depicted in **Appendix 4.**

The references cited in this section are included in the reference list provided at the end of the Appendices.

Please note that any use of copy may alter the order of the references used; alignment between the numbering of citations throughout the copy and the listing of references used should be ensured.

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APPENDIX 7

EAT A RAINBOW:

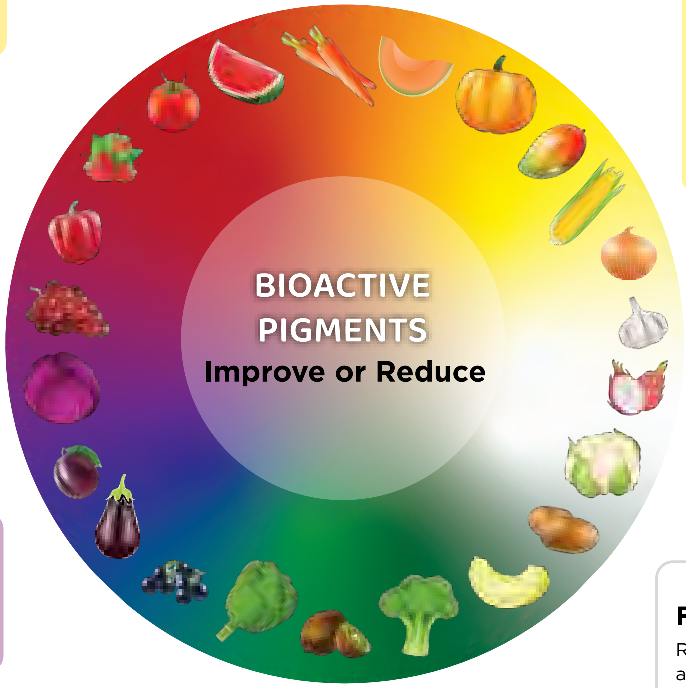
Maximising the health benefits of colour variety

WHY A VARIETY OF COLOUR?

Naturally occurring and pigmented phytonutrients (i.e., bioactive pigments) give fruits and vegetables their vibrant colours and are linked to beneficial effects on health[1].

A new world-first umbrella review representing 83 SLRs and containing data from over 37 million participants[1], has shown that colour variety is just as important as the total serves of fruits and vegetables consumed, supporting the message to: **"EAT A RAINBOW"** of colour.

COLOUR-ASSOCIATED HEALTH BENEFITS



Carotenoids
HDL-cholesterol, body weight, BMI, waist circumference, total cholesterol.

Beta-carotene
Risk of T2DM, all-cause mortality, CVD mortality, breast and gastric cancers, CHD, total or hip fracture.

Alpha-carotene
Risk of bladder, gastric, and breast cancer, all-cause mortality.

Lutein
Risk of T2DM.

Lutein & Zeaxanthin
Risk of bladder & breast cancer.

Lycopene
Risk of T2DM, all-cause mortality, stroke, CVD, breast, cervical, lung, oral, laryngeal, and pharyngeal cancers.

Beta-cryptoxanthin
Risk of bladder, lung, oral, laryngeal, pharyngeal cancers, T2DM, all-cause mortality, hip fracture.

Flavonols
Blood pressure, lipid profile, glycemic biomarkers, inflammatory biomarkers.
Risk of ovarian cancer, CVD, CHD.

Proanthocyanidin & Proanthocyanin
Blood & arterial pressure.
Risk of colorectal cancer.

Flavones
Risk of liver & smoking-related cancer, all-cause mortality, CVD mortality.

Anthocyanin & Anthocyanidin
Glycemic and insulinemic biomarkers, lipid profiles, body weight, vascular function, inflammatory & oxidative stress biomarkers.

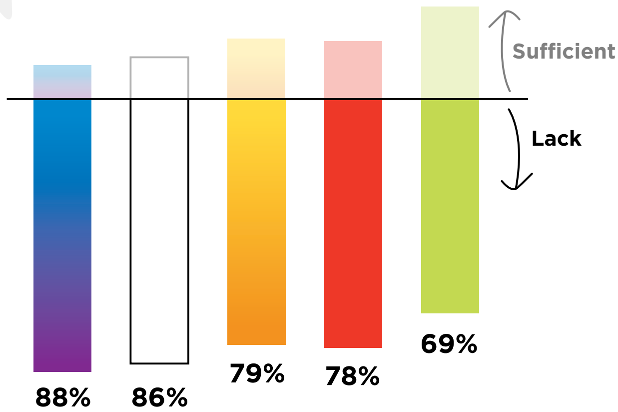
Chlorophyll
Seasonal rhinitis.

Figure adapted from Figure 2 of Blumfield et al (2022)[1] to capture outcomes with highest level of certainty.
CHD, coronary heart disease; CVD, cardiovascular disease; T2DM, type 2 diabetes mellitus.

MOST PEOPLE ARE NOT GETTING ENOUGH FRUITS AND VEGETABLES, OR COLOUR VARIETY[1-4]

Around the world, 78% of adults do not eat enough fruits and vegetables[3]:

And colour variety is **lacking**[4]:

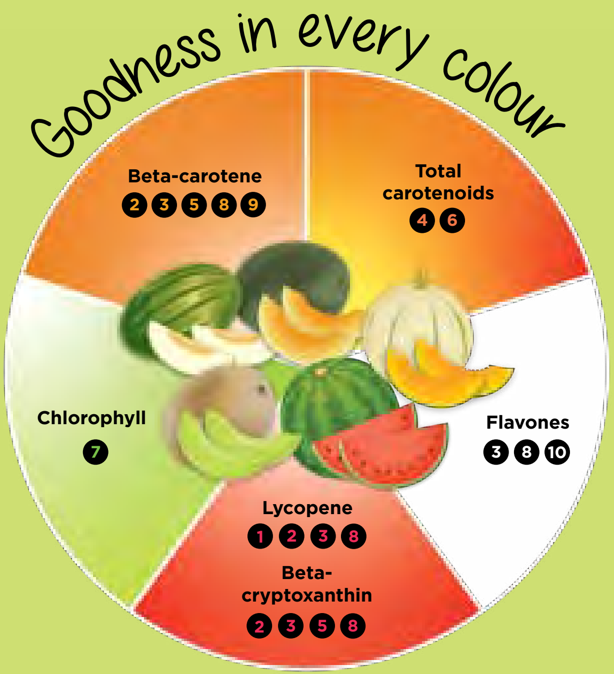


ARE YOUR CLIENTS GETTING ENOUGH COLOUR VARIETY?

It is easy to check!

- Ask about how many colours of fruit and vegetables feature from their shopping cart to their plate.
- Take a look at photos from your client's shopping trolley, fridge, fruit bowl, plate, and child's lunchbox.
- A diet containing optimal colour variety includes a fruit or vegetable from a range of different colours - such as **purple/blue**, **red**, **orange**, **yellow**, **green**, and **white** - every day.

Just add MELONS TO GET THE BENEFITS OF COLOUR VARIETY



Melons come in a variety of colours, providing red, orange, yellow, green, and white health-promoting[1] bioactive pigments.

1. Reduced risk for cardiovascular disease
2. Reduced risk for type 2 diabetes mellitus
3. Reduced risk for a range of cancers
4. Reduced bodyweight and waist circumference
5. Reduced risk for bone fractures
6. Improved cholesterol levels
7. Relief from symptoms of allergic rhinitis
8. Reduced risk for mortality
9. Reduced risk for coronary heart disease
10. Reduced risk for cardiovascular disease mortality

Just add MELONS TO SUPPORT THE INTAKE OF KEY BIOACTIVES & NUTRIENTS [6,12,13]

Melons contain:	Watermelon	Rockmelon	Orange honeydew	Green honeydew	Piel de Sapo melon
Bioactive pigments	Lycopene, Beta-cryptoxanthin, Total carotenoids, Flavones	Beta-carotene, Total carotenoids, Flavones	Beta-carotene	Chlorophyll	Chlorophyll
			per 150 g serve[a]		
Energy	191 kJ, 2% RDI	175 kJ, 2% RDI	202 kJ, 2% RDI	202 kJ, 2% RDI	N/A
Sugars	10.4 g	8.8 g	9.9 g	9.9 g	N/A
Water	5% RDI	5% RDI	5% RDI	5% RDI	5% RDI
			% RDI per 150 g serve[a]		
Vitamin A	7%	48%	1%	1%	N/A
Vitamin C	18%	78%	50%	50%	93%
Folate	1%	9%	6%	6%	N/A
Potassium	5%	9%	7%	7%	11%

[a]Based on requirements of a 31-50 year old male with energy intake of 8700 kJ/day[12]. [b]Based on Adequate Intake for potassium.
N/A, nutrient composition information not available for Piel de Sapo melon; %RDI, percentage of recommended daily intake.

HOW MUCH IS NEEDED?

Just one serve of a combination of colourful melons every day can provide levels of bioactive pigments linked to health benefits[5-11].

1 SERVE = 1 CUP (150 G)

LOW GLYCEMIC LOAD

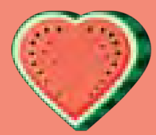
Melons contain only 8.8-10.4g sugars per serve (150 g) and have a low glycemic load, shown to support healthy blood sugar levels[15].

SOURCE OF HYDRATION

At over **90% water**, one serve of melons provides over half a cup of water, (5% of the daily requirement)[6,12,14].

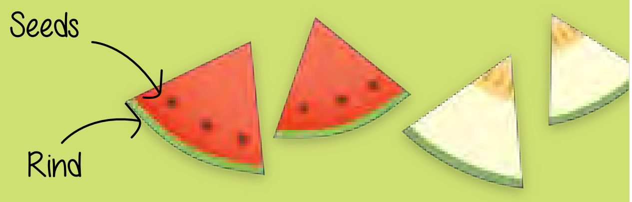
CITRULLINE & ARGININE FOR CARDIOVASCULAR HEALTH

Watermelon contains citrulline and arginine, which support the production of nitric oxide, a vasodilator that increases blood flow and reduces blood pressure[16].



THE WHOLE MELON COUNTS

Emerging research has found that the peel and seeds of melons also contain bioactive pigments such as chlorophyll, beta-carotene, and lutein[17,18], and have been linked with potential health benefits, such as reduced cardiovascular risk factors[19].



Just add MELONS TO BOOST COLOUR VARIETY

Melons maximise the benefits of colour variety by providing **red**, **orange**, **yellow**, **green**, and **white** bioactive pigments as well as key nutrients to a balanced diet, to support overall health.

For more recipe ideas and inspiration, check out the **Melons Australia website**.

Goodness in every colour
MELONS

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EAT A RAINBOW:

Maximising the benefits of colour variety with melons

DID YOU KNOW?

"Eat a rainbow" is supported by science!

Adding colour variety to your diet doesn't just add a pop to every plate, it also provides extra health benefits.

A world first study shows that **"eating a rainbow", a range of different coloured fruits and vegetables, is important for health**[1]. The colour pigments found in fruits and vegetables are called 'bioactives', with each offering a range of health benefits[1].

The benefits of eating a variety of colours go beyond those of just having more fruits and vegetables in the diet.

Australians are not getting enough colour in their diet.

This is because Aussies are not choosing a variety of different coloured fruit and vegetables, nor eating enough of them[1,2].

But it's easy to get more **COLOUR VARIETY** in your diet with melons!

Melons come in many colours and help to boost both fruit intake and colour variety.

Just add **MELONS** TO GET THE BENEFITS OF COLOUR VARIETY

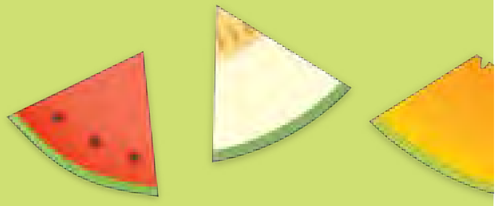
- fruit intake & variety
- colour intake & variety
- taste & enjoyment

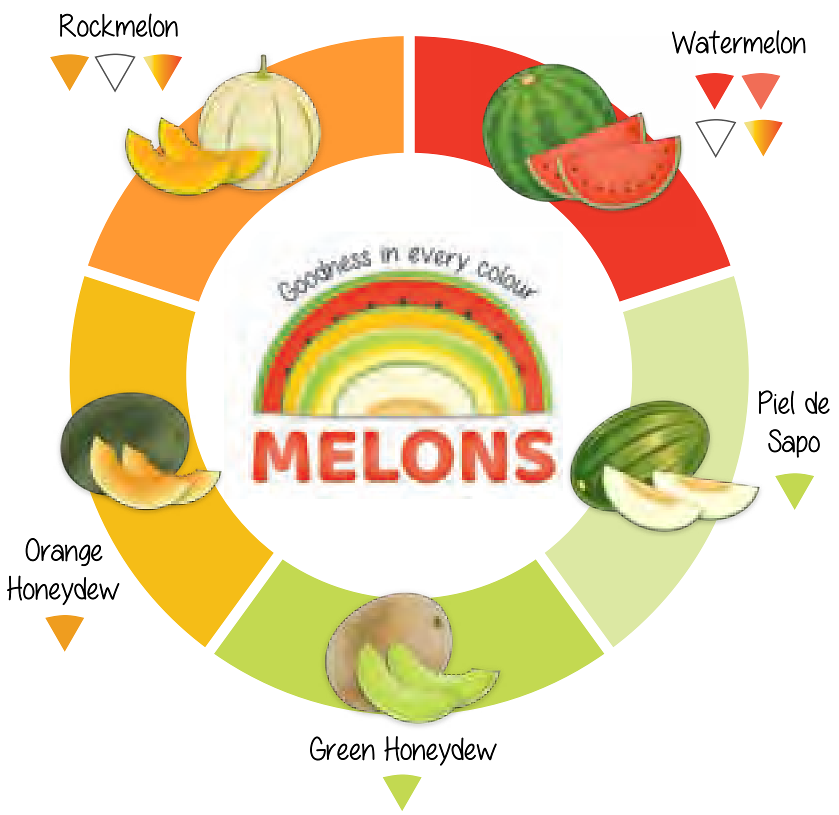
WHY MELONS?

Melons contain goodness in

EVERY COLOUR

Each melon colour provides its own blend of health-promoting pigments[1], plus essential nutrients, as part of a healthy, balanced diet.





Red lycopene supports:

- a healthy heart
- normal metabolism
- protection from some cancers
- a long life

Orange beta-carotene supports:

- a healthy heart
- normal metabolism
- protection from some cancers
- a long life
- healthy bones

Green chlorophyll helps with:

- seasonal allergy symptoms

Red beta-cryptoxanthin supports:

- normal metabolism
- protection from some cancers
- a long life
- healthy bones

Red, orange, and yellow total carotenoids support:

- a healthy heart
- normal metabolism

White flavones support:

- a healthy heart
- protection from some cancers
- a long life

Just add MELONS TO SUPPORT THE INTAKE OF KEY NUTRIENTS[9-11]

WATER for hydration

VITAMIN C to support immunity

FOLATE to support energy levels, growth and development

VITAMIN A to support healthy vision

POTASSIUM to support electrolyte balance and muscle function

*Based on 1 serve (150 g) as part of a healthy, balanced diet. Vitamin A, rockmelon only; Folate, rockmelon and honeydew melon; Potassium, rockmelon, honeydew melon, and Piel de Sapo.

Melon FUN FACTS

COLOUR VARIETY IN ONE CUP PER DAY

Just one daily serve of mixed melons, as part of the recommended fruit intake and a healthy, balanced diet, can benefit health[3-9].

1 SERVE = 1 CUP (150 G)

HALF A CUP OF WATER IN EACH SERVE

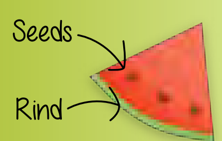
At around 90% water, melons are also great for hydration[4]!

LOW GLYCEMIC LOAD

which can help to support healthy blood sugar levels[12].

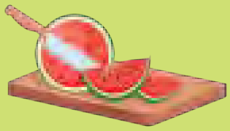
THE WHOLE MELON COUNTS!

Seeds and rind also contain bioactives. The rind can be cooked into a stir-fry and the seeds are being used by food scientists to turn it into oil and flour[13,14], reducing food waste while creating new products!

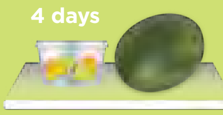


IT IS EASY & DELICIOUS TO Just add MELONS

1 MAKE IT EASY



CHOP

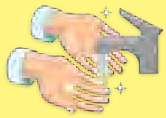


Research shows that fruit intake is increased when it is convenient and accessible[15].

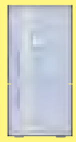
STORE AT EYE LEVEL IN THE FRIDGE

FREEZE

2 MAKE IT SAFE



WASH hands, chopping boards and knives before and after handling.

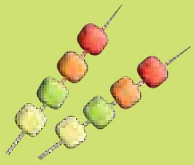


STORE at 5 degrees or below. Consume within 4 days (cut melon), two weeks (whole melons), or one month (frozen melon). Cut melons that have been out of the fridge for more than 2 hours should be discarded.

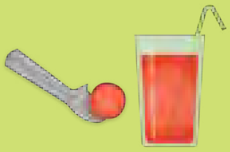
AVOID:
Melons with cracked, bruised, decayed or mouldy skin.

AVOID:
Rockmelons if pregnant or immune-compromised[16].

3 MAKE IT FUN



FRUIT KEBABS
Create different shapes and sizes to make it fun to eat.



SUMMER SNACK
Add as the base of smoothies, melon sorbets or as ice-cubes for drinks.

SALAD
Try watermelon with feta, Piel de Sapo with chicken, rockmelon with prosciutto, or honeydew with cucumber.

GET INSPIRED
Scan for recipes.

Just add MELONS AT EVERY STAGE OF THE JOURNEY - FROM YOUR SHOPPING CART TO YOUR PLATE

Shopping cart looking bland?
Just add melons

Fridge grey and uninspiring?
Just add melons

Salad looking too green?
Just add melons

Freezer looking too much like ice?
Just add melons

Afternoon tea needing a colourful pick-me-up?
Just add melons

References:
1. Blumfield, M. et al., Molecules 27 (2022). **2.** Australian Bureau of Statistics (2016). **3.** Choudhary, B. et al., Ind. J. Agri. Sci. 85 (2015). **4.** US Department of Agriculture. FoodData Central. **5.** INRAE. Phenol-Explorer 3.6. **6.** de Oliveira, G. L. R. et al., Food Chem 348 (2021). **7.** Fleshman, M. K. et al., J Agric Food Chem 59 (2011). **8.** Lecholocholo, N. et al., Food Chemistry 393 (2022). **9.** Miller, F. A. et al., Horticulturae 6, 60 (2020). **10.** FSANZ. Australian Food Composition Database (2022). **11.** Curtin University. (2021). **12.** Atkinson et al., AJCN, 114, 2021. **13.** Rabadán, A., et al., Foods 9, 2020. **14.** Rico, X., et al., Food Res Int, 132, 2020. **15.** Wansink, B., et al., Am. J. Prev. Med. 44 (2013). **16.** New South Wales Government Food Authority (2022).

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Goodness in every colour MELONS

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APPENDIX 8:

NRAUS

Melons HCP Webinar:
Evaluation Report

Prepared for Hort Innovation

December 2022


NRAUS
Free Webinar:
'EATING A RAINBOW' OF COLOURS
Bringing the science to your kitchen!
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MELON FUND
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In this FREE healthcare professional webinar hosted by Dr Emma Beckett, you'll join changemaker and nutrition scientist DR. FLAV to explore the importance of colour variety for health and learn all about the under-rated superstars of nutrition, the colour-associated bioactive pigments. Plus, award-winning celebrity cook, and author ALICE ZASLAVSKY will host a live cooking demonstration from her kitchen to provide inspiring and practical tips and insights to bring more COLOUR to the table.

Registrants will go in draw to WIN 1 of 3 bundles of best-selling cookbooks by Alice up for grabs!

You'll learn about:

- The under-rated superstars of nutrition and health - the colour associated bioactive pigments in fruit and vegetables.
- World-first research on the health benefits of 'Eating a rainbow'.
- How to assess and recommend colour variety in the diet from the supermarket to your plate.
- Australian Melons and how they can add colour variety to the diet.
- Alice's passion for eating a rainbow of colours with culinary tips and tricks that bring more colour to the table.
- Alice's rainbow cookbook 'In Praise of Vege', tips and recipes.

Join us on our journey to help us light up this world with more COLOUR!

Brought to you by NRAUS and sponsored by Melons Australia.

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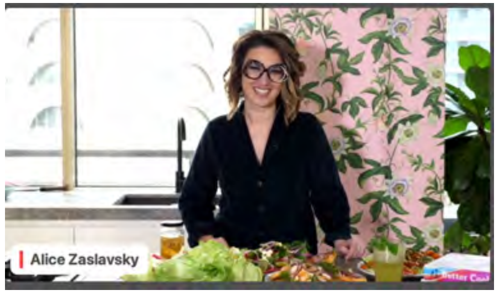
Note: Webinar will be recorded and a link to view will be sent out to all registrants post event.



"EATING THE RAINBOW" – bringing the science to your kitchen

Summary Results

275 registered
88 attended live
132 views online
17 questions asked
34 feedback surveys completed(38.6%)

Recruitment Sources

Facebook (n=150)
NRAUS EDM (n= 97)
LinkedIn (n= 11)
NRAUS Team Shares (n= 17)

Total ad spend: $376.06 ($0.71/click)
Social media reach: 43,200

Professions

Nutritionist (31.2%)
Dietitian (28.1%)
Nurse (12.5%)
Ex Physiologist (3.1%)
Other (25%)

- Wellness coach
- Nutrition Student (n=5)
- Retired

Polls showed that overall, there was **increased knowledge of the health benefits of colour-associated variety** and **improved their knowledge relating to melons.**

- ✓ **10.5% increase** in recognition that health benefits colour variety go beyond that of just eating more fruits and vegetables
- ✓ **83% reduction** in respondents identifying melons as having a high glycaemic load
- ✓ **112% increase** in respondents identifying that melons contain 5 different bioactive colours

100% learnt something new

100% would recommend adding **melons** to improve colour variety

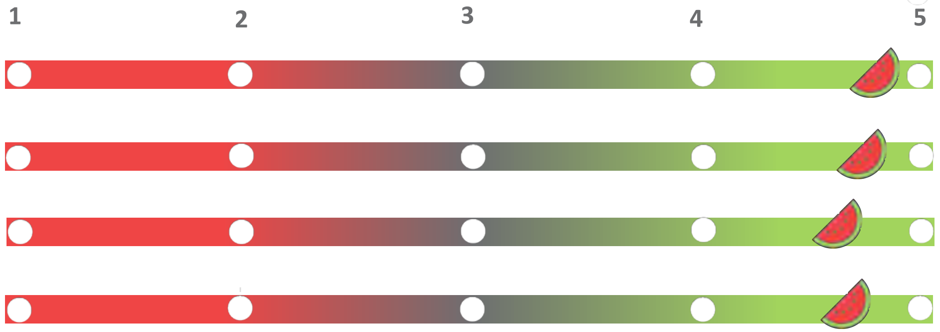
100% rated the event as "Excellent" or "Very Good"

100% rated **informativeness** as "Exceptional" or "Above average"

100% rated **engagement** as "Exceptional" or "Above Average"

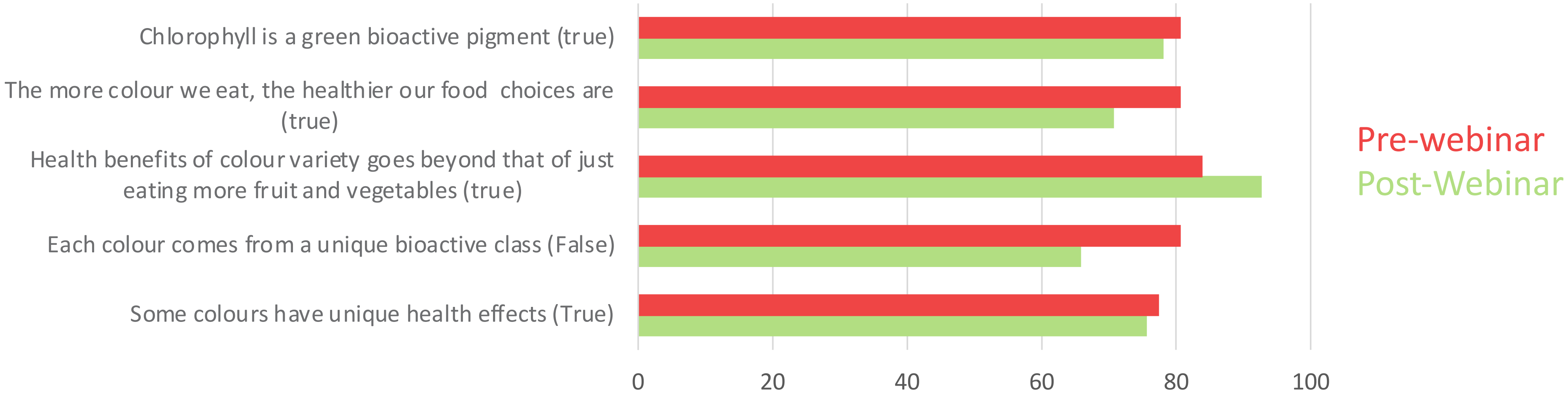
97% rated **usefulness** as "Extremely Useful" or "Very Useful"

Overall, how would you rate the event?	4.79
How **informative** did you find the event?	4.72
How **engaging** did you find the event?	4.60
How **useful** do you feel the information presented to you was?	4.61

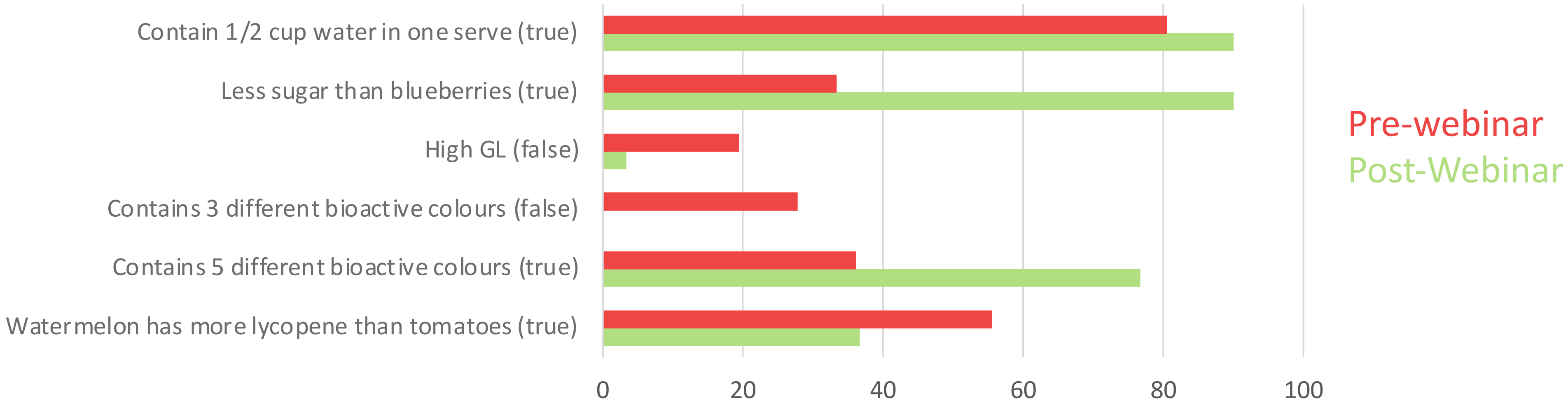


"EATING THE RAINBOW" – bringing the science to your kitchen

What's true about **colour-associated bioactives**?



What is true about **Melons**?



“EATING THE RAINBOW” – bringing the science to your kitchen

Participants thought the webinar was professional, well-designed, with knowledgeable and well-prepared speakers.

“Extensive knowledge of the subject but presented in an easy to understand manner” “Level of detail, clear explanations, great infographics, passionate presenter” “Very well presented, use of graphics and expert knowledge” “Great layout with seamless transition between slides, speakers etc. Quality content and visuals too”

Participants found the surveys/polls throughout the webinar, positive interactions between the presenters, and information presented clearly using graphics helped make the webinar engaging and enjoyable. They also appreciated the culinary demonstration from Alice, to help ‘bring the science to life’

“The polls were good to engage throughout the first section” “Loved the interactions between all the presenters!” “Really enjoyed the use of polls as well as Q&A for interactivity” “Super engaging & felt really included in the presentation. The positive & wholesome energy coming off the screen.” “The interaction via the polls encouraged you to keep up with the information and gave an opportunity to check your learning” “Submit a question and got it answered” “Again, excellent graphics and explanations” “Having a presentation side & then seeing the cooking/visual side. Nice mix of dynamics. Really upbeat and engaging speakers.” “Because of the real food, polls, and interesting information.” “Alice was the perfect chef/cook to bring the science to life” “Great visuals from Alice”

Participants reported that the information was credible and well resourced, with information that is easily translated into practice., but would like greater access to slides and information prior to the webinar.

“it was detail and comprehensive with quality referencing backup” “Dr Flavia presented relevant & recent research that easily translates into practice” “It was a good mix of the science and background which was presented in an interesting way and easy to understand plus practical with the cooking tips. I was sceptical about how this would work and was impressed” “Love the concept of changing the boring terms of eating 5 + 2, to focussing on eating the rainbow. This will be very useful for clients, and even for my own diet.” “slides avalible prior to make notes on for people like me who struggle with that kind of thing” “I would like to receive study documents used in webnar” “When slides PDF is shared before session, can make notes on them when presenters whiz through quickly due to time constraints.”

The colour-variety messaging was very well received.by participants., and they were keen to share their learnings with colleagues.

“Creative and evidence-based without being constrained by 20 year old rules.” “Different colours of fresh produce help different parts of our body for life- eye opening. If everyone understands the why behind the importance of eating a rainbow everyday, we will have a healthier world” “I really liked the movement from serving sizes and nutrients to focusing on eating a rainbow to increase fruit and veg intake. It was also interesting to hear more focus on bioactives and using the whole fruit in cooking e.g. watermelon rind in stir fries. I think this is a great initiative I hope to implement in my health promotion and nutrition roles” “The webinar has definitely encouraged me to extend my learnings with fellow peers and friends.” “How much of an impact this had on my team. Really positive outlook & clear, Simple & easy to understand information. Also how I can apply this to my every day life so simply. Looking at food for what it actually is & the components of plant based foods.”

Participants would like more webinars using the same format, and they would be happy with more time, presenters, and opportunities for participant interaction. There is opportunity to apply the colour-related variety message across other Hort Innovation projects.

“I could not fault anything, the presenters were fantastic and all the information was easy to understand and valuable” “Look forward to watching another webinar soon, thanks for a great way to spend a lunch break.” “Perhaps extend the length of time and introduce another presenter with a different perspective.” “Obviously this webinar needed to hero melon, but it would be nice to have a broader array of fruit and veg”

APPENDIX 9:

FOODiQ global

VM20003

Digital Activation Outreach

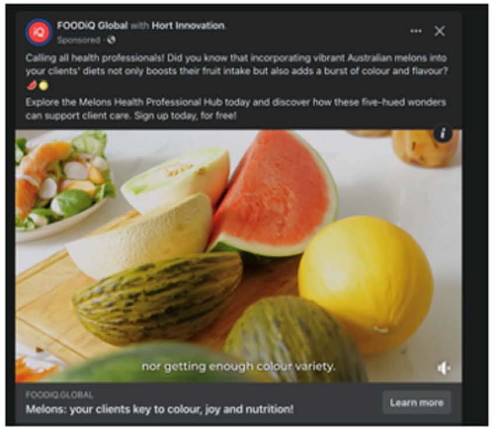
June 2024

Objective

Drive awareness of the melons hub and project resources with HP.

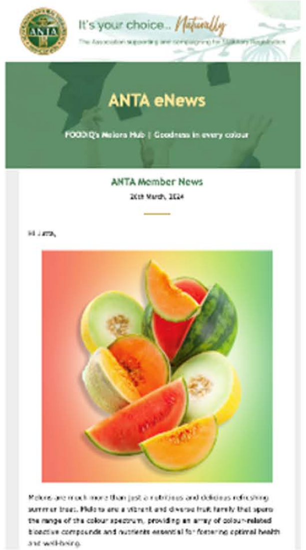
Activity

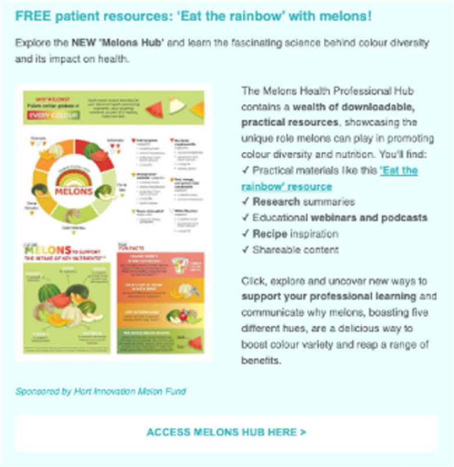
Social Media



Activation: 26th March – 4th May 2024

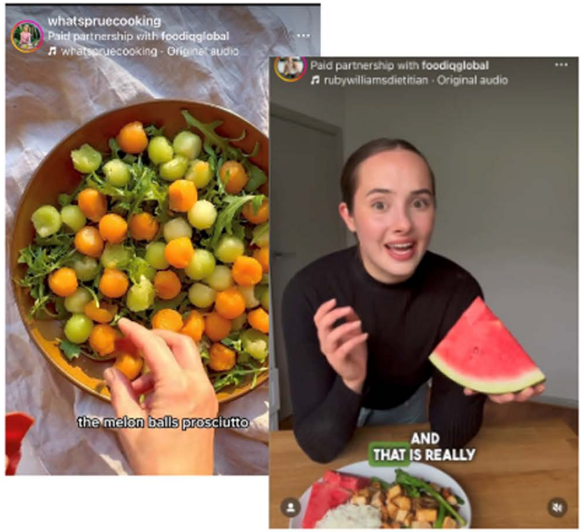
Channel comms





Melons HP Database EDM: April 2024
Australian Naturopath solus EDM: March 2024
Dietitian Connection solus EDM: March 2024

KOL Influencer



Activation: March 2024

Results

Channel & social media results

	Audience	Open rate %	Reach	Total clicks	CTR %	
Dietitian Connection	12, 149	45%	5414	183	1.5%	
Australian Natural Therapists	7000	28.1%	1960	154	2.2%	
		Impressions	**Reach**	**Total clicks**	**Av CTR%**	**Sign up database**
Social media (HP)		128,000	49, 940 (KPI:20,000)	4328	3.37%	38
		>50% view				
Animation		11, 545 (KPI: 15,000)				
KOL influencers	20,000 views					

EDMs

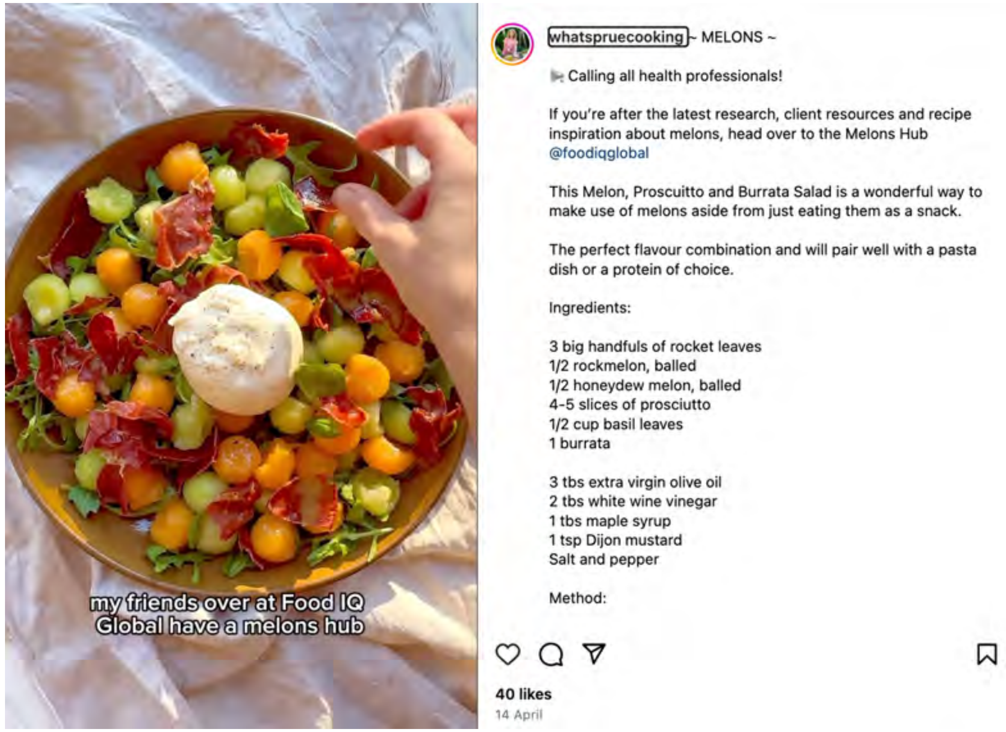
	Topic	Date sent	Open rate
EDM 1 *	Recruitment to ASR	2022	52.1%*
EDM 2*	Umbrella Review published	August 2022	47.8%*
EDM 3	Umbrella Review published	24th August 2022	28.6%
EDM 4	Webinar invite	28th October 2022	29.8%
	Factsheets	12th April 2023	52%
EDM 5	Podcasts	10th July 2023	40%
EDM 6	Video on UR	15th Dec 2023	38.2%
EDM 7	Animations	8th March 2024	*43%*
EDM 8	End of Campaign - Hub	19th April 2024	41.2%
EDM 9	ASR Recruit	19th June 2024	40.7%

*EDM 1 sent to FOODiQ database for recruitment. Open Rate Target >25%

KOL activation – Summary

2 KOLs with combined following **25000 followers** were engaged to communicate the Melon Hub to their followers in their own authentic voice.

	Profession	Followers
Prue Mynard	Dietitian	20,000
Ruby Williams	Dietitian	5,000
TOTAL REACH		25,000



Learnings and recommendations

Learnings & Recommendations

Learning

- ✓ Overall digital activation was effective in driving reach awareness of 82,500 HPs
- ✓ Solus EDM (ANTA) performed better than e-news item in EDM (DC) in overall click through rate.
- ✓ Video/animation content tends to drive greater engagement than static. Social content moving towards shorter bite sized video content.
- ✓ KOL influencers cost effective and credible way to amplify comms.

Recommendation

- ✓ A solus ad is preferable when cost possible. DC solus ad is very expensive and not recommended unless comms very newsworthy such as whitepaper or new research published.
- ✓ KOL influencers should always be included as part of the strategy.

Learnings & Recommendations

Learning

- ✓ Building owned database is key long-term strategy as this is most cost-effective comms channel. Subscribers are highly engaged with 33-50% open rates and are ultimately at no cost.

Recommendation

- ✓ Work with professional body channels to experiment with creatives/hooks to drive better engagement.
- ✓ Develop an ongoing recruitment strategy to continue to build database long term.
- ✓ Move towards developing an 'always on' digital communication strategy with owned database to maintain top of mind awareness to drive recommendation.

FOODiQ global

Thank YOU!

foodiqglobal

@foodiqglobal

foodiqglobal

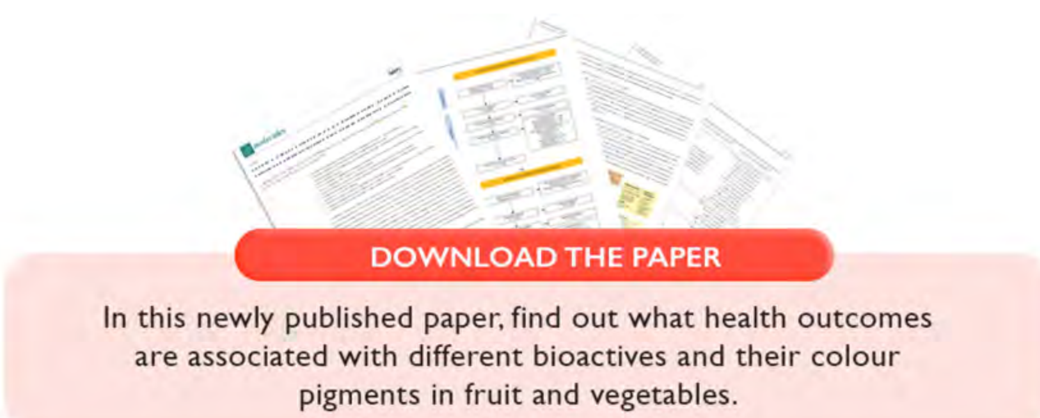
info@foodiq.global

www.foodiq.global

APPENDIX 10:

'Eating the Rainbow' – consuming fruits and vegetables featuring various colours – has long been embraced by dietitians and nutritionists as a cornerstone of a healthy diet. However, despite its ubiquity in nutrition, until now no-one has synthesised all the colour pigment research to support a rainbow message.

But no more! A recently published umbrella review by NRAUS shows that there are several unique health effects associated with eating fruits and vegetables across the entire spectrum of the rainbow. In addition, consuming fruits and vegetables featuring a range of colours is likely to provide health benefits above and beyond just the benefits you would get just from eating your daily 2 and 5.
Now you can confidently tell your clients that "eating the rainbow" is good for their health!



Red and yellow and orange and green and white - Australian Melons, including watermelon, rockmelon, honeydew melon, and Piel de Sapo, contain a range of bioactive colour pigments.

One 150g serving of Australian Melons can contribute to daily doses of:

- Lycopene (watermelon)
- Beta-cryptoxanthin (watermelon, rockmelon)
- Beta-carotene (watermelon, rockmelon, honeydew melon)
- Alpha-carotene (rockmelon)
- Lutein and zeaxanthin (watermelon, rockmelon, honeydew melon)
- Flavones (watermelon, rockmelon)
- chlorophyll (Piel de Sapo).

With goodness in every colour, Australian Melons are a unique fruit, representing a spectrum of colour across their varieties. They provide a delicious way to help clients to increase colour-associated FRUIT variety in their diets.

Goodness in every colour

MELONS

TAKE OUR QUICK POLL!

How often do you specifically recommend melons to clients?

- Always
- Often
- Sometimes
- Never, as I don't see clients
- Never, but I do see clients

Hort Innovation
Strategic levy investment

MELON FUND

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For more information on the fun and strategic levy investment visit horticulture.com.au

Hi << Test First Name >>,

You're invited to join **Dr Flav** and award-winning cook and author **Alice Zaslavsky** who will bring together their expertise in food, nutrition and education, to showcase how we can get more colour variety in our diet to reap the benefits of 'eating a rainbow'.

Date: 22nd November 2022
Time: 12:00 – 1:00 pm AEST

Register Now

In this free webinar hosted by **Dr Emma Beckett**, you'll join changemaker and nutrition scientist **Dr. Flav** to explore the importance of colour variety for health and learn all about the under-rated superstars of nutrition, the colour-associated bioactive pigments. Plus, award-winning celebrity cook, and author **Alice Zaslavsky** will host a live cooking demonstration from her kitchen to provide inspiring and practical tips and insights to bring more **COLOUR** to the table.

Registrants will go in draw to **WIN** 1 of 3 bundles of best-selling cookbooks by Alice up for grabs!

You'll learn about:

🌈 The under-rated superstars of nutrition and health - the colour associated bioactive pigments in fruit and vegetables.
🌈 World-first research on the health benefits of ‘Eating a rainbow’.
🌈 How to assess and recommend colour variety in the diet from the supermarket to your plate.
🌈 Australian Melons and how they can add colour variety to the diet.
🌈 Alice’s passion for eating a rainbow of colours with culinary tips and tricks that bring more colour to the table.
🌈 Alice’s rainbow cookbook ‘In Praise of Vege’, tips and recipes.

Join us on our journey to help us light up this world with more COLOUR.

We hope to see you there!

NRAUS and **Melons Australia**.

CONTACT US | MEDIA ENQUIRIES | NRAUS WEBSITE

Hort Innovation
Strategic levy investment

MELON FUND

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Hi << Test First Name >>,

As you know, a balanced diet rich in fruits and vegetables is essential for good health. Now we can also substantiate recommendations to increase colour variety on our plates - our world-first umbrella review demonstrated that **consuming a rainbow of colours from fruits and vegetables improves health beyond just reaching your daily 2&5.**

Melons are the perfect way to add a splash of colour to your patients' diets to take advantage of their naturally-occurring and pigmented phytonutrients.

Australian Melons provide red, orange, yellow, green, and white bioactive pigments, as well as key nutrients, like vitamin C, folate, and potassium, making them **a great addition to the plate.**

Following on from our umbrella review, we are excited to share these brochures which summarise the science around colour variety and melons, **translating the research into simple, practical tips**.

Visit the **Melons Hub** to download our healthcare professional and consumer-friendly brochures. Learn about the **colour-associated benefits of melons** and how to incorporate them into daily meals.

And remember next time you are looking for a delicious and fun way to add more colour variety to a meal, snack or salad … Just add melons!

NRAUS and **Melons Australia**.

CONTACT US | MEDIA ENQUIRIES | NRAUS WEBSITE

Hort Innovation Strategic levy investment | MELON FUND

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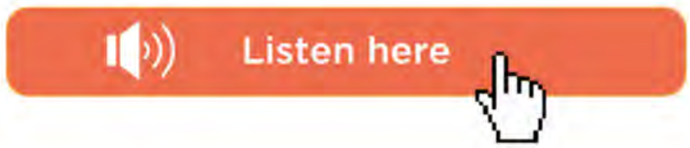
Hi << Test First Name >>,

Including a wide variety of different colour pigments from fruits and vegetables is more than just making the plate pretty. It not only helps introduce a range of bioactives with unique health effects into the diet - **increasing colour variety is an evidenced-backed way to increase overall fruit and vegetable intake**.

Nutrition Scientist and Nutrition Research Australia's CEO Dr Flavia Fayet-Moore (Dr Flav) spoke with Accredited Practicing Dietitian Leanne Ward on her popular evidence-based nutrition podcast about:

🍉 Why fruits and vegetables are so important in our diet
🍉 The latest statistics on fruit and vegetable consumption
🍉 The recommended serves for fruits and vegetables
🍉 The world first "Eating the Rainbow" study about the health benefits of bioactive pigments
🍉 The nutritional benefits of different types of melons
🍉 The best ways to incorporate melons into your diet, so that you "Eat the Rainbow"

Want to know more? Listen to this easily digestible podcast to hear Leanne and Dr Flav explore the evidence base and put the latest research findings into context.



You can find the podcast on all popular podcast platforms, including Apple, Spotify, and Google podcasts:

About Leanne (the_fitness_dietitian)

Leanne is a renowned Australian media dietitian, nutritionist, sports dietitian and online social media influencer known as The Fitness Dietitian. She has over 10 years of nutrition experience and over 300,000 followers on her Instagram (@the_fitness_dietitian) and 400,000 on her TikTok (leanne_ward_nutrition).

*With over 100 episodes and 1.5 million+ downloads including a significant healthcare professional following, her 5-star rating podcast series **Leanne Ward Nutrition** is one of the most popular nutrition podcasts in Australia on Apple podcast and Spotify, currently rated in the top 10 on Apple.*

If you'd like to learn more about the topics covered in the podcast, visit the **Melons Hub** to download our healthcare professional and consumer-friendly brochures. Learn about the **colour-associated benefits of melons** and how to incorporate them into daily meals.

And remember next time you are looking for a delicious and fun way to add more colour variety to a meal, snack or salad … Just add melons!

NRAUS and **Melons Australia**.

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Hi << Test First Name >>,

Almost all Australians can benefit from increasing their fruit and vegetable intake. A great way to facilitate this is by increasing the **colour variety of plant foods** on the plate by using a colourful family of fruits - like melons!

Melons are not only refreshing, particularly as the weather starts to heat up, but they are a **DELICIOUS** way to boost the overall colour variety of a meal!

Learn more in this short clip featuring Registered Nutritionists **Dr Flavia Fayet-Moore** and **Dr Emma Beckett** and Accredited Practicing Dietitian **Jutta Wright**, as they demonstrate the value of adding **COLOUR** to the diet using **Australian Melons**.

https://youtu.be/iL3uk4ywriY

Share the video with your networks!

Share Share Tweet Forward

For a deeper dive, listen to **Dr Emma Beckett** on a recent Dietitian Connection Podcast as she explores the evidence behind bioactive pigments to understand why quantity isn't the only thing to consider when recommending fruits and vegetables. Using sweet and savoury culinary inspirations, Emma explores how and why colourful and nutritious **melons** are the perfect example of the pot of gold at the end of the fruit and vegetable rainbow.

https://dietitianconnection.com/podcasts/surprising-new-science-behind-eat-rainbow/

Share the podcast with your colleagues.

Share Share Tweet Forward

You can find this, and more, in our brand-new **Melons Hub**, where you can download and use our health professional and consumer-friendly brochures for **FREE**.

Learn about the **colour-associated benefits of melons** and how to incorporate them into daily meals, so your clients can reap the benefits.

And remember next time you are looking for a delicious and fun way to add more colour variety to a meal, snack or salad … **Just add melons!**

FOODiQ (Formerly Nutrition Research Australia) and **Melons Australia**.

NOTE: Nutrition Research Australia has exciting news - we have rebranded to become FOODiQ Global! You can read more about our journey here:

THE FOODIE NERDS HAVE GONE GLOBAL

This means that emails from us will now come from a FOODiQ Global email address - info@foodiq.global. Be sure to add this to your 'safe' list!

CONTACT US | MEDIA ENQUIRIES | FOODiQ WEBSITE

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Hi << Test First Name >>,

When it comes to health information, more and more consumers and clients are relying on social media, especially video formats. In one **cross-sectional analysis of young Australian adults**, researchers found that video formats were: more likely to be engaged with; visually preferred; more motivating to change health behaviours; and more likely to be perceived as containing relevant health and nutrition information.

But creating videos to share can be intimidating, which is why we have done the hard work for you, and created short, sharable, and visually engaging animations to demonstrate the value of adding **COLOUR** to the diet using **Australian Melons**.

Currently, only **half** of Australians regularly eat two serves of fruit per day recommended as part of healthy eating guidelines. Using specific, actionable recommendations - like *'add more melons'* - helps facilitate behaviour change, increasing the likelihood of your clients making successful and sustainable lifestyle changes.

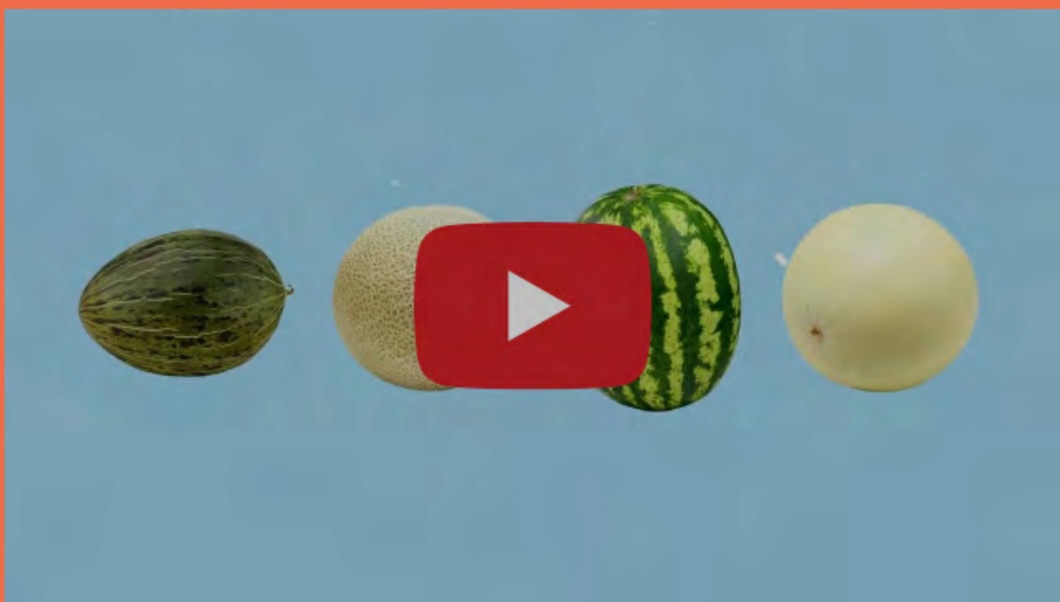
These educational animations provide evidence-based health and nutritional information on melons, covering both the **WHY** and the **HOW** - knowing how to prepare, store, and use the fruits properly can help people access **more of its goodness**, **reduce food waste**, and **save money**.

Learn the WHY in this engaging, evidence-based educational video which showcases the health and nutritional benefits of Watermelon, Rockmelon, Honeydew, & Piel de Sapo melons.

🔗 https://youtu.be/8Y4DIATG4gs

Share the video with your networks

Share Share Tweet Forward



Demonstrate the HOW - empower your clients in achieving sustainable behaviour changes and facilitate smart choices in the kitchen so they can maximise the goodness they receive.

https://youtu.be/XQaQ8-ILHIY

Share the video with your networks

Share Share Tweet Forward

You can find these videos by jumping over to the FOODiQ **YouTube channel**, or by visiting the refreshed **Melons Hub**, where you can also find our health professional and consumer-friendly brochures, which are **FREE to download**, **share**, and **use in your clinical practice**.

And remember next time you are looking for a delicious and fun way to add more colour variety to a meal, snack or salad … **Just add melons!**

FOODiQ and **Melons Australia**.

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Hi << Test First Name >>,

Thank you for being a part of the Melons community of health care professionals! We'd love to share some of the key things we've learnt about melons and showcase the amazing resources available to you on the **Melons Hub**.

WHY MELONS?

Naturally occurring and pigmented phytonutrients (i.e., bioactive pigments) give fruits and vegetables their vibrant colours and are linked to beneficial effects on health.

Melons are the perfect way to maximise the benefits of colour variety by providing five different bioactive hues - **red**, **orange**, **yellow**, **green**, and **white** - as well as key nutrients to a balanced diet, to support overall health.

You can learn more by visiting the **Melons Hub** and taking a look at our vibrant and engaging evidence-based resources - everything is free to download, share, and use in your daily practice.

EXPLORE THE MELONS HUB

What you'll find on the hub

PROFESSIONAL DEVELOPMENT AND LEARNING RESOURCES

PUBLICATION: Should we ‘Eat a Rainbow’? An umbrella review of the health effects of colorful bioactive pigments in fruits and vegetables

This umbrella review synthesises the evidence of a variety of colour-associated bioactive pigments (carotenoids, flavonoids, betalains and chlorophylls), on health outcomes including body weight, lipid profile, inflammation, cardiovascular disease, mortality, type 2 diabetes and cancer.

Blumfield *et al*. Molecules, 2022;**27**:4061

VIDEO: Goodness in every colour

Hear about the latest science on colour variety and discover how Australian melons, as a diverse fruit family, offer an array of colour-related nutrients and bioactive compounds essential for fostering optimal health and wellbeing, in this short educational video.

EDUCATIONAL FACT SHEETS FOR HEALTH PROFESSIONALS

Evidence-based educational brochure highlighting the importance of colour variety in the diet, and how melons can help maximise the benefits of colour variety by providing bioactive pigments **plus** key nutrients to support health.

WEBINAR: ‘Eating a rainbow’ of colours – Bringing the science to your kitchen

Join nutrition scientist and registered nutritionist **Dr Flav** and award-winning cook, author, and broadcaster **Alice Zaslavsky** as they delve into the value of diverse colours in promoting health and share practical strategies for incorporating them into our diets.

PODCASTS

Update your learning on the run with these podcast episodes featuring FOODiQ Global's **Dr Flav** and **Dr Emma Beckett,** as they discuss how promoting colour variety amongst fruits and vegetables can facilitate increased fruit and vegetable intake.

CLIENT-FRIENDLY RESOURCES AND SHAREABLE CONTENT

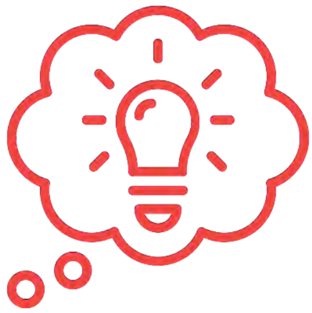
CLIENT-FRIENDLY FACT SHEET

A fun and practical educational brochure to support clients to maximise colour variety in their diet by just adding melons. Includes nutrition education and practical tips using simple, easily understood language, to demonstrate the HOW and WHY.

SHORT, INFORMATIVE ANIMATIONS

Access more goodness, reduce waste and save money with melons! Check out some top tips to prepare, store and use delicious colourful melons, in these engaging and informative short videos.

We want to know what you think!!
- your chance to WIN



As a valued member of our community, we'd like to ask for **5 minutes** of your time to complete a short survey, to help us understand what you have learnt and get valuable feedback on the resources.

Everyone that completes the survey will have the chance to enter the draw to win **one of five $100- gift cards.**

COMPLETE THE SURVEY

Thank you for being a member of our community. And remember next time you are looking for a delicious and fun way to add more colour variety to a meal, snack or salad … **Just add melons!**

FOODiQ and Melons Australia.

Hort Innovation Strategic levy investment | MELON FUND

This project has been funded by Hort Innovation using the melon research and development levy and funds from the Australian Government.
For more information on the fund and strategic levy investment visit horticulture.com.au

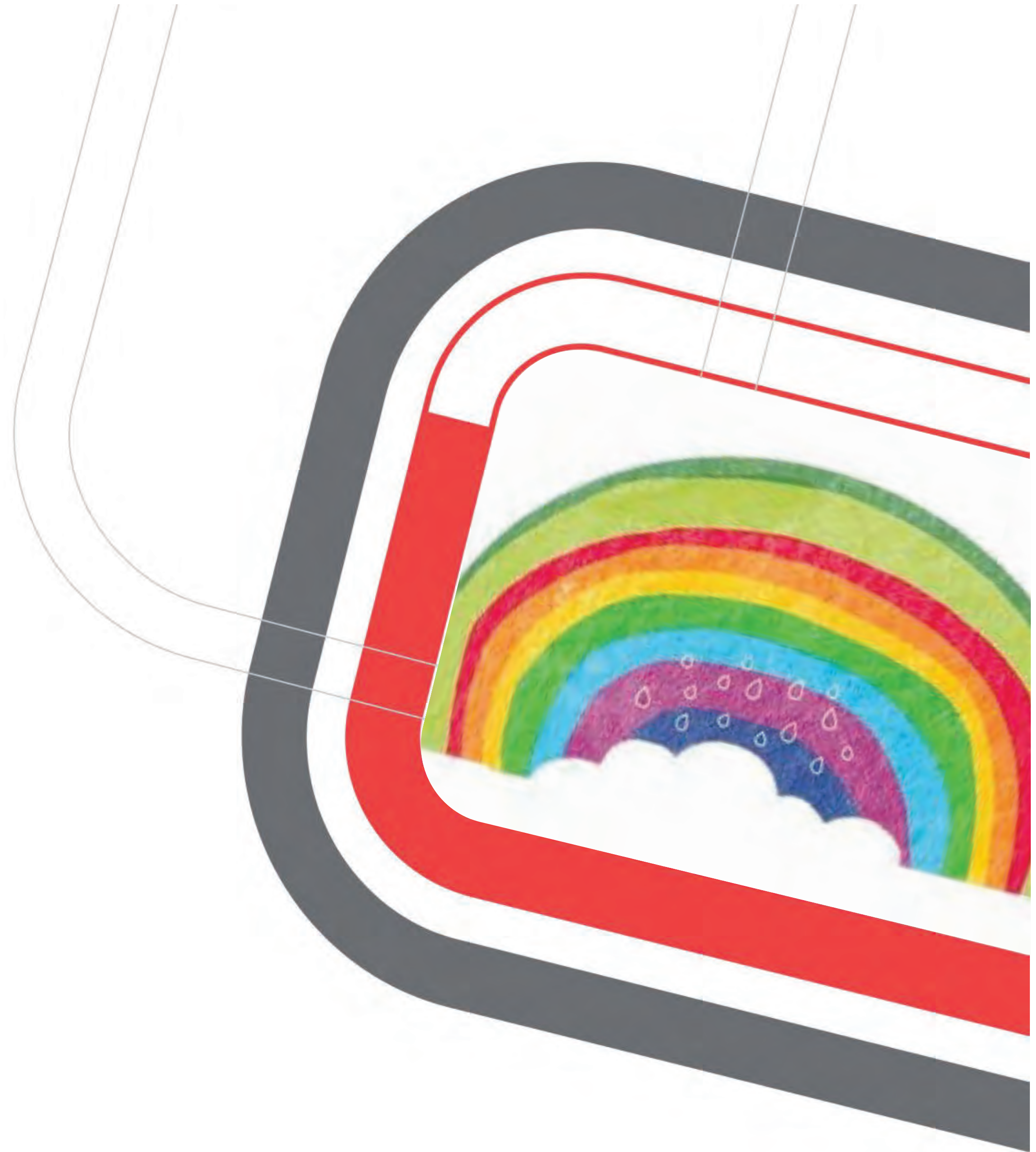
APPENDIX 11:

APPENDIX 12:

VM20003 Educating Health Care Professionals on Australian Melons

Project Reference Group Meeting 1

8th December 2021



Agenda

1. Introductions
2. Melon varieties
3. Project aims
4. Melon science
5. Education strategy
6. Monitoring and evaluation
7. Feedback

Introductions

PRG Membership

The Project

Aim: Establish Australian melons as a fruit which can provide a range of colour-associated nutrients and bioactives required to achieve optimal health and wellbeing.

Outcomes:

- ✓ Create new science quantifying the full nutritional and bioactive profile of Australian melons and translate this into an updated Australian Food Composition Database and health care professional (HCP) resources
- ✓ Increased awareness of the unique colour-associated nutritional and bioactive properties and health benefits of Australian melons by HCPS
- ✓ Practising HCPs will increase their focus, confidence, and proficiency in improving the fruit variety of their clients' using melons as the example to eat a double rainbow, in order to achieve optimal health and wellbeing across all life stages

Melon selection approach

1 Selection criteria

2 Proposed melons

3 Client consultation

4 PRG ratification

1. Grown in Australia
2. Relevant to growers who contribute to the Hort Innovation melon levy
3. Come in a variety of colours to relate to key messages

1. Watermelon (red)
2. Rockmelon (orange)
3. Honeydew melon (green)
4. Piel de sapo (yellow)
5. Crispy pear (white)

Exclude bitter melon:
- Represented by AgriFutures
- Dominates the nutrition and health research
- Consumed as a vegetable rather than fruit

Comments:
- Crispy pear = hello melon. ?Still grown.
- ?Honeydew some have white.
- Piel de sapo – has white/pale yellow. → white to yellow.
- Top four most commercially relevant.
- Crispy pear as "specialty" melon.
- If HCPs to recommend <u>need to be available</u>.
- Science point of view – want to represent all colours.
- Piel's are more white rather than yellow.
- Focus on top 3 as more available; keep specialty melons for other coloured melons.
- Rainbow message if limited colours?

Melon Science

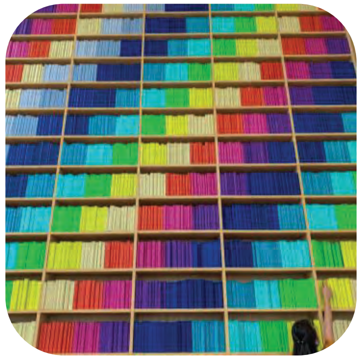
Activities and outputs

Manuscript & Report
Systematic umbrella review of the health effects of bioactive pigments in fruits and vegetables

2021-2022

Gaps analysis
Matrix of the nutrient and bioactive content of Australian melons
+ Dryad publication

2022



NUTRITIONiQ
Literature Database
Melon Research & Media

2021-2024

Manuscript Journal

Should we "Eat a Rainbow"? An umbrella review of the health effects of natural bioactive pigments in fruits and vegetables.

1 FIRST CHOICE

Critical Reviews in Food Science and Nutrition.
Impact: Very high IF of 11.2 & open access.
Relevance: Publishes on diet, bioactives, nutrients, and biochemistry.
Time: Feasible turnaround.

2 SECOND CHOICE

Advances in Nutrition.
Impact: High IF of 8.7 & open access.
Relevance: Publishes on anything nutrition.
Time: Quick to first decision.

3 THIRD CHOICE

Journal of Nutritional Biochemistry.
Impact: High IF of 6.1 & open access.
Relevance: Focused on bioactives.
Time: Feasible turnaround.

Melons tested

ST19036: Curtin University testing
Data available early 2022

WATERMELON	HONEYDEW MELON & ROCKMELON		
Sugars	Protein	Pantothenic acid	Phosphate
Beta-carotene	Fat	Folates total	Molybdenum
Alpha-carotene	Sugars	Arsenic	Manganese
Antioxidants	Dietary fibre	Iron	Potassium
Lycopene	Ash	Zinc	Sodium
Biotin	Isomers	Selenium	Aluminium
Vitamin C	Vitamins B1, B2, B3	Copper	Tryptophan
	Biotin	Calcium	Antioxidants
	Vitamin C	Magnesium	

Our Matrix Research

Supplemented by a literature review

- All included melons (+ Piel de sapo, crispy pear)
- Food composition databases
- Phenol-explorer
- PubMed and Google Scholar
- Prioritise Australian melons
- Data published after year 2000

Gap identification

- Compile matrix
- Identify missing nutrients and bioactives
- OPTIONAL ADD-ON: Additional nutritional testing to address gaps
- Quote TBC.

Key messages

Melons: The double rainbow fruit

Eat a rainbow of colourful fruits and vegetables for optimal health,

→ such as red watermelons, orange rockmelons, green honeydew melons, yellow piel de sapo melons, and white crispy pear melons.

→ Australian melons come in a rainbow of colours.

Lycopene is associated with improved <<*X* health outcome>>, red watermelon is a source of lycopene.

Chlorophyll is associated with reduced risk of <<*Y* health outcome>>, honeydew melon is a source of chlorophyll.

Education and communication

Activities and outputs

Websites
1x Melon hub
1x Website audit

2022-2024

Webinars
1 x full webinar
2 x podcasts

2022-2023

Brochures
2 x patient-friendly brochures
1 x HCP technical brochure
1 x HTML interactive brochure

2022-2023

Film
1 x live film
2 x animated films

2023

eDM + Signup
Social media sign-up
1 x database
3 x eDMs

2022-2024

Monitoring & Evaluation

Continuous feedback to ensure maximum impact

1 Activities

1. Client monthly updates
2. Milestone reports

2 Outputs

1. Milestone reports
2. PRG meetings

3 Outcomes

1. Market research
2. eDM open rate
3. Melon hub analytics
4. Social media analytics
5. Post webinar survey

PRG feedback on strategy

Top line comments:

- Double rainbow concept isn't clear → rainbow focusing on colour not arch.
- HCP translation – culinary nutrition relevant. Add the "how to" aspects incl. food safety/fears. Food rind → sustainability.
- Consider nutrient density due to water content.
- Consider the form of the bioactive pigment → Consume the pigment from a range of sources.
- Concern over social media → ensure doesn't go direct to public.
- Information given to industry → make clear what can/can't be said/shared with public.
- GPs low experience with nutrition. Messaging must be v. clear. Must meet consumer needs but delivered via HCPs. Low burden messages for HCPs.
- Sunshine messaging alternative to rainbow.
- Hospitals, RACs are large consumers of melons → target specifically → add to menu.
- Consideration of hydration and dietary fibre in addition to bioactives.
- Ensuring that colour messages remain relevant to melons.

Please email any detailed commentary or thoughts to: flavia@nraus.com by January 15 2022.

NRAUS

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Thank you

VM20003
Educating Health Care Professionals on Australian Melons

Project Reference Group Meeting 2

23rd February 2022

NRAUS

VM20003
Educating Health Care Professionals on Australian Melons

Project Reference Group Meeting 3

8th July 2022

Agenda

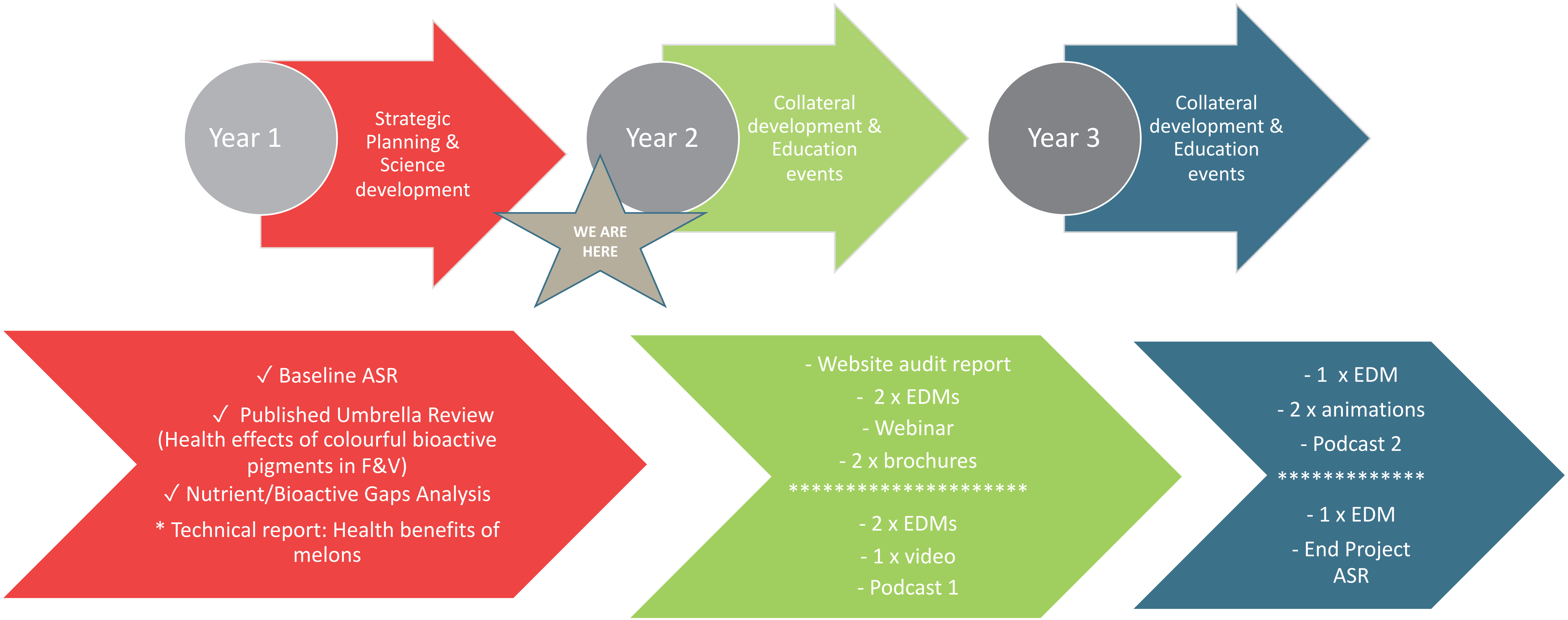
1. Project recap & status
2. Current outputs update:
   - ✓ Umbrella review
   - ✓ Gaps Analysis
   - ✓ Technical report
3. Communication strategy
4. Upcoming outputs update
5. Feedback

Goodness in every colour

MELONS

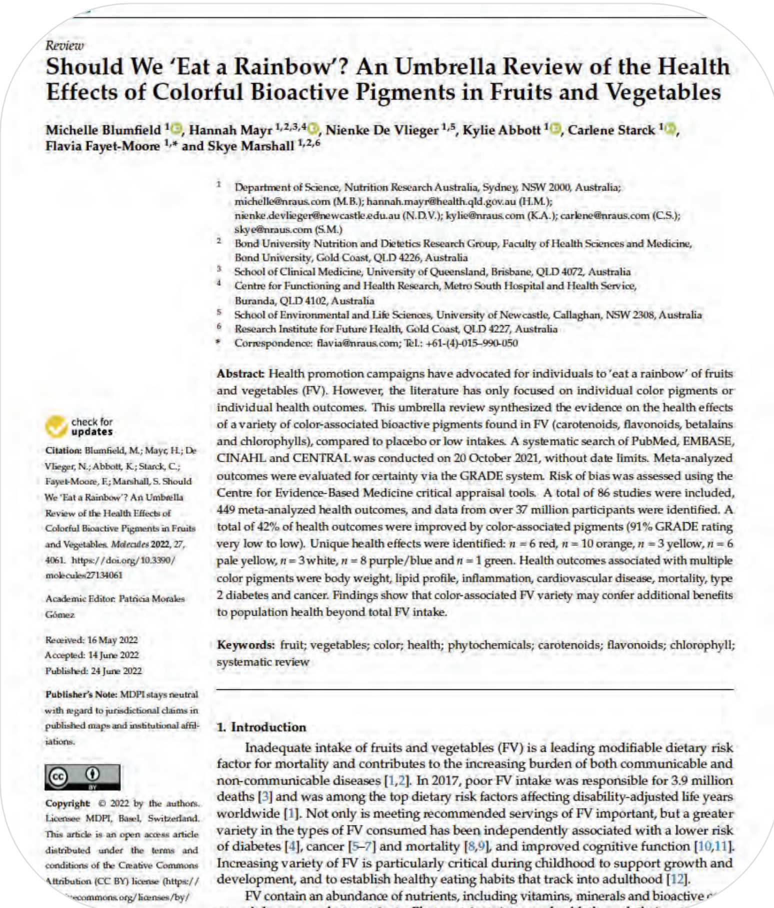
Project recap & status

Where are we?


Year 1
Strategic Planning & Science development
Year 2
Collateral development & Education events
Year 3
Collateral development & Education events
WE ARE HERE
✓ Baseline ASR
✓ Published Umbrella Review (Health effects of colourful bioactive pigments in F&V)
✓ Nutrient/Bioactive Gaps Analysis
* Technical report: Health benefits of melons
- Website audit report
- 2 x EDMs
- Webinar
- 2 x brochures
****
- 2 x EDMs
- 1 x video
- Podcast 1
- 1 x EDM
- 2 x animations
- Podcast 2
****
- 1 x EDM
- End Project ASR

Current outputs: Update

Umbrella review just published in ‘Molecules’



Review

Should We ‘Eat a Rainbow’? An Umbrella Review of the Health Effects of Colorful Bioactive Pigments in Fruits and Vegetables

Michelle Blumfield [1], Hannah Mayr [1,2,3,4], Nienke De Vlieger [1,5], Kylie Abbott [1], Carlene Starck [1], Flavia Fayet-Moore [1,*] and Skye Marshall [1,2,6]

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Abstract: Health promotion campaigns have advocated for individuals to ‘eat a rainbow’ of fruits and vegetables (FV). However, the literature has only focused on individual color pigments or individual health outcomes. This umbrella review synthesized the evidence on the health effects of a variety of color-associated bioactive pigments found in FV (carotenoids, flavonoids, betalains and chlorophylls), compared to placebo or low intakes. A systematic search of PubMed, EMBASE, CINAHL and CENTRAL was conducted on 20 October 2021, without date limits. Meta-analyzed outcomes were evaluated for certainty via the GRADE system. Risk of bias was assessed using the Centre for Evidence-Based Medicine critical appraisal tools. A total of 86 studies were included, 449 meta-analyzed health outcomes, and data from over 37 million participants were identified. A total of 42% of health outcomes were improved by color-associated pigments (91% GRADE rating very low to low). Unique health effects were identified: $n = 6$ red, $n = 10$ orange, $n = 3$ yellow, $n = 6$ pale yellow, $n = 3$ white, $n = 8$ purple/blue and $n = 1$ green. Health outcomes associated with multiple color pigments were body weight, lipid profile, inflammation, cardiovascular disease, mortality, type 2 diabetes and cancer. Findings show that color-associated FV variety may confer additional benefits to population health beyond total FV intake.

Keywords: fruit; vegetables; color; health; phytochemicals; carotenoids; flavonoids; chlorophyll; systematic review

check for updates

Citation: Blumfield, M.; Mayr, H.; De Vlieger, N.; Abbott, K.; Starck, C.; Fayet-Moore, F.; Marshall, S. Should We ‘Eat a Rainbow’? An Umbrella Review of the Health Effects of Colorful Bioactive Pigments in Fruits and Vegetables. *Molecules* **2022**, *27*, 4061. https://doi.org/10.3390/molecules27134061

Academic Editor: Patricia Morales Gómez

Received: 16 May 2022
Accepted: 14 June 2022
Published: 24 June 2022

1. Introduction

Inadequate intake of fruits and vegetables (FV) is a leading modifiable dietary risk factor for mortality and contributes to the increasing burden of both communicable and non-communicable diseases [1,2]. In 2017, poor FV intake was responsible for 3.9 million deaths [3] and was among the top dietary risk factors affecting disability-adjusted life years worldwide [1]. Not only is meeting recommended servings of FV important, but a greater variety in the types of FV consumed has been independently associated with a lower risk of diabetes [4], cancer [5–7] and mortality [8,9], and improved cognitive function [10,11]. Increasing variety of FV is particularly critical during childhood to support growth and development, and to establish healthy eating habits that track into adulthood [12].

FV contain an abundance of nutrients, including vitamins, minerals and bioactive

Role:

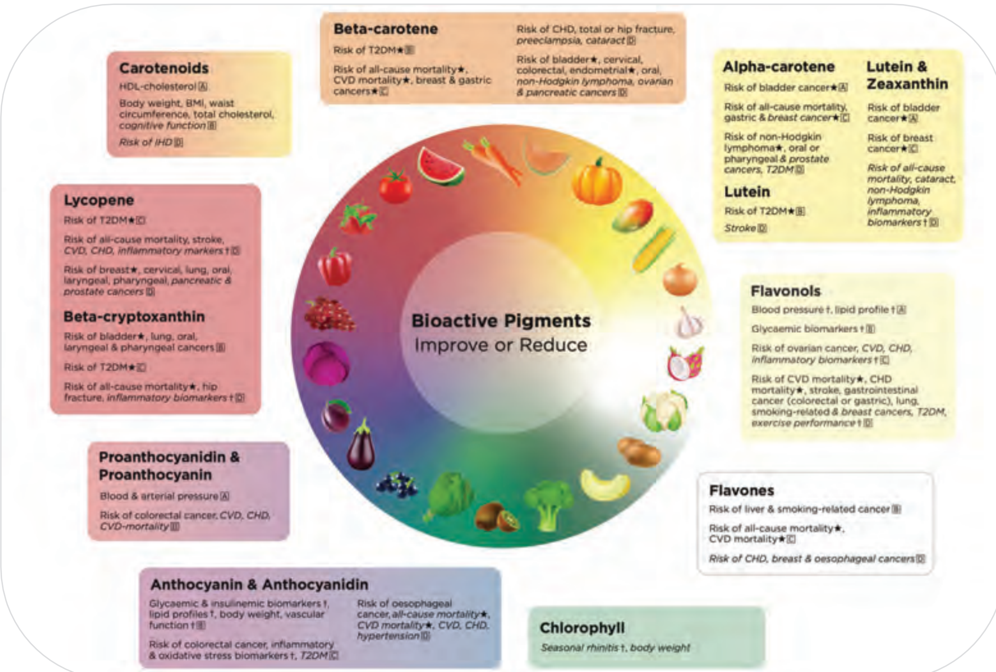
Ā Credible evidence for the importance of colour pigment on health

Ā Support to build a relevant nutrition story for HCP comms (i.e. there is a need to address colour-associated fruit variety in the Australian diet)

Ā Colour pigments in different melons to be leveraged as indirect evidence of health effect of melons and used in collateral development

Status: Published June 2022.

Umbrella review



- Unique health effects were identified: n = 6 red, n = 10 orange, n = 3 yellow, n = 6 pale yellow, n = 3 white, n = 8 purple/blue and n = 1 green.
- ***White, Orange, Red:*** lower risk of all-cause and CVD mortality
- ***Yellow:*** lower risk of CVD and CHD mortality
- ***Green:*** helps with seasonal rhinitis + bodyweight

Huge engagement so far (in 1 week) - 1000 full-text downloads before officially indexed.

Next Steps: Housed on NRAUS Melon Hub+ world-first publication communicated in first EDM to Melons HCP database.

Gaps Analysis

Desktop audit of food composition databases, in liaison with Curtin University (ST19036), to compile a dataset of all nutrient and bioactive composition research on Australian melons and comparable melon varieties.

Ā Current data on the composition of nutrients and bioactives in Australian melons to be used in the education of HCPs.

Role: Inform the education campaign and identify opportunities for any additional nutritional testing.

Status: Due for completion by 15 July 2022

Gaps Analysis

MELON	ENERGY & MACROS	MACRO COMPONENTS	MINERALS	VITAMINS	BIOACTIVES& POLYPHENOLS
Honeydew	*Testing performed before 2000*	*Amino acids not covered in Australian Food Composition Database*	*Australian Food Composition database missing mineral data and testing was performed before 2000*	*Testing performed before 2000*	*Polyphenols, flavonoids and carotenoid types (lycopene, lutein) not covered in Australian Food Composition Database*
Rockmelon					
Watermelon					
Piel de Sapo	*Little to no Australian data*				

Red: Little to no Australian data, requires Australian testing

Orange: Missing some data, requires Australian testing

Yellow: Requires updating testing (testing performed before 2000) but current Australian Food Composition data still align with more recent nutrient data

Ā No Australian data on amino acids and fatty acids.
Ā International data indicate that melons contain a range of amino acids.
Ā US data- watermelon seeds contain PUFAs and amino acids.

		PER 100G					
MELON (COUNTRY)	SOURCE (YEAR)	ENERGY (KJ)[2]	PROTEIN (g)	CARBS (g)	TOTAL SUGARS (g)	DIETARY FIBRE (g)	TOTAL FATS (g)
Honeydew (Australia)[1]	AFCD (1983-84)	128	0.75	5.8	5.8	0.30	0.95
Honeydew (Australia)	CU (2021)	126	0.40	6.9	6.9	<0.20	0.80
Honeydew (UK)	UK-CoFID (1985-2013)	72	0.30	4.2	4.2	0.10	0.40
Honeydew (US)	USDA (2000-19)	150	0.54	9.1	8.1	0.14	0.80
Rockmelon (Australia)	AFCD (1983-84)	99	0.50	4.7	4.7	0.10	1.0
Rockmelon (Australia)	CU (2021)	100	0.70	4.9	4.9	<0.20	1.1
Rockmelon (UK)	UK-CoFID (1985-2013)	62	0.50	3.2	3.2	0.10	1.4
Rockmelon (US)	USDA (2000-19)	150	0.83	8.2	7.9	0.19	0.85
Watermelon (Australia)	AFCD (1983-84)	130	0.60	7.3	7.0	0.00	0.40
Watermelon (Australia)	CU (2021)	125	NR	6.9	6.6	NR	NR
Watermelon (UK)	UK-CoFID (1985-2013)	105	0.40	5.6	5.6	0.25	NR
Watermelon (US)	USDA (2000-19)	127	0.61	7.6	6.2	0.15	0.40
Watermelon Seeds (US)	USDA (2000-19)	2330	28	15	NR	47	NR

Table 1 footnotes:

Recommendations: Update and perform new testing on missing amino acids, vitamins + minerals

Technical report: Health effects of melons

Research on health effects (CVD health, metabolic health, exercise performance) associated with Australian melons has focused on watermelon only.

Ā **Watermelon:** red bioactive pigments lycopene and beta-cryptoxanthin, lowers risk of cardiovascular disease.

Ā **Honeydew and rockmelon:** orange bioactive pigment beta-carotene, lowers risk of type 2 diabetes.

Ā **Watermelon and rockmelon:** white bioactive pigments called flavones, lowers risk of cancer.

Ā **Piel de Sapo:** chlorophylls, green bioactive pigments found to relieve symptoms of seasonal allergic rhinitis.

Role: Inform the education campaign

Status: Report currently being finalised and due completion end July

Communication strategy

Making Melons meaningful and relevant to HCPs

The current landscape

There is a need to increase colour-associated **FRUIT** variety in the Australian diet, and despite believing it is important when asked, few HCPs are assessing or recommending fruit variety in practice.

- ✓ Australians fruit variety intake is lacking[1,2]
- ✓ Colour associated F&V variety improves health, beyond total intake[3]
- ✓ F&V intake increases with fruit variety[4]
- ✓ 8 out of 10 HCPs report colour-associated fruit variety is important[5]
- ✓ Only 12% HCPs assess and 14% recommend fruit variety regularly[5]

Potential influences:

- Colourful + *fruit* variety not top of mind with HCPs
- Vegetables get more of the limelight as a strategy to increase bioactive-rich plant rich foods, despite fruit being more readily accepted

1. Marshall et al, 2012, Nutrition Journal; 2. Ashton et al, 2017, Nutrients; 3. Blumfield et al, 2022, Molecules; 4. Hendrie & Noakes 2017, CSIRO 5. Australian HCP Melons Audience Sentiment Research 2022

The opportunity

Melons to be the 'hero' fruit to support the need and desire for HCP to increase colour-associated fruit variety in the Australian diet.

How: Create awareness & relevancy of need for colour-associated fruit variety & hero MELONS by:

Developing relevant story of need to address lack of coloured fruit variety in diet

- Leverage umbrella review as compelling reason why colour-fruit variety important. Variety of colourful F&V likely confers additional benefits beyond total intake plus research showing Australians lack fruit variety.

Providing solutions to address variety using melons as the hero example

- Provide practical tips on how to assess and improve dietary variety.
- Use melons – goodness in every colour – a unique and delicious fruit representing a spectrum of colour across their varieties as the lead example.
- Educate on nutritional and health benefits of melons to increase confidence in recommendations.

The story

Melons are a unique fruit, representing a spectrum of colour across their varieties, and provides a delicious way to increase colour-associated FRUIT variety.

Both fruit & vegetables contain colour associated bioactive pigments, linked with positive health outcomes and behind strategies and campaigns such as Go for 2 & 5. Recent research now supports the adage of 'Eating a rainbow' showing ***variety*** of colour-associated F&V likely confers **additional benefits** beyond total dietary F&V intake.

Despite barriers to intake related to taste and convenience, vegetables more often gets the limelight as a strategy to increase colour-associated variety**.** **Fruit is often forgotten** despite being more readily accepted and research indicating colour-associated FRUIT variety is lacking in Aussie diets. It's time to focus on the role that melons have in providing both fruit and colour-variety.

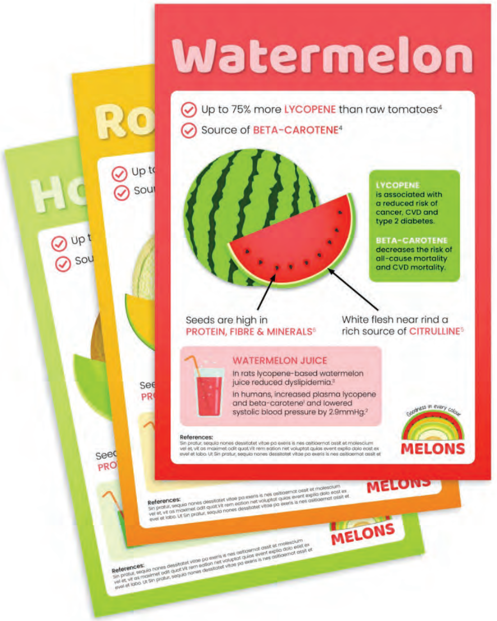
Upcoming outputs: Update

Brochures

1. **Increasing colour-associated fruit variety: Goodness in every colour**
   Ā 2-page HCP brochure focused on health benefits of increasing colour-associated fruit variety and providing practical tips on how to assess and improve dietary fruit variety with melons as a superhero food.

2. **Melons: Goodness in every colour science summary factsheets OR collated infographic brochure**
   Ā 3 x A4 (double sided) individual infographic style fact sheets or a 6-page melons combined infographic style brochure showcasing the nutrition and health benefits of watermelon, rockmelon, honeydew melon and potentially Piel de Sapo utilising the nutritional analysis (melon matrix), umbrella review and technical report (NIQ database) . Will also address food safety.

Goodness in every colour
MELONS



Next steps: Confirm outputs and commence development outline and key messages.

Webinar

Topic: "***Melons – the 'Superfruit' to increasing intake of health-promoting colour-associated bioactive pigments key for health***."

Presented by: Dr Flav and another key nutrition influencer (TBC).

Aim: Present the need for improving colour-associated fruit variety in the diet and provide practical tips on how to assess and improve variety using melons as the hero fruit.

Target audience: Dietitians, nutritionists, GPs, fitness professionals.

Presentation key messages:

Ā Fruit variety Australian diet lacking

Ā Colour-associated F&V variety likely confers additional benefits over total intake.

Ā Melons unique fruit, representing a wide spectrum of colour across their varieties and provides delicious and healthful way to increase colour-associated fruit variety.

When: October 2022

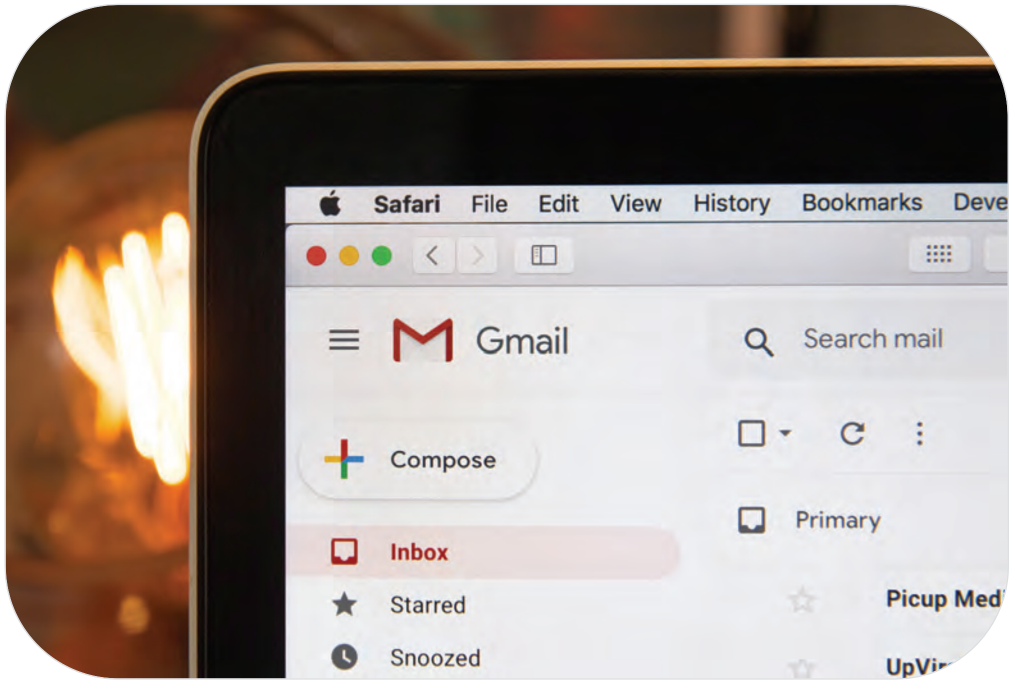
Website audit report

User friendly report that clearly outlines Melons Australia website content to be removed or improved; or new substantiated content that has HCP impact and complies with the FSANZ Food Standard Code.

Status: Plan to commence in next quarter.

Next steps: PRG to inform best contact at Melons Australia

EDMs



Ongoing communication (2-3 per year) to Melons HCP database utilised to educate on melons nutrition and health, disseminate educational materials and communicate upcoming events.

EDM 1 –July – Communicate just published research and link to melons story

EDM 2 – Mid-Aug – Advertise upcoming webinar

Status: Template and copy development in progress

PRG Minutes

- **Overall** unanimous overall positive feedback to outputs delivered to date and strategic communication direction.
- **Over-arching communications strategy**: agreement with proposed strategy/approach to proceed
    - The main take out by all is that COLOUR is what bridges both nutrition/health benefits and appeal and enjoyment of food (which drives intake) and is a great theme for Melons to own. Seen as great main theme to bring excitement and grab attention to arguably 'boring' topic (F&V).
    - Noted by Lisa use of language is key and the term 'colour associated fruit variety' is a new coined term that has ability to provide needed engagement.
    - COLOUR seen to be accessible and practical and lots of opportunity seen by Emma to bring it alive across all the touchpoints – shopping, fridge, fruit bowl, recipes, plate.
    - Emma noted practical tools to support and educate HCPs will be important and opportunity - would benefit from education and upskilling in bioactives with idea of developing a 'glossary of terms' to educate on what it is and what it does. Consider tracking tools to shop, cook, prep and change dietary habits that could be communicated.
    - Anthony from a grower's perspective like the simplicity and see the merit of this working across both HCP and consumers. How it translates to consumers is noted to be important consideration.
    - Discussion by all around practical elements of leveraging from culinary nutrition, weaving in fun and enjoyment messages – melon art.

PRG Minutes Continued

- **Brochures:** Agreement with 2 brochures and top-line strategic content
  - Agreement from group for client friendly brochure to be a single combined brochure (6page) that includes all melons nutrition/health info plus food safety tips rather than individual single melon variety brochures.
- **Webinar:** agreement with proposed strategy/approach to proceed
  - Recommended by Anthony and supported by Chris to include growers perspective in the presentation to build the connection of HCPs with growers which has benefit also of leveraging the a key NHW trend of desire for provenance and the connecting of ‘farm to fork’.
- **Website audit:**
  - NRAUS to follow up with Jonathan Davey for next steps/contact at Melons Australia to commence this output.

NRAUS

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Thank you

NRAUS

VM20003 Educating Health Care Professionals on Australian Melons

Project Reference Group Meeting 4

1 December 2022

Agenda

1. Project recap & status
2. Current outputs update:
   - ✓ Brochures
   - ✓ Webinar
   - ✓ EDMs
3. Upcoming outputs update
4. Feedback

Project recap & status

Where are we?

Year 1
Strategic Planning & Science development

Year 2
Collateral development & Education events

Year 3
Collateral development & Education events

✓ Baseline ASR
✓ Published Umbrella Review (Health effects of colourful bioactive pigments in F&V)
✓ Nutrient/Bioactive Gaps Analysis
* Technical report: Health benefits of melons

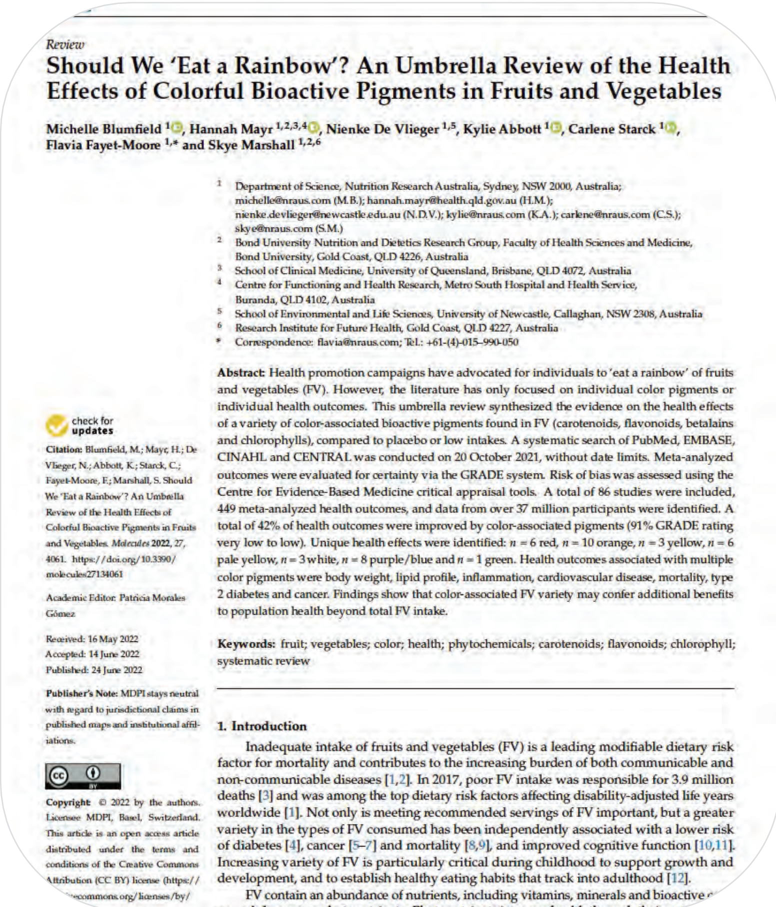
WE ARE HERE

- Website audit report
- 2 x EDMs
- Webinar
- 2 x brochures
****
- 2 x EDMs
- 1 x video
- Podcast 1

- 1 x EDM
- 2 x animations
- Podcast 2
****
- 1 x EDM
- End Project ASR

Current outputs: Update

Umbrella review - over 6.8 Million reach!



Review

Should We 'Eat a Rainbow'? An Umbrella Review of the Health Effects of Colorful Bioactive Pigments in Fruits and Vegetables

Michelle Blumfield [1], Hannah Mayr [1,2,3,4], Nienke De Vlieger [1,5], Kylie Abbott [1], Carlene Starck [1], Flavia Fayet-Moore [1,*] and Skye Marshall [1,2,6]

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Abstract: Health promotion campaigns have advocated for individuals to 'eat a rainbow' of fruits and vegetables (FV). However, the literature has only focused on individual color pigments or individual health outcomes. This umbrella review synthesized the evidence on the health effects of a variety of color-associated bioactive pigments found in FV (carotenoids, flavonoids, betalains and chlorophylls), compared to placebo or low intakes. A systematic search of PubMed, EMBASE, CINAHL and CENTRAL was conducted on 20 October 2021, without date limits. Meta-analyzed outcomes were evaluated for certainty via the GRADE system. Risk of bias was assessed using the Centre for Evidence-Based Medicine critical appraisal tools. A total of 86 studies were included, 449 meta-analyzed health outcomes, and data from over 37 million participants were identified. A total of 42% of health outcomes were improved by color-associated pigments (91% GRADE rating very low to low). Unique health effects were identified: $n = 6$ red, $n = 10$ orange, $n = 3$ yellow, $n = 6$ pale yellow, $n = 3$ white, $n = 8$ purple/blue and $n = 1$ green. Health outcomes associated with multiple color pigments were body weight, lipid profile, inflammation, cardiovascular disease, mortality, type 2 diabetes and cancer. Findings show that color-associated FV variety may confer additional benefits to population health beyond total FV intake.

Keywords: fruit; vegetables; color; health; phytochemicals; carotenoids; flavonoids; chlorophyll; systematic review

check for updates

Citation: Blumfield, M.; Mayr, H.; De Vlieger, N.; Abbott, K.; Starck, C.; Fayet-Moore, F.; Marshall, S. Should We 'Eat a Rainbow'? An Umbrella Review of the Health Effects of Colorful Bioactive Pigments in Fruits and Vegetables. *Molecules* **2022**, *27*, 4061. https://doi.org/10.3390/molecules27134061

Academic Editor: Patricia Morales Gómez

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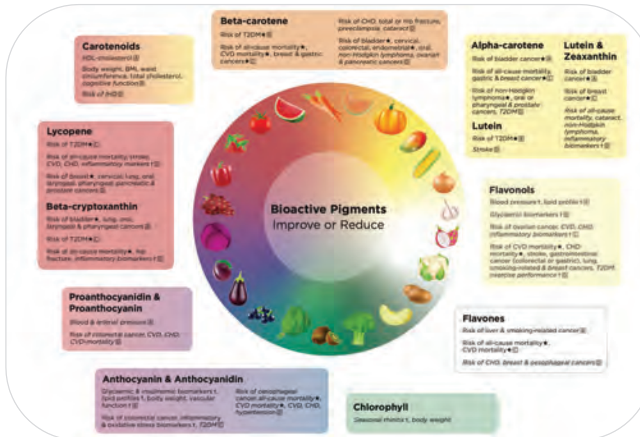
Published: 24 June 2022

1. Introduction

Inadequate intake of fruits and vegetables (FV) is a leading modifiable dietary risk factor for mortality and contributes to the increasing burden of both communicable and non-communicable diseases [1,2]. In 2017, poor FV intake was responsible for 3.9 million deaths [3] and was among the top dietary risk factors affecting disability-adjusted life years worldwide [1]. Not only is meeting recommended servings of FV important, but a greater variety in the types of FV consumed has been independently associated with a lower risk of diabetes [4], cancer [5–7] and mortality [8,9], and improved cognitive function [10,11]. Increasing variety of FV is particularly critical during childhood to support growth and development, and to establish healthy eating habits that track into adulthood [12].

FV contain an abundance of nutrients, including vitamins, minerals and bioactive



2.8 K original research studies

> 37 million people

3K full text downloads

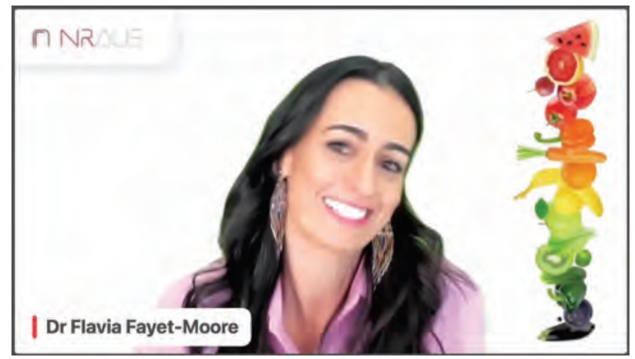
Status: Published June 2022.

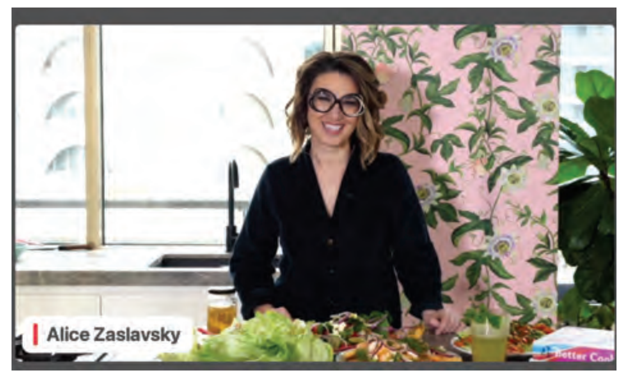
HCP & Consumer friendly brochure

- **HCP brochure**: Educational brochure on importance of colour variety, bioactives, dietary 'colour gap' and how melons can help.
- **Consumer friendly brochure**: Printable handout with easy to understand information and practical tips on how melons can help add more colour variety to the diet.

Webinar

275 registrants
89 live attendees





"Very engaging and uplifting presentation. The simplicity of the concept is very enticing and I loved the recipes and learning about melons! I'm going to start growing some ! Thank you for such an inspiring, fun and thoughtful webinar."

Webinar hit all KPIs!

All participants evaluated in the top 2 options:

Very informative, with a great overarching message'.

100% learnt something new
80% rated webinar excellent overall, 20% very good
72% rated exceptionally informative, 28% very good
59% rated exceptionally engaging, 21% above average
67% rated extremely useful, 33% very useful

100% intend to recommend melons to clients to help improve colour variety

What did you like best?
'Everything! One of the best webinars I've attended .. presentation , Colours! Information and speakers very knowledgeable and interesting ; easy to follow.'

What did you like best

Well presented information that was also inspiring

‘It was a good mix of the science and background which was presented in an interesting way and easy to understand plus practical with the cooking tips. I was sceptical about how this would work and was impressed.’

‘Level of detail, clear explanations, great infographics, passionate presenter.’

Excellent mix of science, practical answers to questions and fun/taste.’

‘I really liked the movement from serving sizes and nutrients to focusing on eating a rainbow to increase fruit and veg intake. It was also interesting to hear more focus on bioactives and using the whole fruit in cooking e.g. watermelon rind in stir fries. I think this is a great initiative I hope to implement in my health promotion and nutrition roles.’

‘Very well presented, use of graphics and expert knowledge.’

What did you like best

I could not fault anything, the presenters were fantastic and all the information was easy to understand and valuable

Having a presentation side & then seeing the cooking/visual side. Nice mix of dynamics. Really upbeat and engaging speakers.

Perfectly timed and topical info shared

Love the concept of changing the boring terms of eating 5 + 2, to focussing on eating the rainbow. This will be very useful for clients, and even for my own diet.

Perfect webinar!

Great layout with seamless transition between slides, speakers etc. Quality content and visuals too

Melons Australia website: Melons Nutrition & Health info

Scope changed to provide consumer and healthcare professional new substantiated content that has impact and complies with the FSANZ Food Standards Code.

Status: Approved copy & design inspiration completed and sent Melons Australia

EDMs

EDM 1 –July – Communicate just published research and link to melons story
Open Rate: 30%

EDM 2 – September – Advertise upcoming webinar
Open rate: 30%

Status: 2 x EDMs completed, Post Webinar & Brochure EDM to be sent out December

Upcoming deliverables

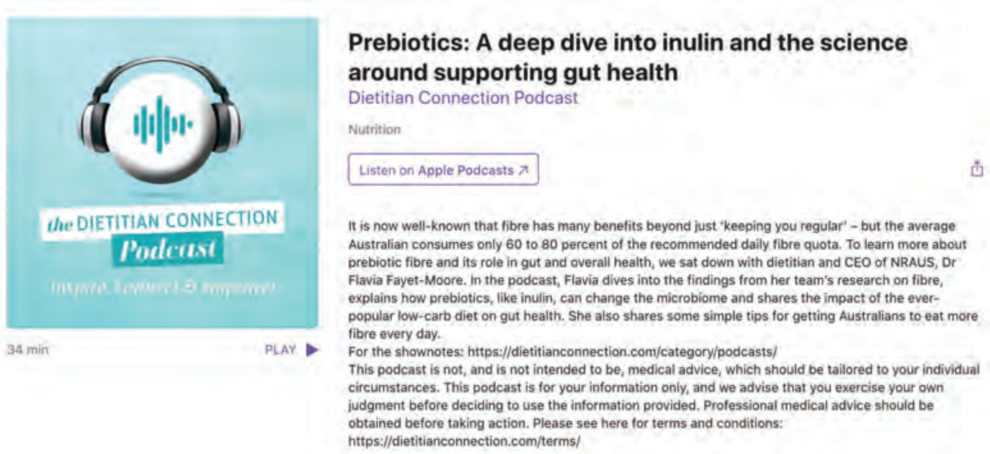
Video

Ā 1.5-minute live recorded short film:
- ✓ Engaging way to drive messages
- ✓ shareable to drive awareness
- ✓ Can be used by health professionals with their clients.

Ā **Content:** Plan to share messages of the webinar in short film - findings of our world class research, using lay language and using Melons as hero example.

Status: Plan to work on in Q2 2023

Podcast



Ā Pre-recorded evidence-based podcast episode leveraging Dr. Flav with high reach nutrition professionals (e.g., Thinking Nutrition with Dr Tim Crowe, 99% Fad Free with Tara Leong, Leanne Ward Nutrition with Leanne Ward APD).
  - ✓ Engaging way to drive awareness message to HCPs

Ā Content: focus on practical ways of increasing colour variety, with fruit and melons as a hero food with practical tips for their patients and clients.

Status: To execute Q2 2023

Feedback & Discussion

PRG Minutes

- PRG members provided overview of the collateral and webinar feedback. Melons Australia reported that they have had positive feedback externally on the webinar.
- Upcoming activations discussed
  - 1.5 min Video:
    - General consensus that would be better to undertake 3 short videos 30 seconds rather than 1 x 1.5 min video. These would be able to be utilized in social media to communicate messages.
    - Lisa suggested to consider filming in supermarket to home to show the bringing colour to every part of the journey from the shop to the plate. NRAUS to share the proposed strategic approach on videos when finalised with the PRG for their feedback.
  - Podcast:
    - Jill recommended key to discuss general information plus also address misconceptions e.g. high sugar content of melons. Discussion by group over leveraging compelling facts that help to reframe and reassess melons e.g. such as ‘There is less sugar per Australian Dietary Guidelines fruit serve(150g) in melons (8-10.6g) than blueberries (13.8g). Sugar content based on Australian Food Composition Tables. Fernando saw this as important factual information that helps to elevate melons. Cautioned by Lisa to be careful with with comparison claims to maintain credibility. NRAUS will aim to ensure credible and compelling communication messages.
    - Lisa and Jill highlighted best to ensure dynamic speaking – tone light and bright and not lecture style to maintain interest.   Key tip from Lisa from radio work is to speak visually – help the listener to generate an image in their mind.

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Thank you

NRAUS

VM20003 Educating Health Care Professionals on Australian Melons

Project Reference Group Meeting 5

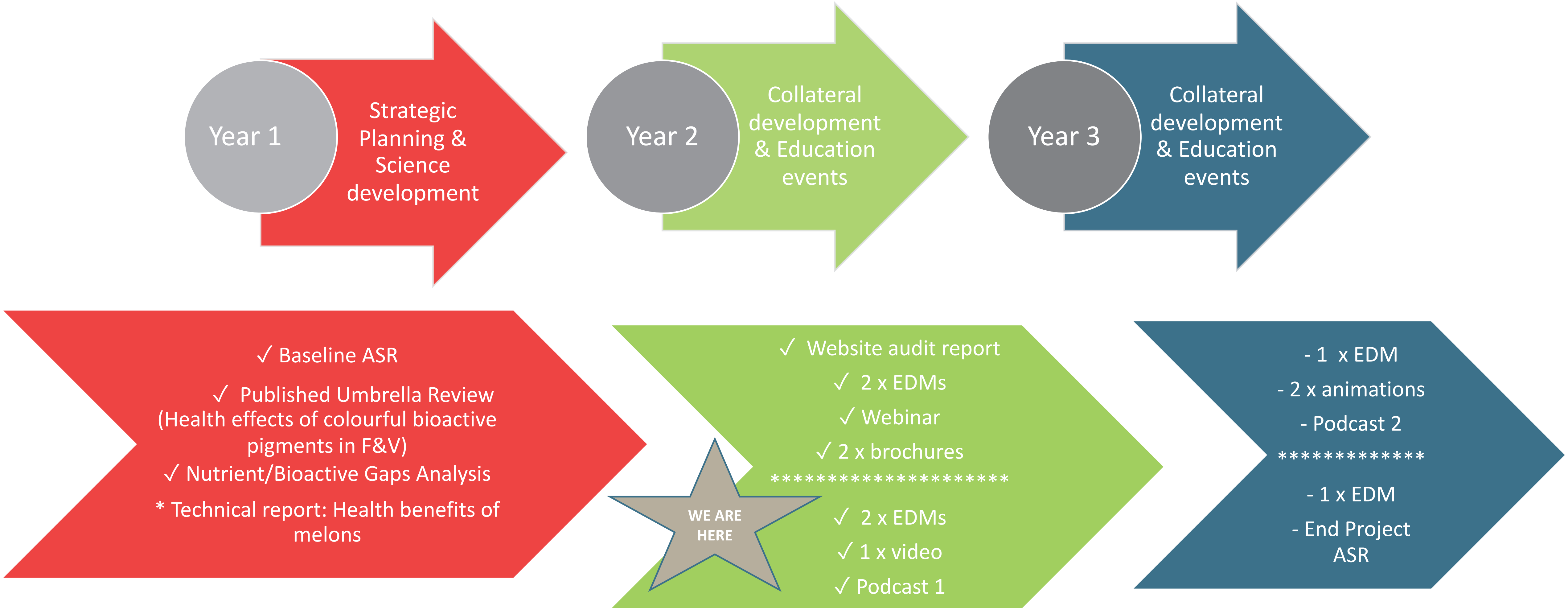
19th June 2023

Agenda

1. Project recap & status
2. Current outputs update:
   - ✓ Leanne Ward Podcast
   - ✓ Video
   - ✓ EDMs
3. Upcoming outputs update
4. Feedback

Project recap & status

Where are we?


Year 1
Strategic Planning & Science development
Year 2
Collateral development & Education events
Year 3
Collateral development & Education events
✓ Baseline ASR
✓ Published Umbrella Review (Health effects of colourful bioactive pigments in F&V)
✓ Nutrient/Bioactive Gaps Analysis
* Technical report: Health benefits of melons
✓ Website audit report
✓ 2 x EDMs
✓ Webinar
✓ 2 x brochures
****
✓ 2 x EDMs
✓ 1 x video
✓ Podcast 1
WE ARE HERE
- 1 x EDM
- 2 x animations
- Podcast 2
****
- 1 x EDM
- End Project ASR

Current outputs: Update

Leanne Ward Podcast

- **Leanne Ward Nutrition**: **5 star rated podcast series** and one of most popular nutrition podcasts in Australia, currently rated in top 10.
- Leanne Ward is a renowned Australian media dietitian, nutritionist, sports dietitian and online social media influencer known as *The Fitness Dietitian*
- 300,000 followers on Instagram, over 150 episodes and 1.5million+ downloads

Impact to date:

- Released 5th June
- 7000 downloads to date
- Shared via stories - 4300 impressions

Status: Complete

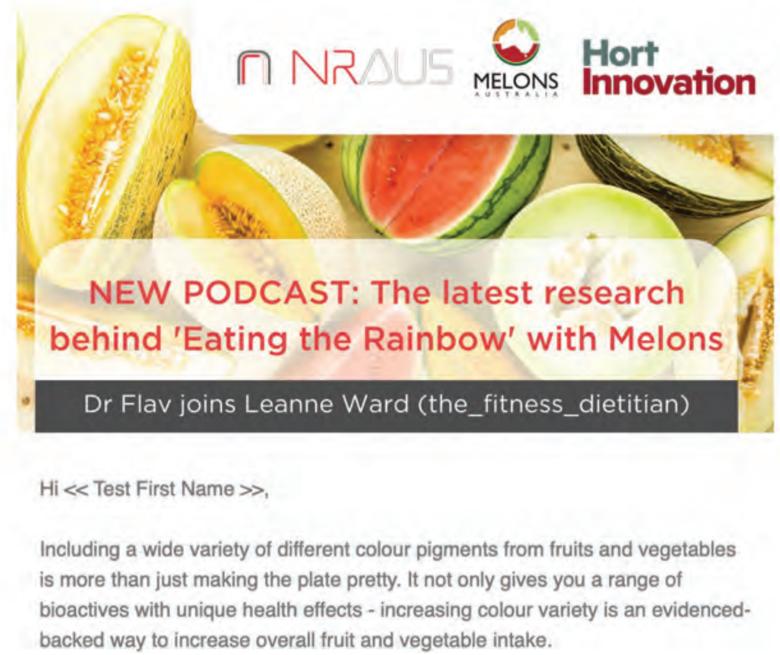
Video

- 1.5-minute live recorded short film
- Script designed to provide three separate 30 second key message – stand alone & together to give flexibility in using the footage in other formats such as social media.
  - Section 1 – Superfoods & supplements are out – colourful families of F&V variety like melons is in.
  - Section 2 – Just add Melons to boost your colour variety
  - Section 3 – Melons are a tasty choice for eating the rainbow

Status: In post production.

EDMs

EDM 3 –March – Communicated the new brochures
Open Rate: 52% (KPI: 25%)

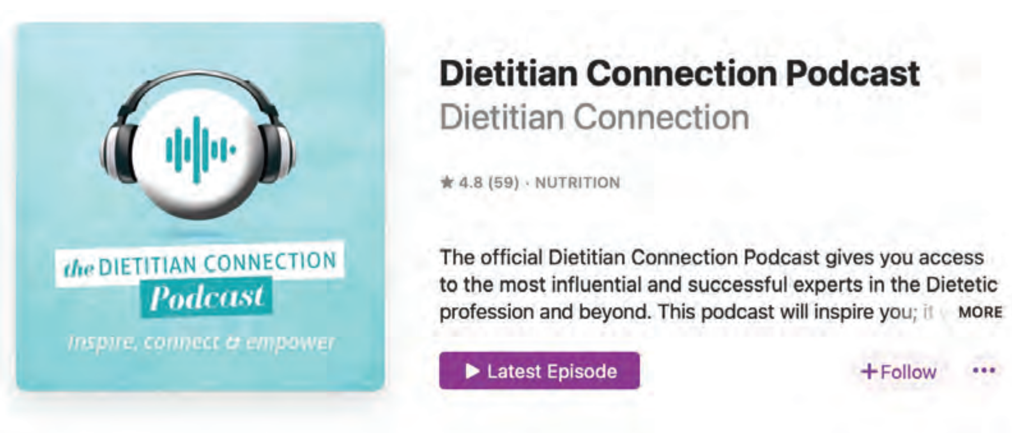


EDM 4 – 22nd June – Advertise podcast release

Status: 1 x EDMs completed, 1 x EDM to be sent out 22 June

Upcoming deliverables

Dietitian Connection Podcast



- Credible podcast series targeting dietitians (8500 members) that aims to provide '*Access to the most influential and successful experts in dietetic profession and beyond*'
- Dr Emma Beckett will feature – strong credibility in DC community
- Will exist as an evergreen resource on DC website.

Status: Recording in August with go live September 14

Animations

ANIMATIONS – 60-90 sec each

1. *Melons – Goodness in every colour Fast Facts*
   - ✓ Colour variety with 5 colours – red, yellow, orange, white, green delivering health promoting bioactives
   - ✓ Delivers vitamin A, C, folate and potassium
   - ✓ Deliciously sweet but delivering low GL goodness with only 9-10g sugar per serve
   - ✓ Hydrating with ½ cup water in every serve

2. *Melons – Nutritious, delicious, sustainable*
   - ✓ Emerging research that peel and seeds contain health promoting bioactives.
   - ✓ Recipes: Rind stir fry, toasting seeds
   - ✓ Melons can be frozen

Status: To commence in Q3 2023

Feedback & Discussion

PRG Minutes

Ā Currently about to move into the last year of the project. Brochures, webinar, podcast completed and video in final stages production. Moving into next milestone to deliver another podcast and 2 x videos.
Ā Noted good impact on podcast achieved to date.
Ā Overall PRG reported happy with current progress.
Ā Group happy with top line approach on animations.
Ā Specific feedback and builds with the 'sustainability' animation to not be primarily communicating sustainability or eating rinds/seeds. Rather animation should be focused on bringing to life inspiration and education on practical aspects of preparing and using melons (how to cut whole melons, prepare, store) to support greater purchase and consumption. This can weave in 'no waste' communication benefit.
Ā Ask for feedback from Jill post listening to the podcast to give her thoughts/recommendations on communication nuggets that she feels wouldresonate best with GPs.

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Thank you

FOODiQ global

VM20003: Educating healthcare professionals on Australian Melons

PRG MEETING 6

June 2024

FOODiQ global

Agenda

1 Project Overview
2 Project review
3 Impact
4 Key Learnings
5 Recommendations
6 Discussion

FOODiQ global

Project
OVERVIEW

THE PROJECT: VM20003

Supports the **Strategic Investment Plan** of the Melons Fund to increase domestic consumption of Australian Melons

Aim: Establish Australian melons as a fruit which can provide a range of colour-associated nutrients and bioactives required to achieve optimal health and wellbeing.

End of project outcomes:

Ā 50% increase in Health Professionals (HP) reporting they are familiar and can specify the nutritional properties of melons

Ā 50% HPs aware of HP resources

Ā >80% HPs recommend Australian melons to help improve colour variety in the diet

THE PROJECT: VM20003

Intermediate outcomes:

Ā Materials loaded into the Melon Hub

Ā 10% increase in database subscribers/year

Ā 25% EDM open rate

Ā 20,000 total reach for social campaigns

Ā 15,000 30-sec video plays

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Project Plan

Year 1 – Strategic Planning & Science development

Year 2 – Collateral development & Education events

Year 3 – Collateral development & Education events

Year 1

- ✓ Baseline ASR
- ✓ Published Umbrella Review (Health effects of colourful bioactive pigments in F&V)
- ✓ Nutrient/Bioactive Gaps Analysis
- ✓ Technical report: Health benefits of melons

Year 2

- ✓ Website audit report
- ✓ 2 x EDMs
- ✓ Webinar
- ✓ 2 x brochures

****

- ✓ 2 x EDMs
- ✓ 1 x video
- ✓ Podcast 1

Year 3

- ✓ 1 x EDM
- ✓ 2 x animations
- ✓ Podcast 2

****

- ✓ 1 x EDM
- ✓ End Project ASR

What was the opportunity for melons?

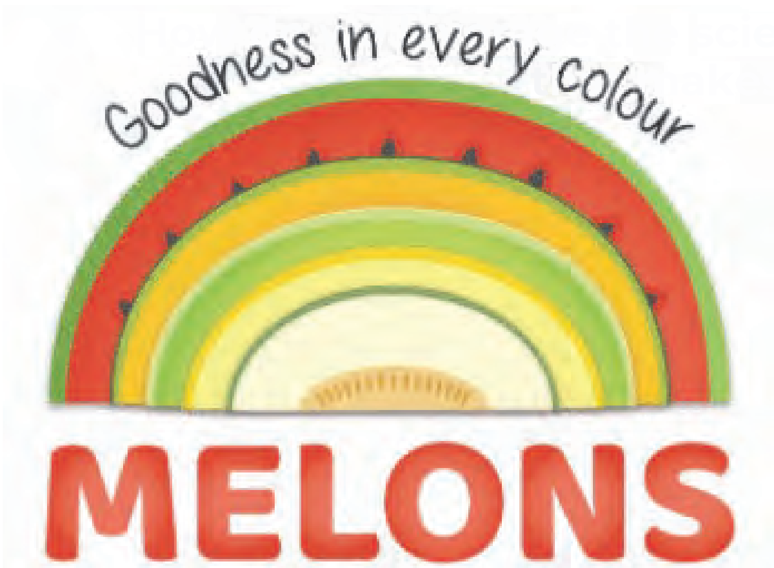
Initial pre-scope identified challenge that we cannot directly talk to health benefits of melons due to there being insufficient human evidence of health effects for SLR.

Health professional research:

- ✓ 65% HCPs don’t know the nutrients or bioactive composition in melons and struggle to identify beyond vitamin C.
- ✓ 80% HCPs believe colour associated fruit variety is important for health
- ✓ 75% HCPs believe Australian's fruit intake is lacking in fruit variety.
- ✓ 80% believing melons play a great role in improving fruit variety in the diet.

Melons to be hero for colour variety

Primary messaging



Just Add **melons for colour variety:** Science says that we should look beyond single foods and supplements, and instead to colourful families of fruits and vegetables like **melons** to get a variety of the colour pigmented bioactives they contain, many with unique health promoting benefits.

No single food has them all, but a colourful family of fruit, like **melons**, represents 5 different hues: red, orange, yellow, green, white - and 6 classes of bioactives - lycopene, beta-cryptoxanthin, carotenoids, chlorophyll, flavones, and citrulline.

Secondary messaging

Mix of essential nutrient and low GL: Vitamins A, C, folate, potassium, water

Sustainability: The whole melon is edible

Culinary: Preparation and usage education and inspiration

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Project
REVIEW

Science support to create collateral and educational messages

Manuscript

Umbrella review

Research linking colour pigments in F&V to health

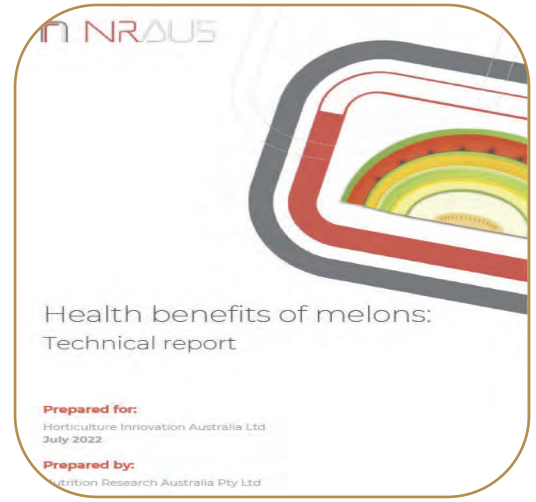
Role: provides strong indirect link melons health benefits to underpin unique melons positioning

Gaps Analysis

Desktop audit

Collaboration with ST19036

Role: Communicate nutritional composition of melons

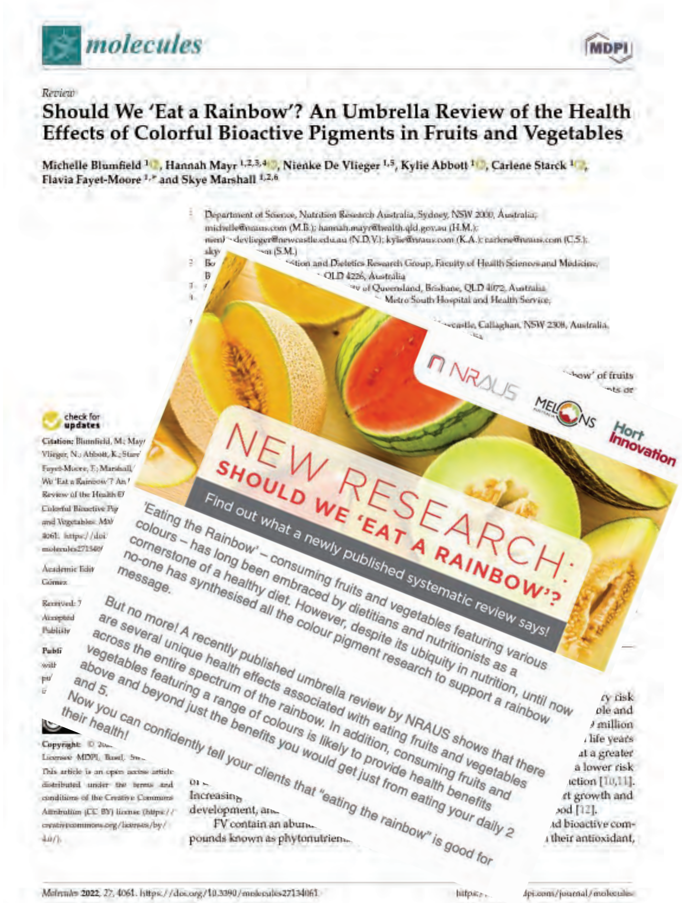


Nutrition & Health Technical Report

Supporting evidence

Role: Key messaging summary tying all science strands.

World first study on colour variety leveraged to showcase Australian Melons



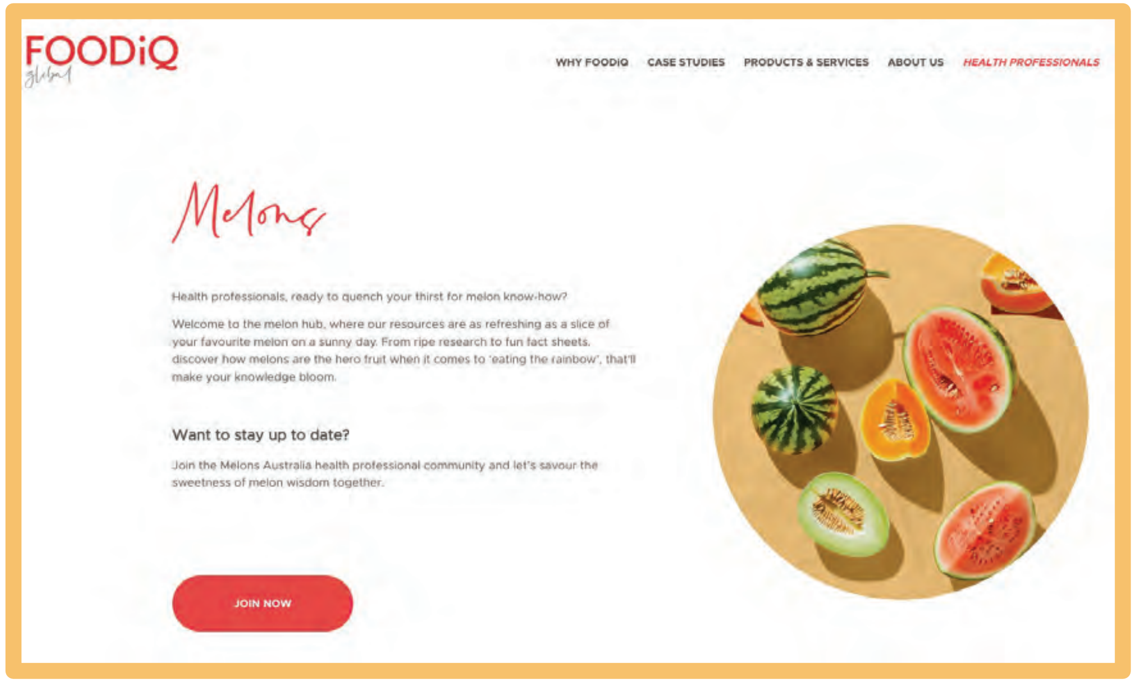
World First Scientific study published

HCP Factsheet

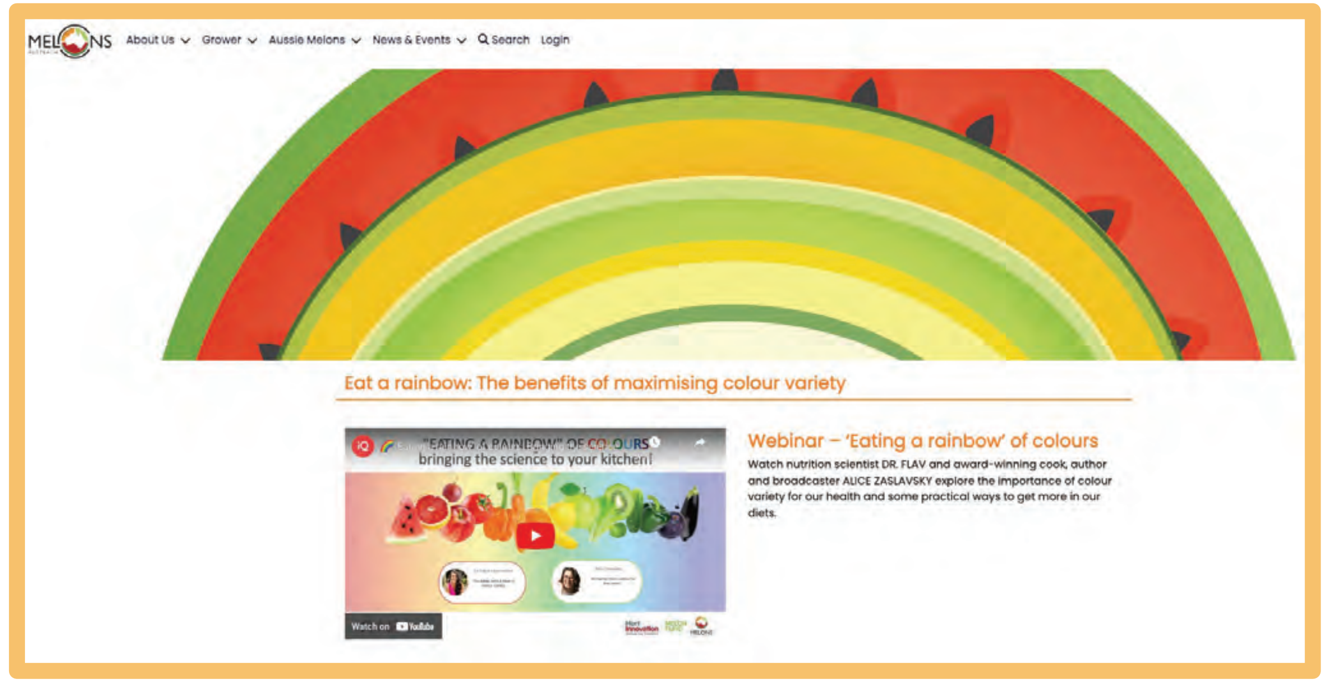
Video

Goodness in every colour
MELONS

Melons HP Hub resource repository



FOODiQ Melons Hub



Melons Australia Nutrition Hub

Professional education via webinars and podcasts to communicate key messages

WEBINAR: Eating a Rainbow with melons: Bringing the science to your kitchen

130. The Latest Research Behind "Eating the Rainbow" with Melons, featuring Accredited Practising Dietitian, Dr Flávia Fayet-Moore
Leanne Ward Nutrition

PODCAST: Dietitian Connection exclusive for members

Professional resources to support education of clients

Just add melons for health: Client factsheet

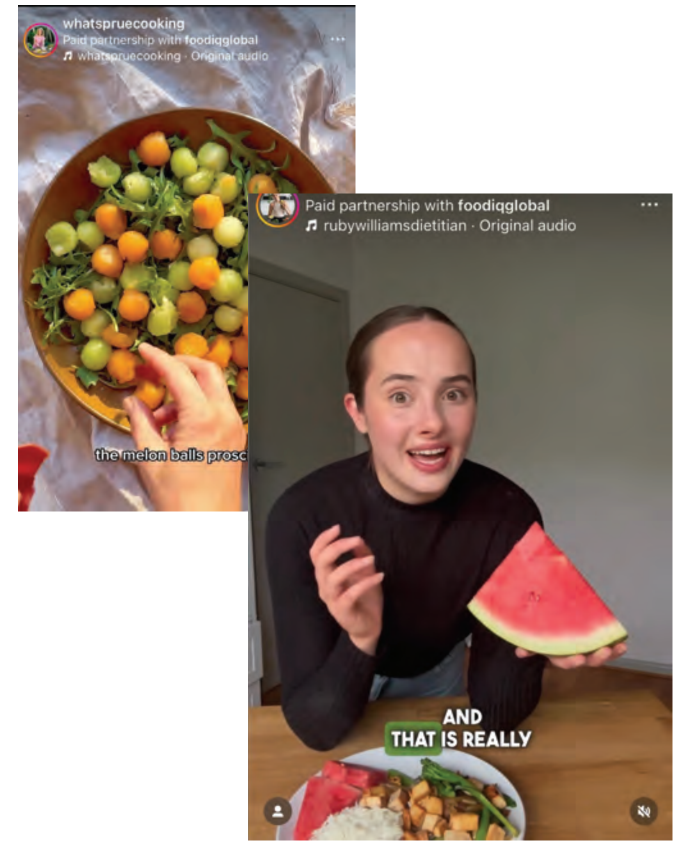
Why recommend Melons? animation

How to prepare, store and use Melons Animation

Digital activation

Social media

Channel comms



KOL Influencer

Key deliverables: and inter-connections

Educational events:
Webinars & Podcasts
Educate clinicians on benefits of melons

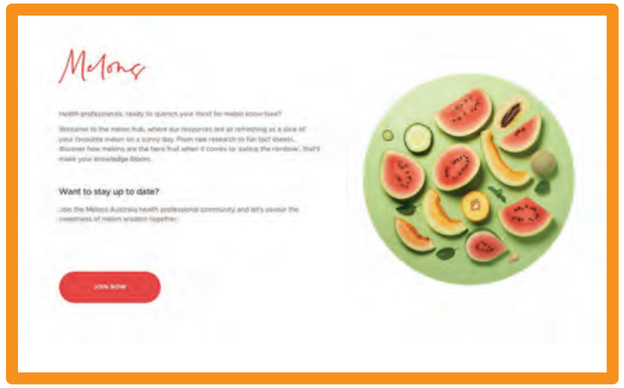
Brining the science to your kitchen webinar
April 2023

Drive attendees to hub & database

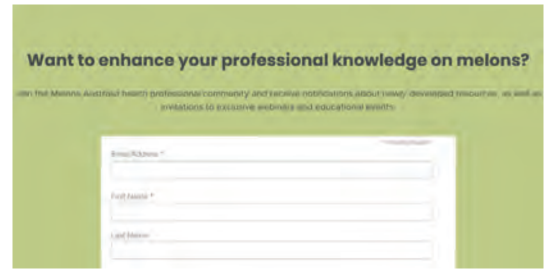
Podcast 2023

Podcast: 2023

Web-page:
Melons Digital Hub – Nutrition & Health Section as central information repository



Digital Outreach Campaign to drive awareness hub/resources/ events & database acquisition



Build Database of subscribers

Resources:
- 1 x **Research Paper**
- 1 x **HCP Factsheets:** Melons & Colour variety
- 1 x **Consumer Factsheet:** Just Add Melons
- **1 x Video** Goodness in every colour
- **2 x animations** Why recommend melons? Culinary nutrition tips.
- **Webinar recordings:** Eating a rainbow – Bringing the science to the kitchen
- **2 x Podcasts** Leanne Ward Nutrition; Dietitian Connection

EDMs to owned Melons HCP database

Educate, disseminate resources, drive to citrus hub

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IMPACT

HCP Database

Educational Activities – Summary

	Audience	Event 'Excellent or Very good' Overall	Event 'Extremely or Very' Engaging	Event 'Extremely or Very' Informative	Event 'Extremely or Very' Useful	Intend to recommend MELONS for colour variety
FOODiQ Webinar*	279 register (KPI:200); 88 live; 420 views	100%	100%	100%	97%	100%
	Downloads	**Benchmark**				
PODCAST – Leanne Ward	>13, 770	Top 3% of podcasts				
PODCAST – Dietitian Connection	2995	2250				

* Target = >80%

Channel & social media results

	Audience	Open rate %	Reach	Total clicks	CTR %	
Dietitian Connection	12, 149	45%	5414	183	1.5%	
Australian Natural Therapists	7000	28.1%	1960	154	2.2%	
		Impressions	**Reach**	**Total clicks**	**Av CTR%**	**Sign up database**
Social media (HP)		128,000	49, 940 (KPI:20,000)	4328	3.37%	38
		>50% view				
Animation		11, 545 (KPI: 15,000)				
KOL influencers	5000 views					

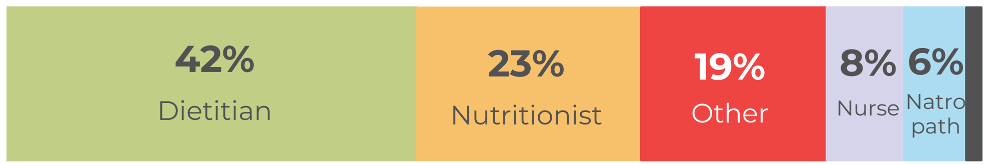
EDMs

	Topic	Date sent	Open rate
EDM 1 *	Recruitment to ASR	2022	52.1%*
EDM 2*	Umbrella Review published	August 2022	47.8%*
EDM 3	Umbrella Review published	24th August 2022	28.6%
EDM 4	Webinar invite	28th October 2022	29.8%
	Factsheets	12th April 2023	52%
EDM 5	Podcasts	10th July 2023	40%
EDM 6	Video on UR	15th Dec 2023	38.2%
EDM 7	Animations	8th March 2024	*43%*
EDM 8	End of Campaign - Hub	19th April 2024	41.2%
EDM 9	ASR Recruit	19th June 2024	40.7%

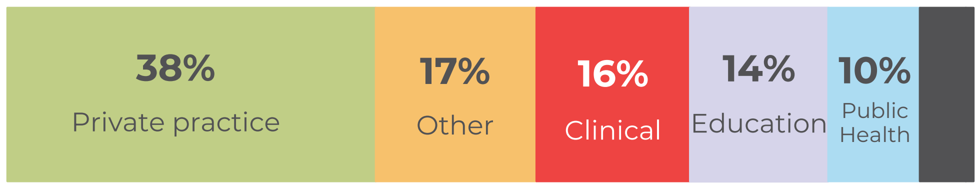
*EDM 1 sent to FOODiQ database for recruitment. Open Rate Target >25%

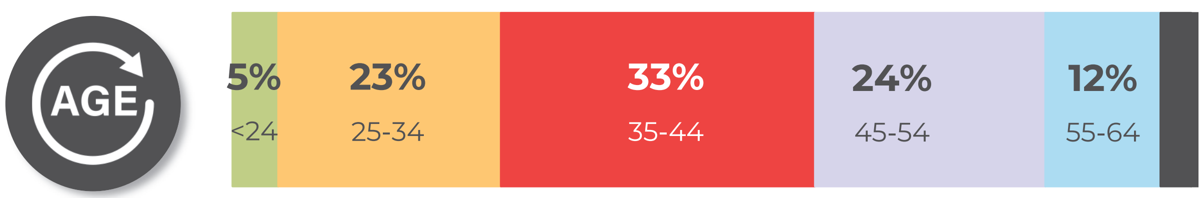
Survey statistics

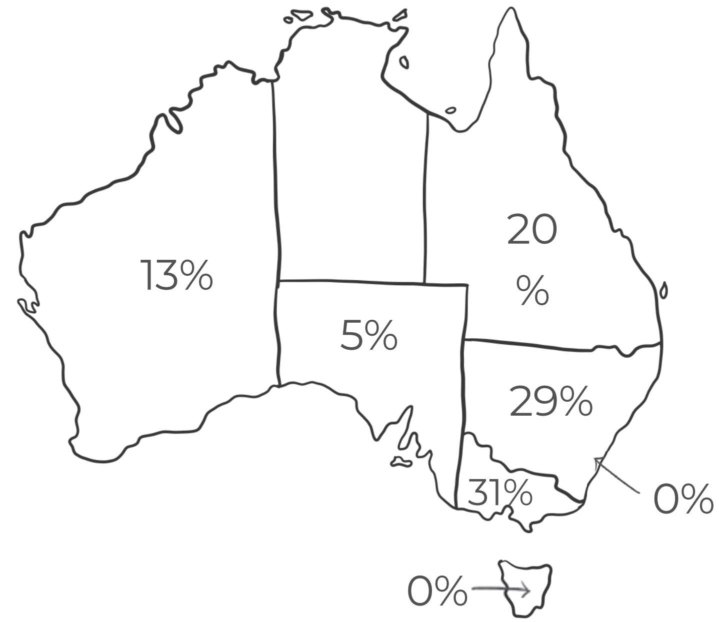
175 surveys completed → 127 eligible

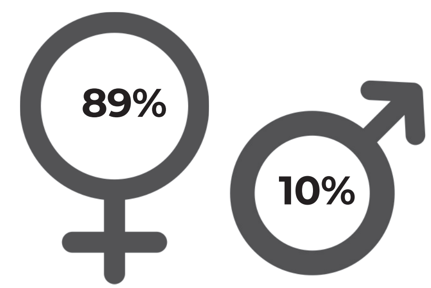


81% HPs; 19% students









Resource Access & usefulness

27% of participants had accessed the Melons Hub resources. **Target: 50%**

100% of participants that accessed the FOODiQ MELONS Hub resources found them useful. **Target: 80%**

Ā44% very useful and I would like more
Ā29% very useful
Ā24% useful
Ā3% somewhat useful

of those who accessed resources would like more.

What do health professionals think of resources?

It provided a great summary of the research on melons for both health professionals and the general public, and it was presented in an aesthetically pleasing way.

A brief but clear information to discover the properties and understand melons in nutrition

they provide detailed nutritional information, highlight health benefits, support dietary variety, offer practical tips for selection and preparation, and enhance client education on the benefits

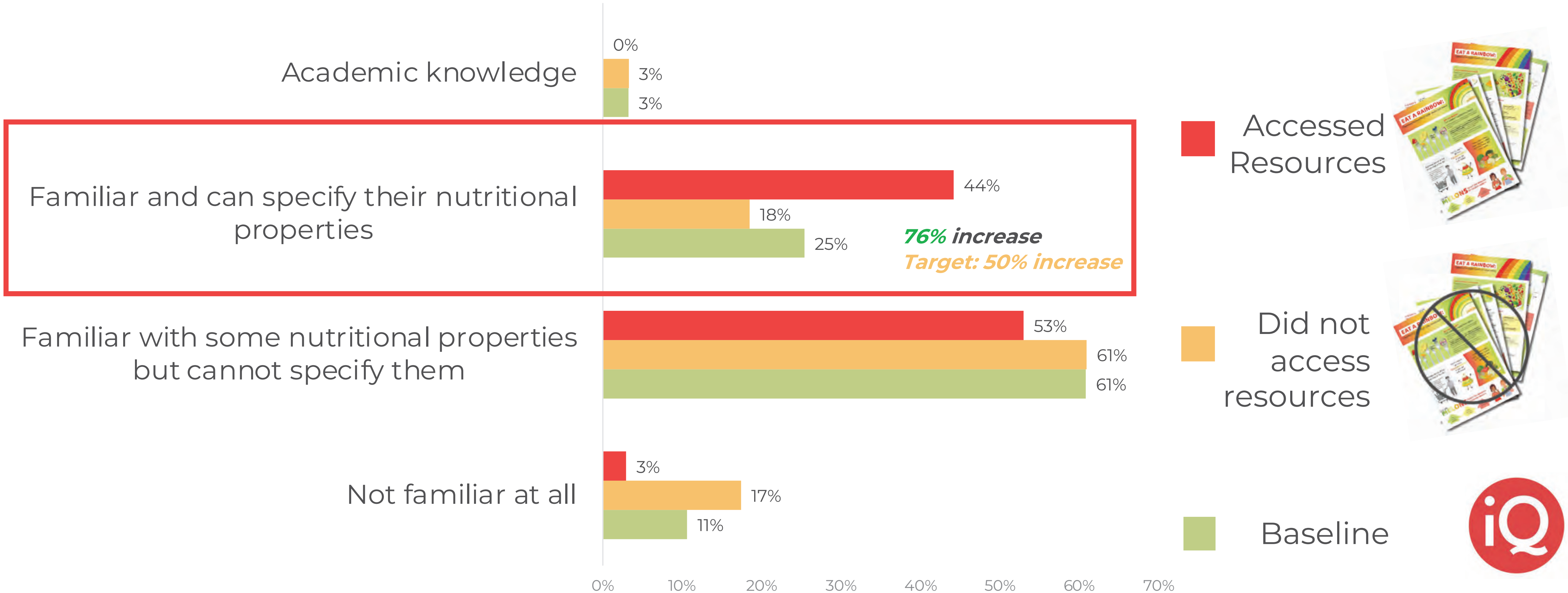
Simple, clear, visual, colourful, informative

They are practitioner-friendly and provide just the right level of info to allow us to convey the key points to the general public.

Evidence based info I can trust

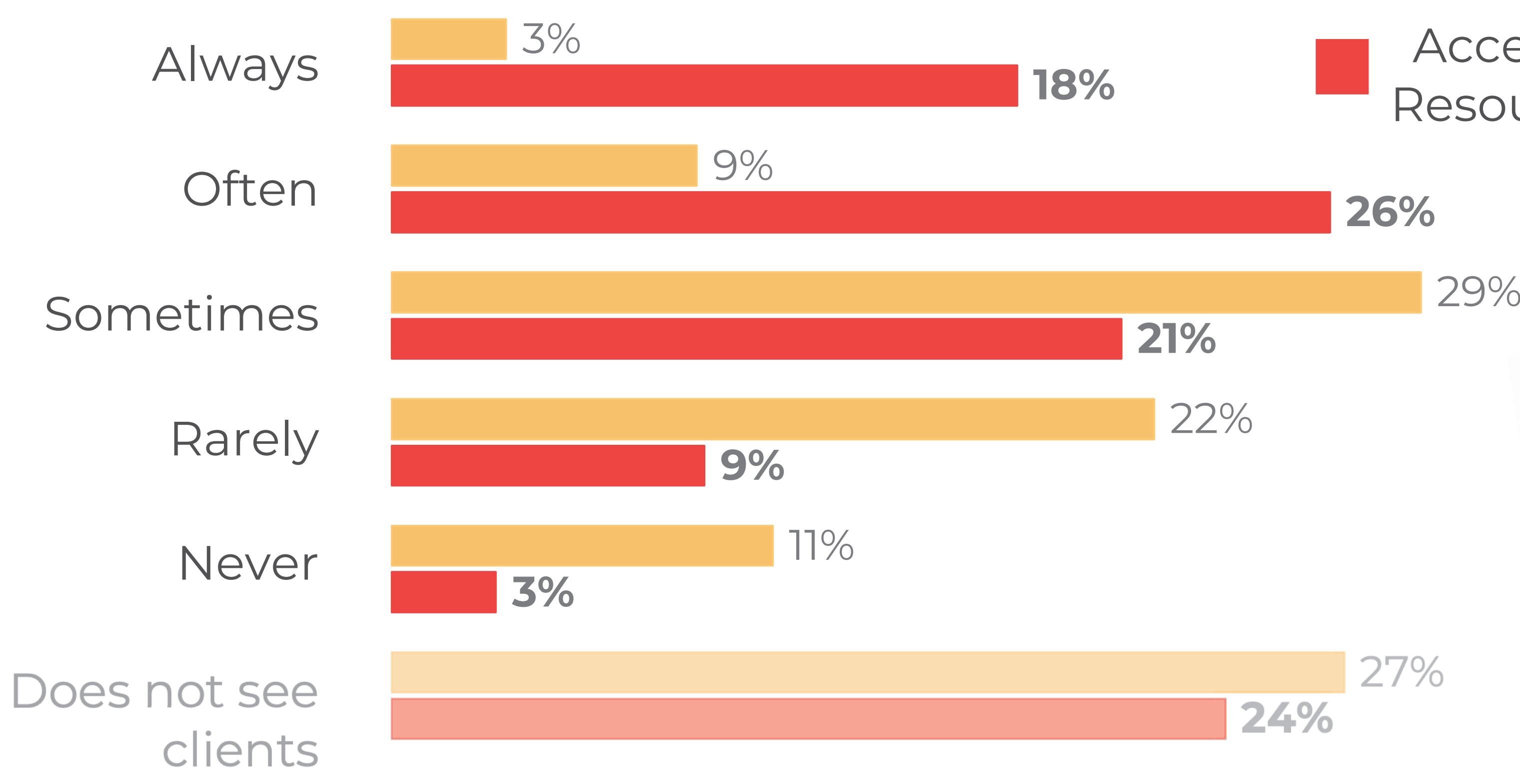
The broader message around eating the rainbow is very useful for connecting with people

Those who accessed resources increased their self-reported familiarity with the nutritional and bioactive properties of melons.



Recommendations to clients increased

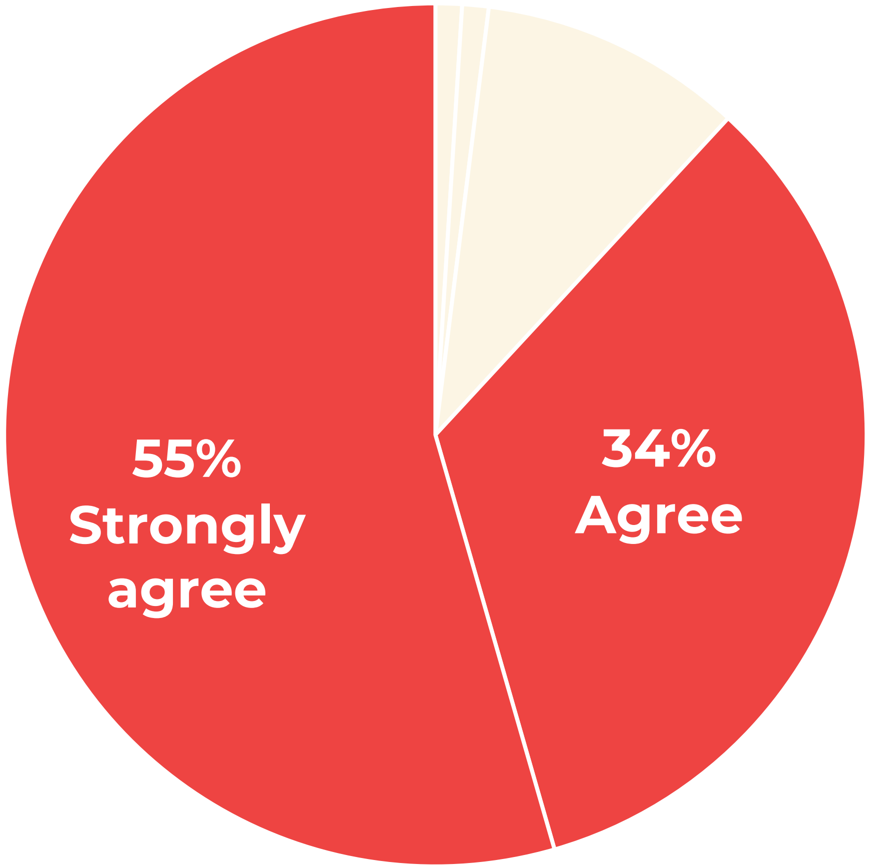
Which statement **best describes** how often you **specifically recommend melons** to your clients or patients?

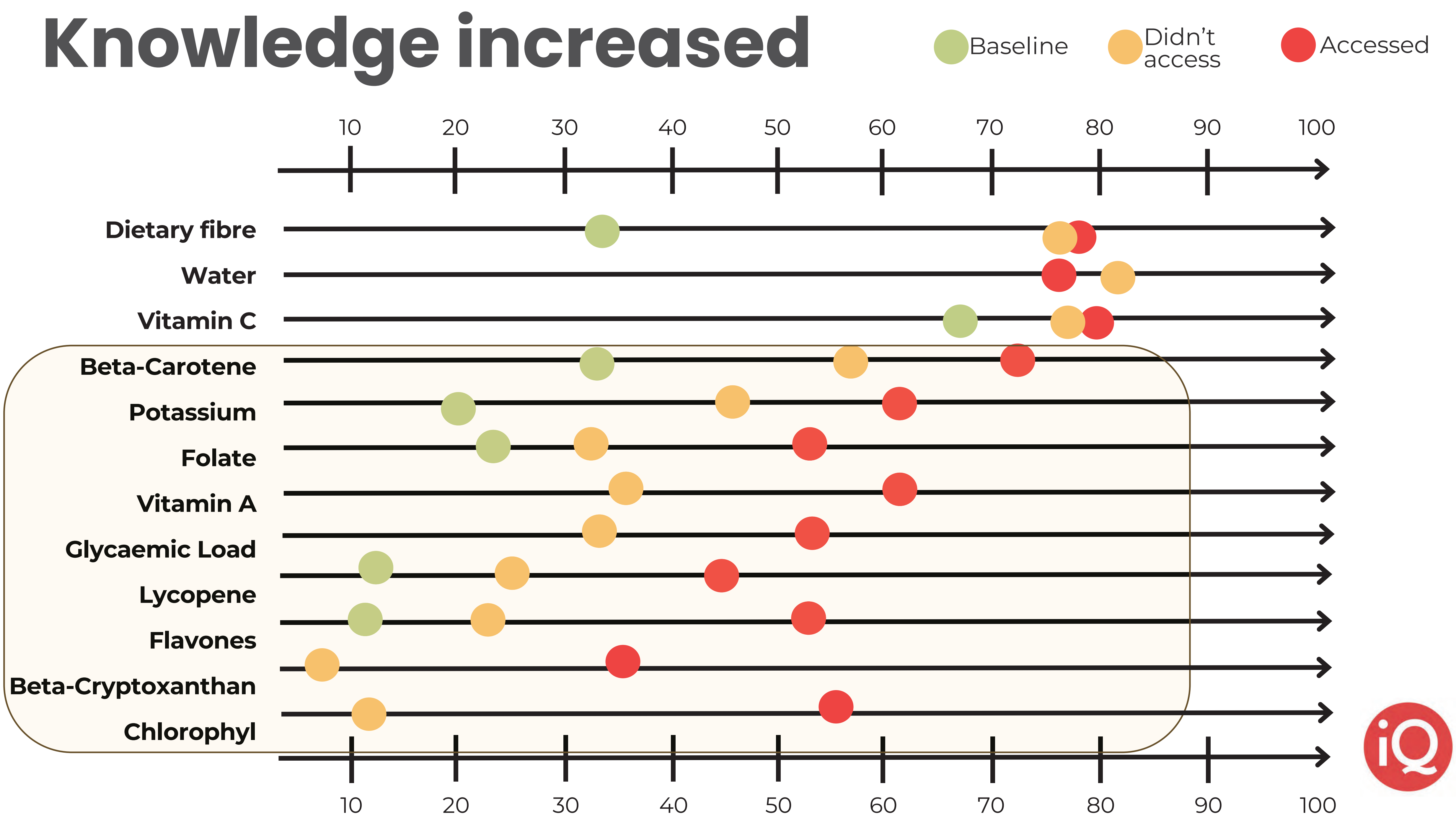


Of those who saw clients, 84% of those that accessed resources reported recommending melons to clients, compared to 55% of those who did not access resources

89% ‘strongly agree’ or ‘agree’ that melons can play a key role in improving colour variety in the diet’

Target: 80%

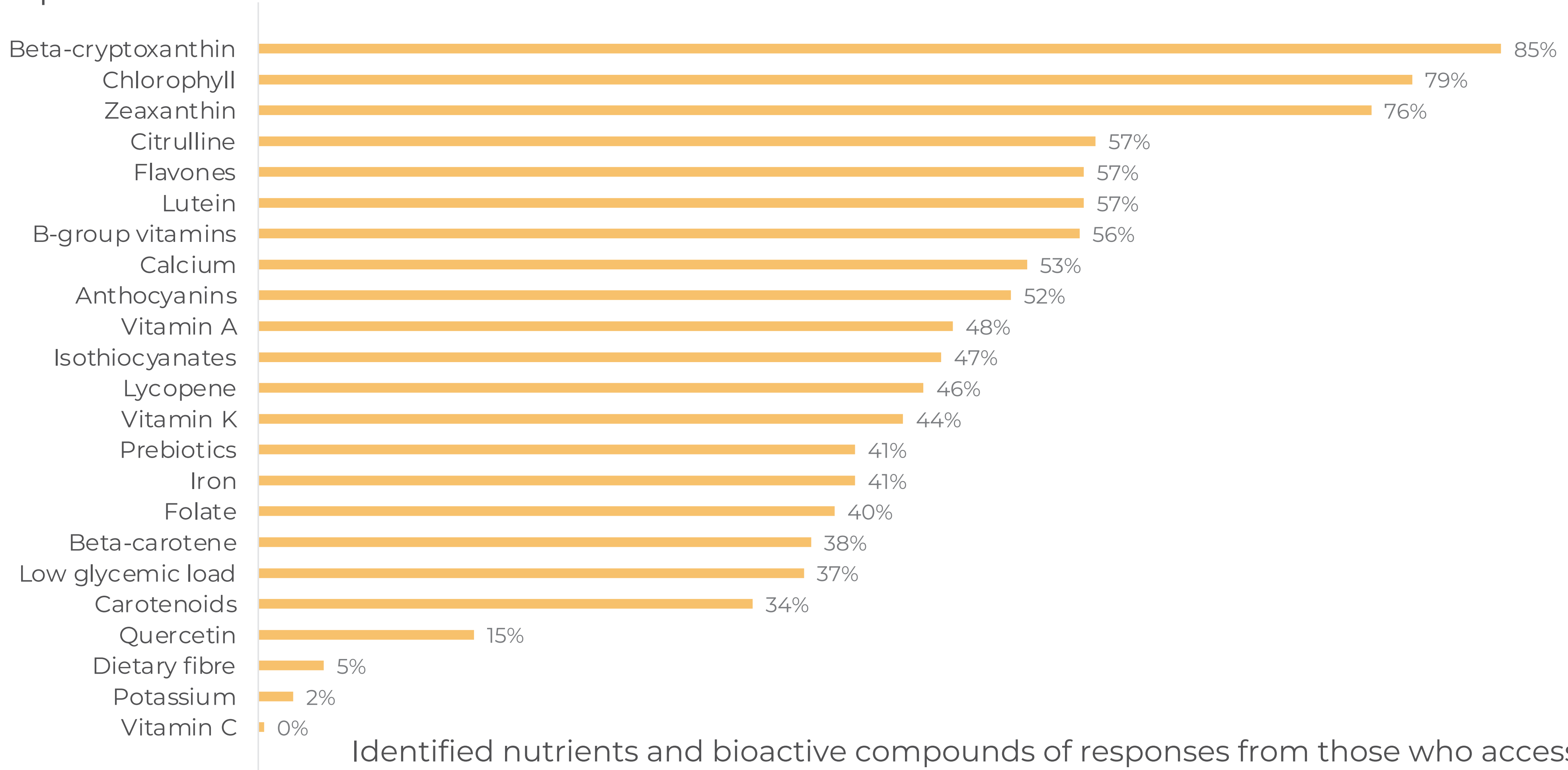




Knowledge increased
Baseline
Didn't access
Accessed
10
20
30
40
50
60
70
80
90
100
Dietary fibre
Water
Vitamin C
Beta-Carotene
Potassium
Folate
Vitamin A
Glycaemic Load
Lycopene
Flavones
Beta-Cryptoxanthan
Chlorophyl
10
20
30
40
50
60
70
80
90
100
iQ

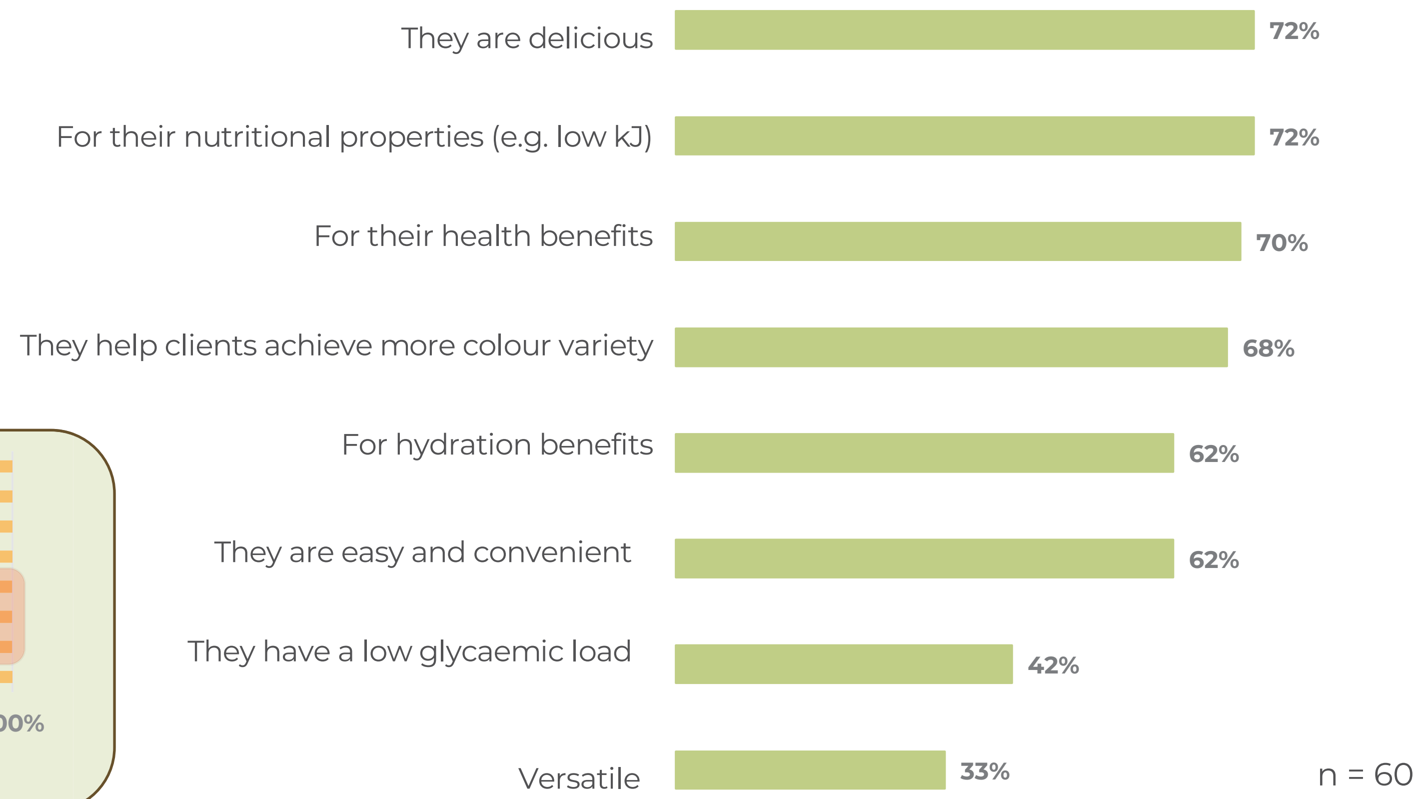
Bioactive knowledge was significantly higher in those who accessed resources*

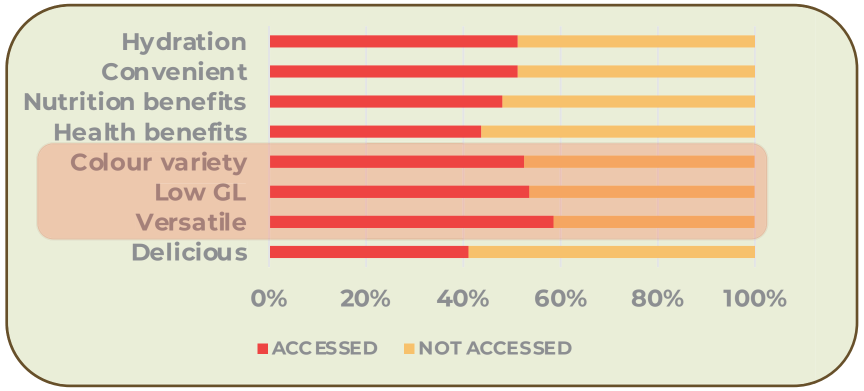
*Compared with those who did not access resources



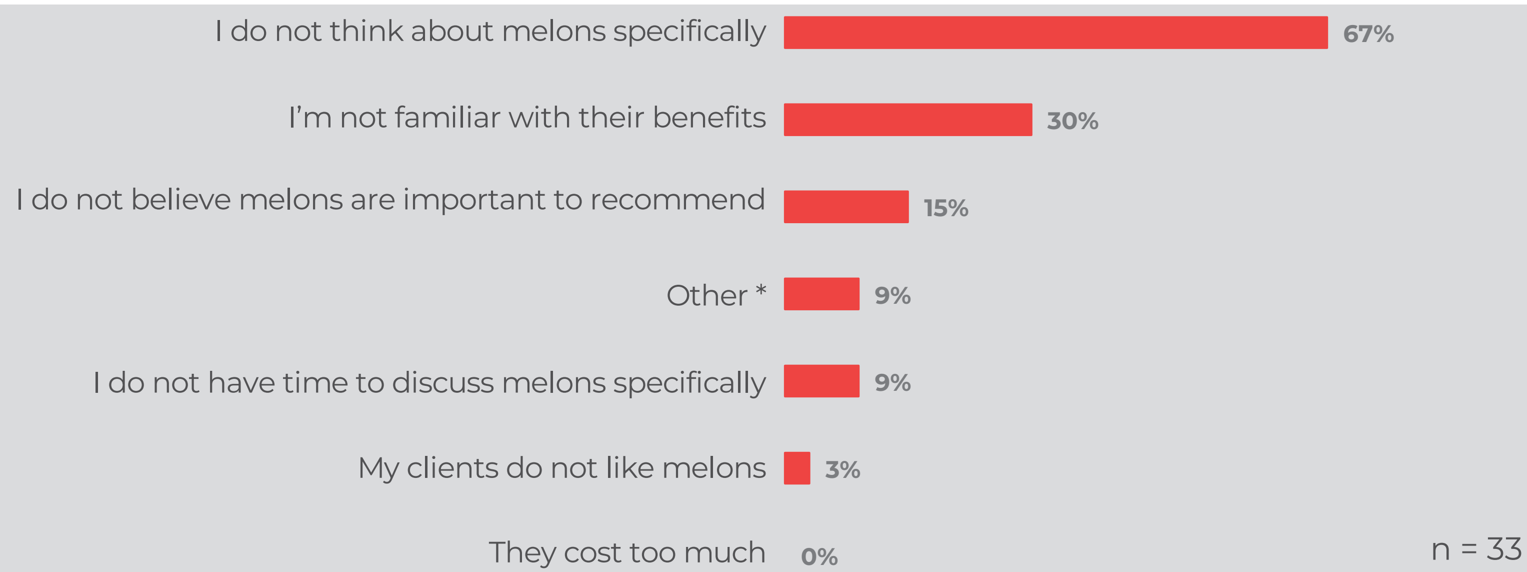
Identified nutrients and bioactive compounds of responses from those who accessed resources as a percent increase of those who did not access resources (%)

DRIVERS FOR RECOMMENDING MELONS





BARRIERS FOR RECOMMENDING MELONS



What else would HP like to see?

Recipe & culinary usage inspiration

Seasonality and impacts on nutrition

Health benefits any science including acceptability in diabetes

> I'd love to see some more novel recipes included.

> About the seasons and the best way to use them and maintain or enhance their nutritional values

> I'll be interested to hear what you have to say other benefits
> Would like information on melons and diabetes.

> Would love to learn more about the bioactives of melons

Key
LEARNINGS

What are project strengths?

Strategy/Messaging

- ✓ Single minded messaging hit mark – HCP knowledge on key messages improved the most.
- ✓ Access to resources & education leads to recommendation

Science/Research

- ✓ View 16803 times
- ✓ 21 citations
- ✓ Alt metric score 261 (top 5% of research article scores)
- ✓ Shared by 294 social media users
- ✓ Shared by 10 news outlets

Education/Comms

- ✓ Outputs all met or exceeded KPIs.
- ✓ Overall positive open feedback on educational events; relevant, informative, practical

What are project weaknesses/limitations?

Strategy/Messaging

- ✓ Only 30% surveyed had accessed hub.

Science/Research

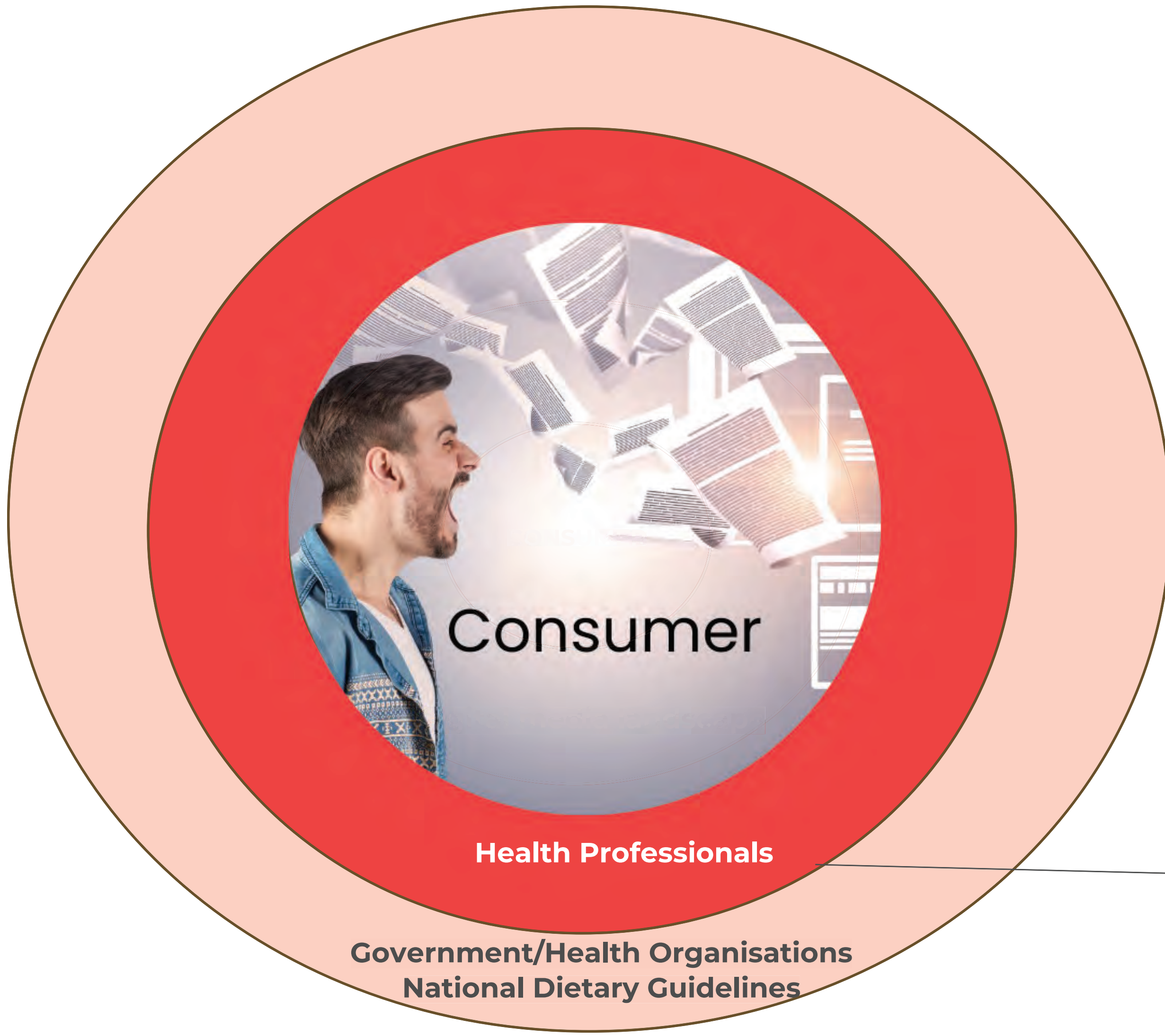
- ✓ Very limited science of links of melons and health benefits.

Education/Comms

- ✓ Database has growth potential.
- ✓ Driving greater reach and consistency of messaging to establish significant cut through to get active melons consideration and recommendation.

PROJECT
Recommendations

HP are a credible and trusted beacon to navigate the consumer ecosystem



What are the opportunities?

Short term

Maintain conversation with HP & grow database to support long term SIP

- ✓ Create & implement an ongoing integrated website-digital HP engagement strategy - develop quarterly science summaries & e-news
- ✓ 'Bring science to kitchen™' - melons roadshow in key locations.
- ✓ Recipe book development & leverage in digital comms

Big Picture

Research iQ – strategic plan to identify research investment opportunities to provide future evidence-based communications

Ā Practical uses
Ā Contribution to nutrients, bioactives & diet quality
Ā Melons & Health Knowledge

✓An iQ process could identify, highlight, prioritise

Target audience

Widen target audience focus

✓Extend HP communications through to consumer comms to establish Melons unique voice and keep top of mind

Research opportunities

Practical Usage of melons

Ā Occasions and style of consumption to inform future education and marketing around the diverse culinary uses of melons

Ā Facilitators and barriers to use of these parts of the melons, contribution to nutrition/bioactives if used. Could take a culinary nutrition perspective

Melons contribution to nutrients, bioactives & diet quality

Ā Contribution of melons to key bioactive intake

Ā Australian melon consumption and impact on nutrient intake and health biomarkers where relevant - do people who eat melons eat better, what nutrients is it key in providing?

Ā Analysis of melons bioactive content compared to other foods and impact of seasonality

Melons & Health knowledge

Ā Publish a scoping review on the research on the relationships between melons and health

Ā Melon interventions in different demographic groups extend on or complement previous findings in the Eat the Rainbow Umbrella review and other research .

DISCUSSION

Minutes

- Ā Feedback from PRG team was complimentary for the project and work done to date.
- Ā Recommendations were well received with research and captilising on communications echoed as key.
- Ā Emma Stirling echoed the importance and value of research and particularly culinary nutrition and consumer behaviour research. She advised how very little of this data exists but how valuable it is to enable clinicians to more effective practitioners. As behaviour change influencers she outlined how clinicians need to understand where people are currently at to be able to formalise better solutions to assist them. She outlined an opportunity around kids snacking a better understanding consumer consumption in terms of where melons are consumed. Opportunity around kids snacking and preschools, childcare and school lunchbox.

THANK **YOU!**

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FOODiQ global

VM20003
Educating Health Care Professionals on Australian Melons

Project Reference Group Meeting 2

23rd February 2022

Agenda

1. Project Recap
2. HCP Sentiment Survey
3. Science Update
4. Communication translation strategy
5. Feedback

The project

Objectives:

1. Establish Australian melons as a fruit which can provide a range of colour-associated nutrients and bioactives required to achieve optimal health and wellbeing.

2. Increase HCP's awareness and knowledge of the nutrition and health benefits of melons and empower them to recommend them to clients.

HCP survey findings

Ā 65% HCPs don't know the nutrients or bioactive composition in melons and struggle to identify beyond vitamin C.

Ā Similarly, health benefits are not well understood, with improved digestion the most identified.

Opportunity: To increase melon consumption through HCPs recommending melons to clients.

How: Increasing HCPs awareness, knowledge and understanding of the nutritional composition and health benefits of melons.

What's the opportunity for melons?

Melons: One of the only fruits providing a variety of colour-associated nutrients and bioactives, linked with optimal health.

- ✓ 80% HCPs believe colour associated fruit variety is important for health
- ✓ 75% HCPs believe Australian's fruit intake is lacking in fruit variety.
- ✓ 80% believing melons play a great role in improving fruit variety in the diet.

Where are we now?

Manuscript

Umbrella review

Research linking colour pigments in F&V to health

Opportunity for strong indirect link to melons

Gaps Analysis

Desktop audit

Nutritional composition of melons

Collaboration with ST19036

NUTRITIONiQ

Supporting evidence

Melon research identified in NRAUS NiQ database

The science will be combined to hero melons

NUTRIENT COMPOSITION

Ā Watermelon contains up to 75% more LYCOPENE than raw tomatoes.[4]

Ā Ripe watermelon a source of BETA-CAROTENE.[4]

Ā White flesh near rind a rich source of the amino acid citrulline.[5]

Ā Watermelon seeds are high in protein, fibre and minerals.[6]

NUTRITIONiQ

Ā In humans, drinking watermelon juice increases plasma LYCOPENE and BETA-CAROTENE.[1]

Ā In nursing students, drinking watermelon juice lowered systolic blood pressure by 2.9mmHg.[2]

Ā In rats, lycopene-based watermelon juice reduced dyslipidemia.[3]

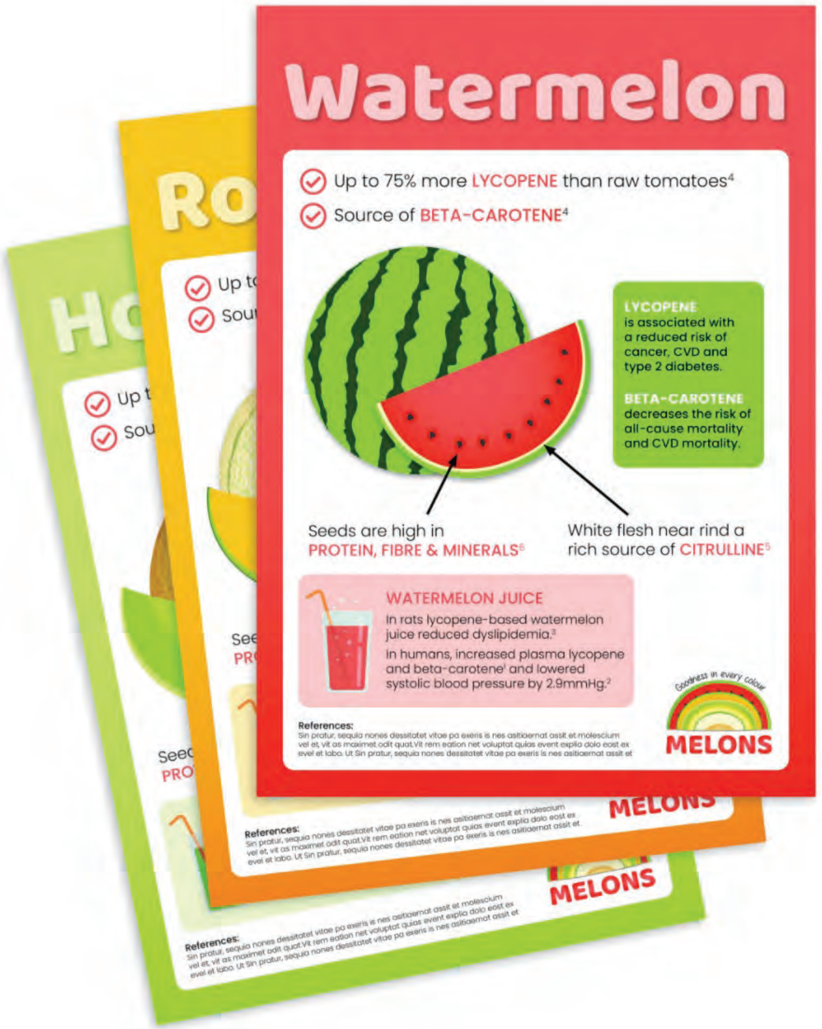
REVIEW FINDINGS

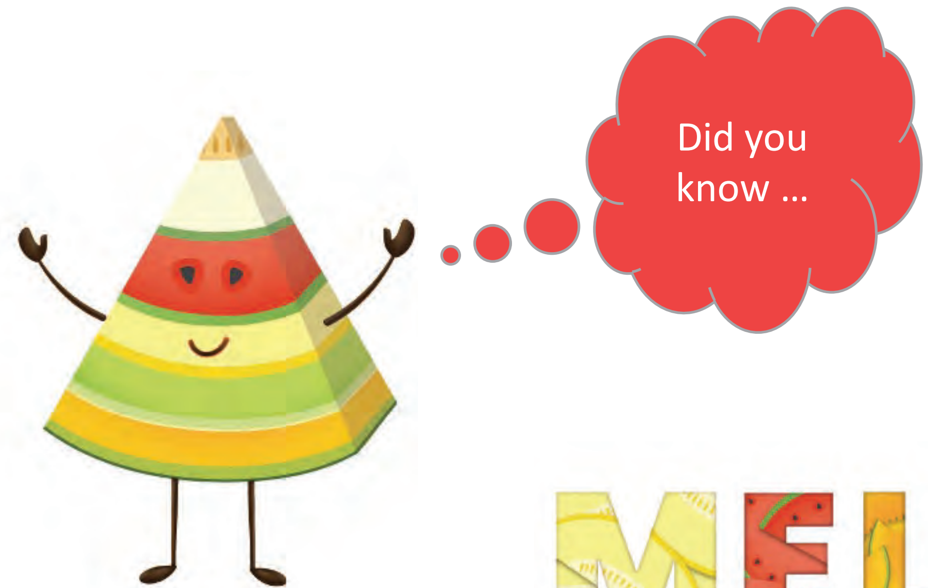
Ā LYCOPENE is associated with a reduced risk of cancer, CVD and type 2 diabetes.

Ā BETA-CAROTENE decreases the risk of all-cause mortality and CVD mortality.


Goodness in every colour
MELONS

Examples of how the logo could be used





Goodness in every colour
MELONS

PRG feedback

- Graphically representation is on-point. Love the focus on the product, plain and simple.
- Has ability to link with industry social media etc...
- Suggestion for term ‘melons’ to be singular not plural. Discussion of the pros and cons of both singular and plural terms. Discussion came back to messaging around increasing fruit variety, how different coloured melons can provide that variety and we want HCPs to think of melons as a group of fruits that can provide that variety. Consensus was to keep the term plural – ‘melons’.
- Questioned the term ‘goodness’. Was it too vague and not scientifically specific enough for HCPs? Workshopped alternative options (e.g., wellness, nourishment, nutrients) but came back to ‘goodness’ as it can represent all types of benefits/good things ranging from nutrient, health, culinary etc… and the slogan ‘goodness in every colour’ can easily be remembered by HCPs and directly communicated to their clients. Logo will be used as an anchor point, accompanied by credible, evidenced based information.
- Like that the term ‘rainbow’ wasn’t used.
- HCP tab to be made on Melons Australia website when resources are ready. Not password protected.
- Would like to see this logo on a schools program or teachers education kit (could be another project). NRAUS could investigate a HCP education kit to encourage consumption in children, could be delivered by HCPs in schools, client consults etc...

NRAUS

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Thank you

APPENDIX 13:

VM20003 Project update

Prepared for:

Melons Australia

May 2022

Prepared by:

Nutrition Research Australia Pty Lt

Project summary

The NRAUS project team have been busy over recent months with the science team, led by Dr Michelle Blumfield, recently completing the world's first research to validate that 'eating a rainbow' of fruits, such as Australian melons, is associated with improved human health. It has just been submitted to a high impact scientific journal for publication. This umbrella review includes more than 450 individual studies showing that colour pigments found in fruit derived from their naturally containing bioactive compounds are associated with decreased risk of cancer, cardiovascular disease, and improved bone and eye health. The science provides important credible evidence that will be leveraged in upcoming future HCP communication and educational activations.

Melons are one of the only fruits providing a variety of these colour-associated bioactives and research undertaken by NRAUS with 339 healthcare professionals (HCPs) towards the end of 2021, supports there is great opportunity to leverage this with HCPs. The research identified that not only do most HCPs agree that colour-associated fruit variety is important for health and Australian's fruit intake lacks variety, but the majority (79%) believe melons have a key role in improving colour associated fruit variety in the diet, specifically for their value in improving dietary quality and increasing vitamin and mineral intake. It was identified however, less than half were assessing fruit variety intake or recommending it to their clients regularly and this was particularly evident with dietitians.

While 2 in 3 agreed melons contain nutritional properties, 1 in 4 didn't know what these were. Overall, HCPs struggle to identify key nutritional components beyond vitamin C, with little knowledge of their bioactive composition. Similarly, the health benefits for melons were not well understood. The research also identified HCPs lack specific knowledge about the food-borne illness risks associated with melons, with over half uncertain and nearly 1 in 10 unaware. The food-borne illness risks of melons affect 1 in 4 HCPs willingness to recommend melons to certain population groups regularly. Excitingly, HCPs wanted to know more about what's in melons, their health benefits and safety considerations.

Dr Flavia Fayet-Moore said, 'The research supports that knowledge around nutrition and health benefits are not top of mind, hence HCPs are not translating it into dietary recommendations even though they see melons has a great role to play in increasing colour associated fruit variety, they consider important for health. If we can increase their confidence and knowledge, we can likely shift them to more frequently assess and recommend increased coloured fruit variety and use melons as the example.'

The team has also been working on the translation of the science message for melons for HCPs, which they believe is about communicating each individual melon's unique colour-associated bioactive compounds and nutrients, but importantly communicating the unique position of melons as a group being the only fruit that provides a *variety* of colour-associated bioactives, deemed important for health.

‘Here we believe using an over-arching device that can be used across different collateral will bring together the individual melon stories while also further strengthening the communication through the powerful and unique ‘variety’ position for the MELON family as a fruit.’ Said Dr Fayet-Moore.

The final device, with tagline ‘Goodness in every colour’ recently got approval from the project reference group. ‘We believe the device and tagline cleverly plays on the unique arch of melons and it’s link to common health advice to eat a ‘rainbow’ of colourful fruit and vegetables, making it engaging and memorable’, said Dr Fayet-Moore.

VM20003 Project update

Prepared for:

Melons Australia

November 2022

Prepared by:

Nutrition Research Australia Pty Ltd

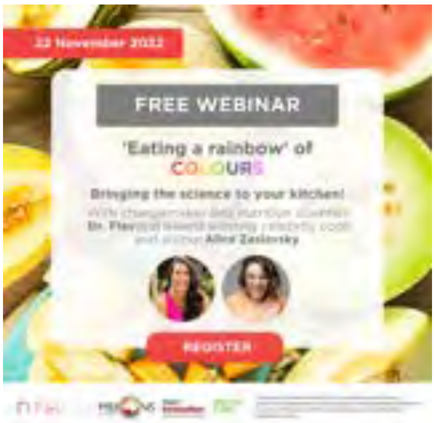
Project summary

VM20003: Educating healthcare professionals on Australian melons, is kicking into the exciting communication and education phase of the project.

In June 2022, our NRAUS project science team, headed by Dr Michelle Blumfield had their world first research, ‘Should We 'Eat a Rainbow'? An Umbrella Review of the Health Effects of Colorful Bioactive Pigments in Fruits and Vegetables’, successfully published in a well-regarded scientific journal, *Molecules*(1). The research paper has had a huge impact in the scientific world with 6.3 million views of the article to date. Our research provides the scientific evidence that supports the wisdom that ‘eating a rainbow’, a range of different coloured fruit and vegetables, is indeed important for health.

Plant foods such as fruit and vegetables contain colour pigments, which are called ‘bioactives’. The research showed that colour-associated bioactive components in fruits and vegetables were important for improving health, and benefits were unique to each colour. It showed that eating a variety of different coloured fruit and vegetables provides benefit to our health over and above intake alone. What this means is that fruits and vegetables contribute to health in two ways – first, they provide nutrients, and second, they provide bioactive pigments. This is important with over 70% people lacking colour variety in their diet (1). Melons are one of the only fruits providing a range of colour-associated bioactives and can therefore help to boost fruit intake and colour variety.

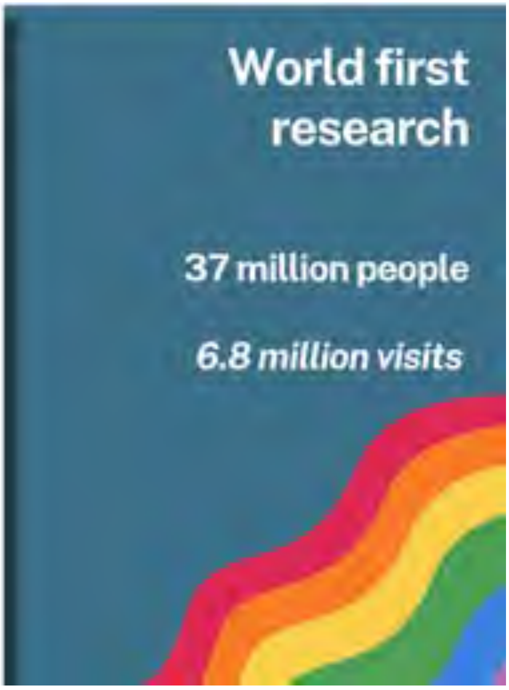
Collateral development is now underway to bring the science to life, including brochures and factsheets, plus development of consumer and healthcare professional nutrition and health information to be communicated on Melons Australia website. A fabulous webinar is planned to take place in November. NRAUS CEO and global nutrition and health changemaker Dr. Flav, will be teaming up with award winning celebrity cook and author Alice Zaslavsky in this webinar, bringing the science of ‘Eating a rainbow’ to healthcare professional’s kitchens! Dr. Flav will be presenting the world first research NRAUS published as part of the project, supporting importance of fruit and vegetable colour variety in the diet. She will also showcase how *melons* are one fruit that provides *goodness in every colour* and can help people boost health-promoting colour variety in their diet. Alice, well known to be one of the energising and colourful voices in food, will be presenting live from her kitchen in Melbourne. She will be inspiring attendees to light up the world with more colour and showcasing delicious melons recipes, including novel uses for melon rind!



molecules MDPI

Review

Should We 'Eat a Rainbow'? An Umbrella Review of the Health Effects of Colorful Bioactive Pigments in Fruits and Vegetables



References:

1. Blumfield, M. et al., Molecules 27 (2022).

VM20003 Project update

Prepared for:

Melons Australia

May 2023

Prepared by:

Nutrition Research Australia Pty Ltd

Project summary

Over the past 6 months the Nutrition Research Australia (NRAUS) project team have been busy communicating the key messages about the goodness in melons to healthcare professionals (HCPs), as part of strategic investment funded project *VM20003: Educating healthcare professionals on Australian melons*.

As part of this, a HCP brochure was developed to educate on the latest research[1] showing importance of colour variety in the diet for health, and how including melons can help. To further support HCPs, a client friendly brochure with easy-to-understand information was also developed to showcase how melons can help add more colour variety and nutrition to the diet with practical advice and tips. The information was also used by Melons Australia to update the nutrition and health educational information for healthcare professionals on their website.

At the end of November 2022, NRAUS CEO and global nutrition and health changemaker Dr. Flav, teamed up with award winning celebrity cook and author Alice Zaslavsky in an engaging and highly successful HCP webinar, 'Eating a rainbow' of colours: Bringing the science to your kitchen! (link here). This was a key educational event for the project that was recorded and now exists as an ongoing resource for HCPs on the melons resource hub. The project's recent funded published paper, 'Should we eat a rainbow' was a timely research topic that was newsworthy and had high appeal to HCPs. It served as a great drawcard to entice HCPs to attend the webinar and provided a great opportunity for melons to be a hero fruit to communicate the key take-home messages.

The webinar aimed to raise awareness of the new research supporting that eating a variety of colourful fruit and vegetables offers benefits to health beyond total intake, that colour variety from fruit and vegetables in the diet is lacking and that melons are a fabulous fruit 'family' that can help people to increase colour variety in their diet. 100% of attendees surveyed post event rated the event as excellent or very good, informative, agreed they had learnt something new and intended to recommend melons to clients.

One attendee said, "Very engaging and uplifting presentation. The simplicity of the concept is very enticing and I loved the recipes and learning about melons! I'm going to start growing some! Thank you for such an inspiring, fun and thoughtful webinar." Attendees loved how the science was brought to life with practical inspiration from Alice. "I really liked the movement from serving sizes and nutrients to focusing on eating a rainbow to increase fruit and veg intake. It was also interesting to hear more focus on bioactives and using the whole fruit in cooking e.g. watermelon rind in stir fries. I think this is a great initiative I hope to implement in my health promotion and nutrition roles." Here is link to one of Alice's favourite melon recipes from her latest cookbook *The Joy of Better Cooking* and a webinar favourite, the watermelon rind recipe . The team are currently now working on a some podcasts, videos and animation activations to share with you in the next update. All resources for the project can be found here.

HCP brochure: Educational brochure on importance of colour variety, bioactives, dietary 'colour gap' and how melons can help.

Consumer friendly brochure: Printable handout with easy to understand information and practical tips on how melons can help add more colour variety to the diet.

References:
1. Blumfield, M. et al., Molecules 27 (2022).

VM20003 Project update

Prepared for:

Melons Australia
November 2023

Prepared by:

FOODiQ Global

Project summary

The FOODiQ Global (formerly Nutrition Research Australia) project team continue to be busy communicating the key messages about the goodness in melons to healthcare professionals (HCPs), as part of strategic investment funded project *VM20003: Educating healthcare professionals on Australian melons*.

To further extend the current resource brochures previously developed and continue to educate on the latest science and the value of adding colour to the diet using Australian melons, an engaging 2 minute video has been created along with two podcasts. Video and podcasts are dynamic mediums that offer unique ways to engage and communicate compared to traditional brochures and factsheets. Both ustilsed and built on the project's key communication strategy, centred on leveraging the topical new news from the project's published research to create engagement and interest as a platform to then hero and showcase melons as a family of fruit that can help people achieve colour variety targets, while simultaneously educating on their key nutrition benefits.

Two 35-40 minute podcasts were strategically undertaken with Leanne Ward Nutrition and Dietitian Connection, both highly respected HCP podcasters that provide credibility and further reach to the messaging. Podcasts are a great way to provide more in depth discussion on a topic, allowing an interactive experience for the listener that can build engagement and greater connection with the audience and messages. They also exist as evergreen educational resources on the podcaster's platform, available for their audiences to watch anytime.

Leanne Ward is a renowned Australian media dietitian, nutritionist, sports dietitian and online social media influencer known as The Fitness Dietitian. Her 5 star rating podcast series Leanne Ward nutrition is one of the most popular nutrition podcasts in Australia on Apple podcast and spotify, currently rated in the top 10 and attracts a high HCP following. In her June episode 'The Latest Research Behind "Eating the Rainbow" with Melons', Leanne interviewed Dr. Flavia Fayet-Moore (Dr. Flav) on the recently published research, and discussed the nutritional benefits of different types of melons and best ways to incorporate melons into the diet, to "Eat the Rainbow". To date it has had nearly 13,000 downloads putting it in the top 3% of podcasts. As Leanne has communicated, "Colleagues have loved it and it has also certainly encouraged them to eat more melons".

Dietitian Connection is a key dietitian member organisation that supports dietitians to keep up to date on the latest food and nutrition research, products and news. Their podcast series is well regarded by members to support their professional development. In their September episode, DC interviewed Dr Emma Beckett from FOODiQ Global who took a deep dive into the latest research for dietitians and discussed how and why nutritious melons are the perfect example of the pot of gold at the end of the fruit and vegetable rainbow. It proved a popular episode achieving downloads higher than the 2022 average for their sponsored episodes.

Two further video animations are currently in development, due to be finalised in December 2023. The next and final milestone period will see all the developed resources for the project leveraged in communication through digital outreach communication to drive greater awareness and reach of both the available resources and messaging with the target audience.

Check out the HCP targeted video here by scanning the QR code:

Dietitian Connection Podcast: In this podcast Dr Emma Beckett, discusses with Dietitian Connection, the key member educational organisation for Australian Dietitians, the evidence behind bioactive pigments to understand why quantity isn't the only thing to consider when recommending fruits and vegetables. Using sweet and savoury culinary inspiration, Emma explores how and why nutritious melons are the perfect example of the pot of gold at the end of the fruit and vegetable rainbow. Scan the QR code below to listen to the podcast.

Leanne Ward Podcast: **The Latest Research Behind ”Eating the Rainbow” with Melons, featuring Accredited Practising Dietitian, from FOODiQ Global, Dr Flávia Fayet-Moore**.

In this podcast Dr Flav discusss the nutritional benefits of different types of melons plus the best ways to incorporate melons into your diet, to "Eat the Rainbow"
Listen to it hear now by scanning the QR code above.

VM20003 Project update

Prepared for:

Melons Australia
June 2024

Prepared by:

FOODiQ Global

Project summary

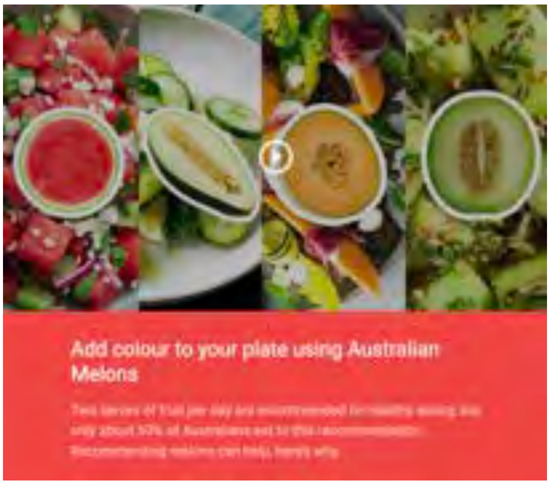
The FOODiQ Global (formerly Nutrition Research Australia) team are currently in the throes of concluding their appointment to the 3-year strategic levy investment project, *Educating healthcare professionals on Australian melons* (VM20003).

In the last six months, the final two video animations were completed (scan QR code below to view). The animations were central to the creative used in the social media outreach as part of a wider digitial outreach campaign that targeted health professionals during the month of March to drive awareness of the resources and associated messaging. The digital outreach campaign also included email outreach communications to HP organisations, and engagement with key opinion leaders (KOLs).

The project has now successfully completed the development of six health professional (HP) resources including a scientific publication, an evidence summary fact sheet, consumer friendly fact sheet, and three educational animations, along with three educational activities including a dedicated FOODiQ HP webinar and two health professional targeted audience podcasts. All resources and educational events are housed on both the FOODiQ Health Professional Melons Hub and health professional page on the Melons Australia website.

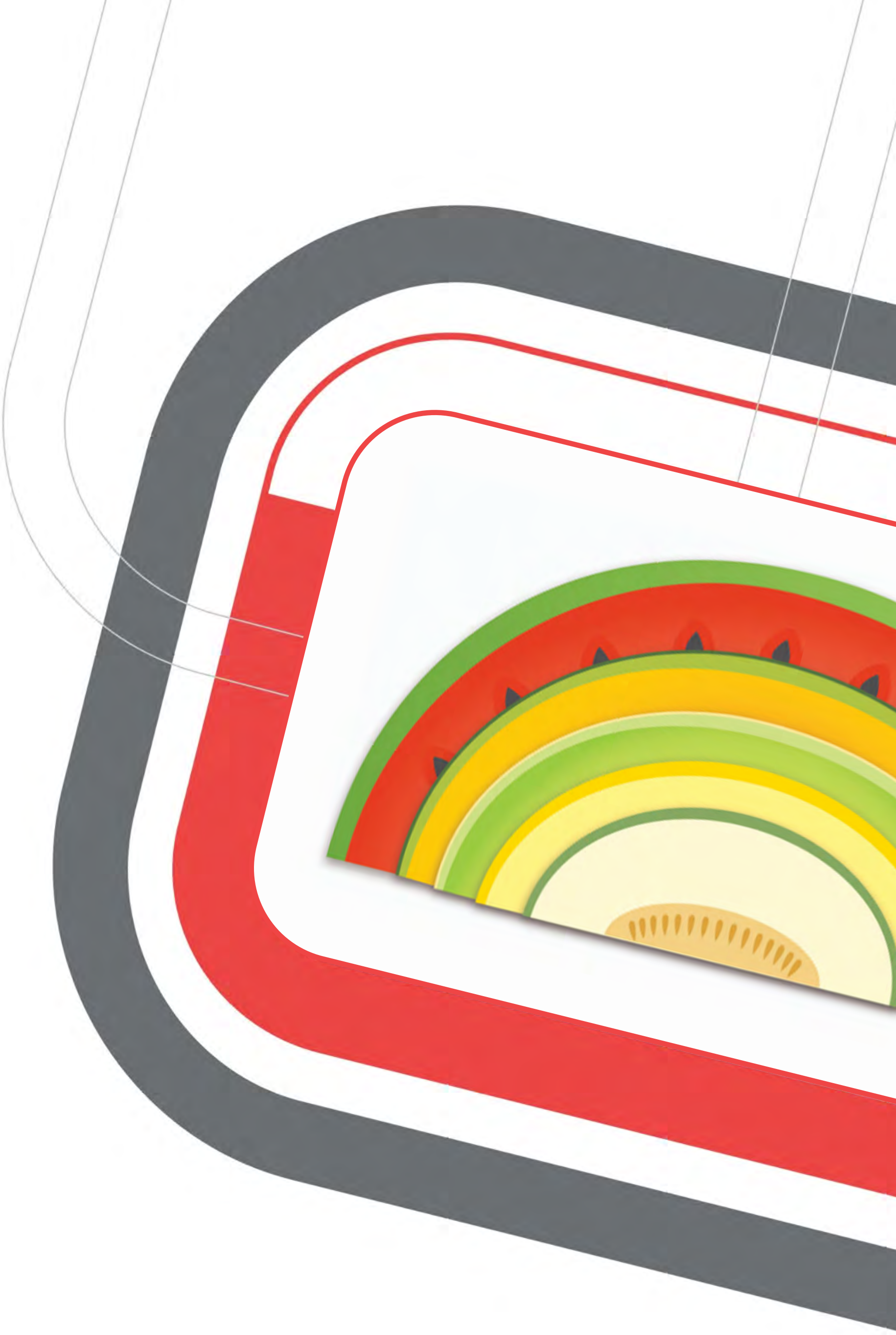
Recent end of project research has shown the project has successfully increased HP knowledge of the nutrition and health benefits of melons, leading to a notable rise in their intent to recommend melons to clients. Specifically, at project end, all HP who accessed the resources found them useful and were more than twice as likely to recommend melons, with 75% recommending them to clients always or often, compared to only a third among those who had not accessed the resources. The resources played a pivotal role in enhancing HP familiarity and recommendation, with those accessing the resources 1.3 times more likely to strongly believe melons can play a key role in improving colour variety in the diet compared to those who did not. The educational events received high ratings for information, usefulness, and engagement.

The impact of the project highlighted a clear correlation between resource access and recommendation behaviour. Despite the resources' perceived usefulness however, the proportion of participants accessing them was lower than anticipated, highlighting the need for further awareness campaigns to maximise resource utilisation. Overall, these findings underscore the importance of driving awareness among HPs as a crucial strategy for promoting melon consumption and driving industry growth. While the project has made significant strides in educating this influential stakeholder group, continued investment to drive awareness is recommended to sustain and expand these efforts in the longer term.



Check out the above HP targeted animations here by scanning the QR code:

APPENDIX 14:



VM20003: NUTRITIONiQ Update

Prepared for:

Hort Innovation

July 2022

Prepared by:

Nutrition Research Australia Pty Ltd

Summary

A search of database for research over the past six months according to agreed search criteria identified 5 relevant studies, comprising one systematic literature review, one compositional study three narrative reviews. No new RCTs or observational research identified in search.

The one systematic review and meta-analysis found watermelon consumption improved pulse wave velocity, an independent predictor of cardiovascular risk, and watermelon juice consumption was associated with a decrease in postprandial glucose concentrations in human adults [1]. As a systematic review and meta-analysis of randomised controlled trials, this study provides good evidence that watermelon consumption may improve vascular function, which can be communicated to health care professionals.

The compositional study cataloged the naturally occurring products present in watermelon and may be a valuable resource to the current project, and any ongoing research studies featuring watermelon [2].

Background

To create a database of all the research conducted on melons and health, and to stay abreast of the latest clinical developments and advances in this area, our NUTRITIONiQ literature database service is executed every 6 months throughout the campaign. The NUTRITIONiQ database service conducts regular scientific searches and media monitoring that targets peer-reviewed literature, media reports, clinical trial registries and updates from bodies such as the Watermelon Promotion Board.

Findings are used to inform the Melons Health Effects technical report as part of Milestone 105, with ongoing research updates conducted to ensure NRAUS stays across the latest in Melons Science and information gathered used to create ‘Fun Facts’, which may be included throughout the campaign to:

- Support key messages for resource and communication development
- Generate ideas for melon-related content
- Provide cutting-edge science for EDM updates
- Be used in the website review and update

Methods

Medline database search was conducted on July 7th, 2022, for any new papers published since the previous search was conducted.

Search terms included those relating to melons (Watermelon or Citrullus lanatus or Muskmelon or Rockmelon or Cantaloupe or Cucumis melo var cantalupensis or Honeydew Melon or Cucumis melon var inodorus or Piel de Sapo or Crispy Pear Melon) and those related to health outcomes of interest (nutr* or Vitamin or Mineral or Bioactive or Health or metab* or Cardiovascular or Respiratory or inflamm* or Obesity or Body weight or diab* or Cognitive or Cognition or Macular or Eyesight or eye sight or vision or Cancer or Exercise or Sports performance or Bone or Renal or kidney or Hepatic or liver or Neural or nervous system or neonat* or Maternal or f?tal* or Pregnancy or Gastrointestinal or "Gut health" or microbio*). Searches were restricted to new articles published since previous search, with no additional limits applied.

Results

From the database search, 202 articles were screened, and five full text articles were retrieved (see **Table 1**).

Of these, two were original research papers, however, only one reported on health effects. Consistent with previous NUTRITIONiQ findings, all the retrieved research is related to watermelon, with no papers examining the health effects of any other melons. The remaining three articles are narrative review articles summarizing: lycopene and cardiovascular disease; watermelon and L-citrulline in cardiometabolic health; and promising nutritional fruits against cardiovascular disease.

The abstracts for all identified relevant papers have been provided in **Table 1**.

Smeets et al [1] reports on a systematic review and meta-analysis of randomised controlled trials, which showed that watermelon consumption was associated with improvements in pulse-wave velocity, as well a reduction in post-prandial glucose after consumption of watermelon juice, when compared to equivalent amounts of glucose or sucrose. These findings show that watermelon consumption may improve vascular function, and provide directions for future research.

Sorokina et al [2] catalogued the naturally occurring products present in watermelon and may be a valuable resource to the current project, and any ongoing research studies featuring watermelon.

While NUTRITIONiQ is not designed specifically to capture narrative reviews, the publication of three reviews on watermelon and its bioactives demonstrate that there is strong academic interest in learning about the health effects of watermelon, and information provided can be captured in health care professional communications.

Table 1: Summary of new published studies on Melons from December 2021 to July 2022 based on search criteria.

AUTHOR/YEAR	TITLE	ABSTRACT	REF
ORIGINAL RESEARCH			
Smeets, E. T. H. C., et al. (2021)	Effects of L-citrulline supplementation and watermelon consumption on longer-term and postprandial vascular function and cardiometabolic risk markers: A meta-analysis of randomized controlled trials in adults	L-citrulline may improve non-invasive vascular function and cardiometabolic risk markers through increases in L-arginine bioavailability and nitric oxide synthesis. A meta-analysis of randomized controlled trials (RCTs) was performed to examine longer-term and postprandial effects of L-citrulline supplementation and watermelon consumption on these markers for cardiovascular disease in adults. Summary estimates of weighted mean differences (WMDs) in vascular function and cardiometabolic risk markers with accompanying 95% confidence intervals (CIs) were calculated using random or fixed-effect meta-analyses. Seventeen RCTs were included involving an L-citrulline intervention, of which six studied postprandial and twelve longer-term effects. Five studies investigated longer-term effects of watermelon consumption and five assessed effects during the postprandial phase. Longer-term L-citrulline supplementation improved brachial artery flow-mediated vasodilation (FMD) by 0.9 %-point (95 % CI: 0.7 to 1.1, $P < 0.001$). Longer-term watermelon consumption improved pulse wave velocity by 0.9 m/s (95% CI: 0.1 to 1.5, $P < 0.001$), while effects on FMD were not studied. No postprandial effects on vascular function markers were found. Postprandial glucose concentrations decreased by 0.6 mmol/L (95% CI: 0.4 to 0.7, $P < 0.001$) following watermelon consumption, but no other longer-term or postprandial effects were observed on cardiometabolic risk markers. To conclude, longer-term L-citrulline supplementation and watermelon consumption may improve vascular function, suggesting a potential mechanism by which increased L-citrulline intake beneficially affects cardiovascular health outcomes in adults. No effects on postprandial vascular function markers were found, while more research is needed to investigate effects of L-citrulline and watermelon on risk markers related to cardiometabolic health.	[1]
Sorokina, M., et al. (2021)	A Catalog of Natural Products Occurring in Watermelon-Citrullus lanatus	Sweet dessert watermelon (Citrullus lanatus) is one of the most important vegetable crops consumed throughout the world. The chemical composition of watermelon provides both high nutritional value and various health benefits. The present manuscript introduces a catalog of 1,679 small molecules occurring in the watermelon and their cheminformatics analysis for diverse features. In this catalog, the phytochemicals are associated with the literature describing their presence in the watermelon plant, and when possible, concentration values in various plant parts (flesh, seeds, leaves, roots, rind). Also cataloged are the chemical classes, molecular weight and formula, chemical structure, and certain physical and chemical properties for each phytochemical. In our view, knowing precisely what is in what we eat, as this catalog does for watermelon, supports both the rationale for certain controlled feeding studies in the field of precision nutrition, and plant breeding efforts for the development of new varieties with enhanced concentrations of specific phytochemicals. Additionally, improved and comprehensive collections of natural products accessible to the public will be especially useful to researchers in nutrition, cheminformatics, bioinformatics, and drug development, among other disciplines.	[3]

NARRATIVE REVIEWS

Bin-Jumah, M. N., et al. (2022)	Lycopene: A Natural Arsenal in the War against Oxidative Stress and Cardiovascular Diseases	Lycopene is a bioactive red pigment found in plants, especially in red fruits and vegetables, including tomato, pink guava, papaya, pink grapefruit, and watermelon. Several research reports have advocated its positive impact on human health and physiology. For humans, lycopene is an essential substance obtained from dietary sources to fulfil the body requirements. The production of reactive oxygen species (ROS) causing oxidative stress and downstream complications include one of the major health concerns worldwide. In recent years, oxidative stress and its counter strategies have attracted biomedical research in order to manage the emerging health issues. Lycopene has been reported to directly interact with ROS, which can help to prevent chronic diseases, including diabetes and neurodegenerative and cardiovascular diseases. In this context, the present review article was written to provide an accumulative account of protective and ameliorative effects of lycopene on coronary artery disease (CAD) and hypertension, which are the leading causes of death worldwide. Lycopene is a potent antioxidant that fights ROS and, subsequently, complications. It reduces blood pressure via inhibiting the angiotensin-converting enzyme and regulating nitrous oxide bioavailability. It plays an important role in lowering of LDL (low-density lipoproteins) and improving HDL (high-density lipoproteins) levels to minimize atherosclerosis, which protects the onset of coronary artery disease and hypertension. Various studies have advocated that lycopene exhibited a combating competence in the treatment of these diseases. Owing to all the antioxidant, anti-diabetic, and anti-hypertensive properties, lycopene provides a potential nutraceutical with a protective and curing ability against coronary artery disease and hypertension.	[4]
Burton-Freeman, B., et al. (2021)	Watermelon and L-Citrulline in Cardio-Metabolic Health: Review of the Evidence 2000-2020	**Purpose of review:** Watermelon (Citrullus lanatus) distinctively contains L-citrulline and L-arginine, precursors of nitric oxide (NO), along with polyphenols and carotenoids suggesting a role in cardio-metabolic health. The goal of this paper is to review the preclinical and clinical trial evidence published from 2000 to 2020 to assess watermelon intake and L-citrulline, as a signature compound of watermelon, on cardiovascular and metabolic outcomes, and to identify future directions important for establishing dietary guidance and therapeutic recommendations actionable by health care professionals, patients, and the general public. **Recent findings**: Watermelon and L-citrulline supplementation reduced blood pressure in human trials. Evidence for benefits in lipids/lipoprotein metabolism is emerging based on human literature and consistently reported in animal models. A role for watermelon intake in body weight control, possibly through satiety mechanisms, warrants further research. Likewise, improved glucose homeostasis in chemically and diet-induced animal models of diabetes is apparent, though limited data are available in humans. Emerging areas include brain and gut health indicated by NO bioavailability in all tissues, and evidence suggesting improvements in gut barrier function and altered microbial composition after watermelon intake that may influence metabolite pools and physiological function. Watermelon fruit contains unique vaso- and metabolically-active compounds. Accumulating evidence supports regular intake for cardio-metabolic health. Future research to determine the amount and frequency of	[5]

		watermelon/citrulline intake for desired outcomes in different populations requires attention to advance preventative and therapeutic strategies for optimal health and disease risk reduction.	
Zuraini, N. Z. A., et al. (2021)	Promising Nutritional Fruits Against Cardiovascular Diseases: An Overview of Experimental Evidence and Understanding Their Mechanisms of Action	Cardiovascular diseases (CVDs) are one of the leading causes of morbidity and mortality in both developed and developing countries, affecting millions of individuals each year. Despite the fact that successful therapeutic drugs for the management and treatment of CVDs are available on the market, nutritional fruits appear to offer the greatest benefits to the heart and have been proved to alleviate CVDs. Experimental studies have also demonstrated that nutritional fruits have potential protective effects against CVDs. The aim of the review was to provide a comprehensive summary of scientific evidence on the effect of 10 of the most commonly available nutritional fruits reported against CVDs and describe the associated mechanisms of action. Relevant literatures were searched and collected from several scientific databases including PubMed, ScienceDirect, Google Scholar and Scopus. In the context of CVDs, 10 commonly consumed nutritious fruits including apple, avocado, grapes, mango, orange, kiwi, pomegranate, papaya, pineapple, and watermelon were analysed and addressed. The cardioprotective mechanisms of the 10 nutritional fruits were also compiled and highlighted. Overall, the present review found that the nutritious fruits and their constituents have significant benefits for the management and treatment of CVDs such as myocardial infarction, hypertension, peripheral artery disease, coronary artery disease, cardiomyopathies, dyslipidemias, ischemic stroke, aortic aneurysm, atherosclerosis, cardiac hypertrophy and heart failure, diabetic cardiovascular complications, drug-induced cardiotoxicity and cardiomyopathy. Among the 10 nutritional fruits, pomegranate and grapes have been well explored, and the mechanisms of action are well documented against CVDs. All of the nutritional fruits mentioned are edible and readily accessible on the market. Consuming these fruits, which may contain varying amounts of active constituents depending on the food source and season, the development of nutritious fruits-based health supplements would be more realistic for consistent CVD protection.	[6]

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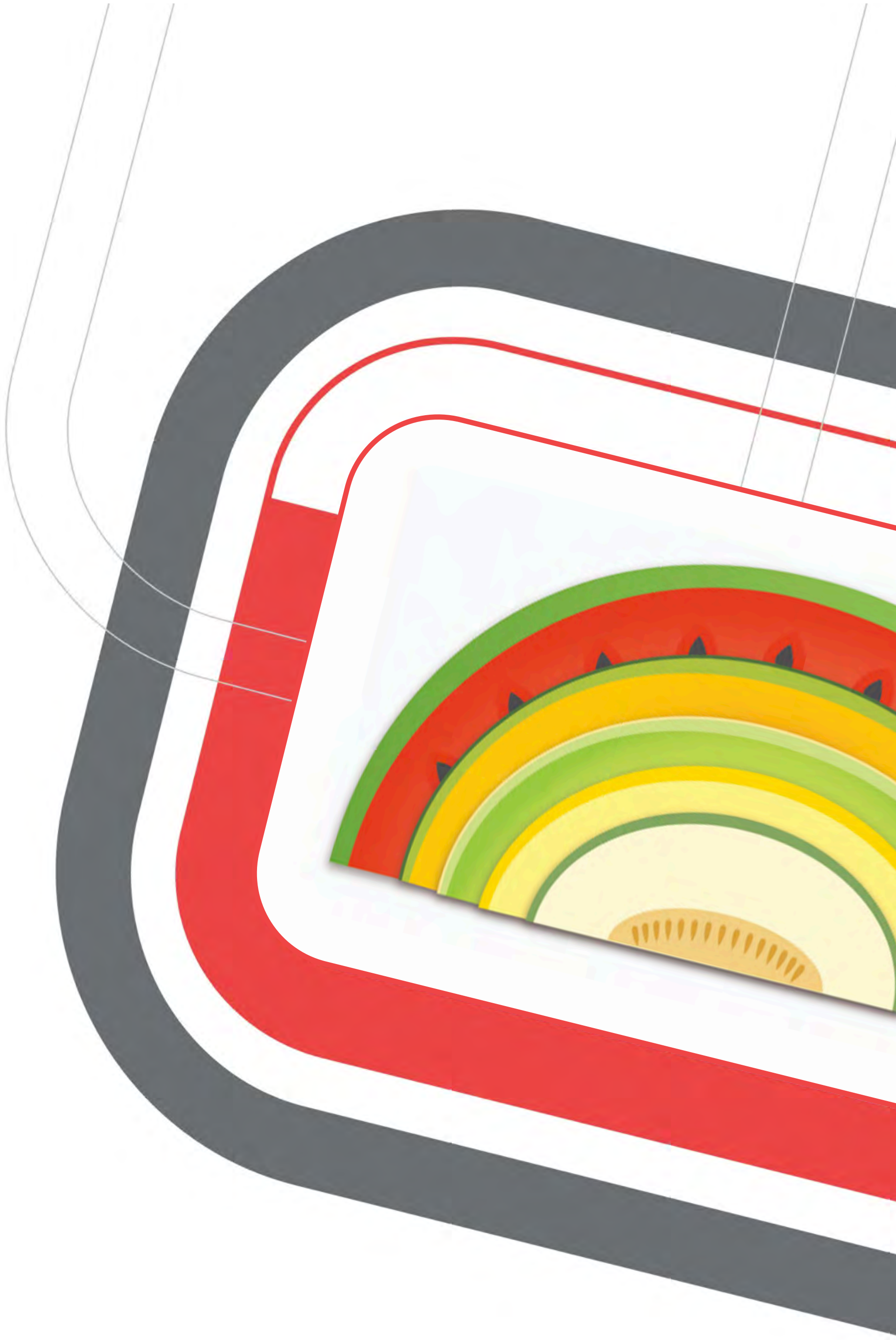

VM20003: NUTRITIONiQ Update

Prepared for:

Hort Innovation

January 2023

Prepared by:

Nutrition Research Australia Pty Ltd

Summary

A search of database for research over the past six months according to agreed search criteria identified four relevant studies. All included papers are primary original research articles comprising of two pilot studies, one of which was a randomised control trial, one observational study assessing watermelon intake and diet quality, and one online consumer research survey.

All papers identified were related to watermelon, and can be used to support the health benefits of watermelon in the diet. Key findings include:

- “Refreshing” is a highly valued quality in foods and drinks for consumers. Watermelon is considered amongst the most refreshing of food and drinks, rating in the top three after only water and cucumber.

- Adults and children who regularly consume watermelon have higher total diet quality scores compared with those who don’t. Compared with non-consumers, consumers have significantly higher levels of dietary fibre, magnesium, potassium, vitamin A, lycopene, and carotenoids, as well as significantly lower levels of added sugars and saturated fats. Although this was a cross-sectional study and causation can’t be established, including watermelon regularly in the diet is associated with better overall diet quality.

- After consuming watermelon juice, there is an acute increase in nitric oxide (NO) in plasma, which peaks at 60 minutes and is sustained at 90 minutes, and a decrease in peripheral arterial stiffness, which peaked after 30 minutes and then gradually decreased to 90 minutes. This adds mechanistic support to previous research findings that showed watermelon intake improves pulse wave velocity, a cardiovascular risk factor, and may add interest to the use of watermelon as an ergonomic aide for sports performance.

- One research paper from Portugal showed that cut melons on grocer shelves shows evidence of microbial transfer from the skin to the flesh of melons. This can be used to support health care professional, consumer, or retailer education campaigns on melons and health, particularly for high-risk individuals.

Background

To create a database of all the research conducted on melons and health, and to stay abreast of the latest clinical developments and advances in this area, our NUTRITIONiQ (NiQ) literature database service is executed every six months throughout the campaign. The NUTRITIONiQ database service conducts regular scientific searches and media monitoring that targets peer-reviewed literature, media reports, clinical trial registries and updates from bodies such as the Watermelon Promotion Board.

Findings from NiQ were initially used to inform the Melons Health Effects technical report as part of Milestone 105, with ongoing research updates conducted to ensure NRAUS stays across the latest in Melons Science and information gathered used to create 'Fun Facts', which may be included throughout the campaign to:

- Support key messages for resource and communication development
- Generate ideas for melon-related content
- Provide cutting-edge science for EDM updates
- Be used in the website review and update

Methods

Pubmed database search was conducted on Jan 9th, 2023, for any new papers published since the previous search was conducted.

The previous search terms were used, including those related to melons (Watermelon or Citrullus lanatus or Muskmelon or Rockmelon or Cantaloupe or Cucumis melo var cantalupensis or Honeydew Melon or Cucumis melon var inodorus or Piel de Sapo or Crispy Pear Melon) and health (nutr* or Vitamin or Mineral or Bioactive or Health or metab* or Cardiovascular or Respiratory or inflamm* or Obesity or Body weight or diab* or Cognitive or Cognition or Macular or Eyesight or eye sight or vision or Cancer or Exercise or Sports performance or Bone or Renal or kidney or Hepatic or liver or Neural or nervous system or neonat* or Maternal or fetal* or Pregnancy or Gastrointestinal or "Gut health" or microbio*). Results were limited to those since the previous search (July 7th, 2022).

Results

The search returned 262 articles for screening. From those, four relevant full text articles were retrieved. These papers have been summarized, with the abstracts for each paper provided in **Table 1.** As with previous searches, all papers were related to watermelon, with no relevant returns for rockmelon, honeydew melon, or Piel de Sapo melons.

Food Safety

- One pilot study (Tseng et al, 2022) in Portugal showed that melons cut by retailors, wrapped in plastic film and stored at room temperature, showed evidence of microbial transfer from the skins of melons to the flesh, and highlighted areas of opportunity for education to both retailors and customers. Whilst the Portuguese market may not be directly applicable to Australian consumers, the research can be used to support educational materials for high-risk consumers of melons, such as during pregnancy.

Health Effects

- One randomised cross-over pilot study (Fujie et al, 2022) showed that a single serve of juice extracted from wild watermelons acutely increased nitric oxide production and reduced peripheral arterial stiffness. Nitric oxide levels peaked after 60 minutes (80% increase from baseline, compared with <20% decrease in the placebo group), and remained at the same level 90 minutes after consumption. Effects on peripheral arteries peaked after 30 minutes, then gradually declined at 60 and 90 minutes. This paper builds on the evidence obtained from the systematic review and meta-analysis in the previous NiQ report which showed watermelon consumption improved pulse wave velocity [1], and providing further direct mechanistic evidence, in humans, that watermelon likely directly improves vascular endothelial function, leading to improved cardiovascular risk markers.

Refreshing

- An online survey of 1,518 participants collected consumer insights into the importance of 'refreshing' as a concept for consumers. Watermelon ranked amongst the top three most refreshing foods or drinks for consumers, with 80.8% rating it as refreshing (along with water, 86.0%, and cucumbers, 83.5%). Three quarters (76.3%) of participants felt the need to consume something 'refreshing' at least once per day, with the qualities identified as being important for refreshing included something that was thirst-quenching, temperature, and cooling taste.

Diet Quality

- In a large, nationally representative sample of children and adults in the National Health and Nutrition Examination Survey (NHANES), the diet quality of watermelon consumers and non-consumers was assessed. Usual intake in watermelon consumers was 125 g/day and 161 g/day for children and adults, respectively. Total diet quality was significantly higher in consumers of watermelon for both children and adults, with higher dietary intake of fibre, magnesium, potassium, vitamin A, lycopene, and carotenoids. Watermelon consumers also had 5% lower intake of total added sugars and saturated fats, both targets for reduction in the Australian Dietary Guidelines. This study was conducted in free-living adults and children in the United States between 2003 and 2018, and findings are likely to be directly applicable to the Australian population.

Table 1: Summary of new published studies on Melons from July 2022 to January 2023 based on search criteria.

AUTHOR/YEAR	TITLE	ABSTRACT	REF
ORIGINAL RESEARCH			
Tseng Y.H. et al. 2022	Microbiological Safety of Cut Melons Sold in Portuguese Retail Markets: A Pilot Study	Due to the increasing consciousness of a healthy diet and pursuit of convenience among consumers, the market for fresh fruit is on the rise, and the melon is among the most welcome of fruits for its sensory attributes and nutritional properties. Consumption safety of cut fruit remains an issue of concern that may affect public health. This study aimed to perform the microbiological characterisation of a melon, Cucumis melo L. var. "Piel de Sapo", cut by retailers, wrapped in plastic cling film and kept at room temperature in local fruit shops. In addition, the possible transfer of relevant foodborne pathogens, during slicing, from the peel to the interior of the melon, and bacterial growth, were also evaluated when the melon slices were stored at abusive temperatures for 2 days. In this pilot study, a low number of samples were characterised microbiologically (26 cut melons), and some isolates were identified by 16S rRNA sequencing. No Listeria spp. or Salmonella spp. were detected in any of the samples, while Escherichia coli and Staphylococcus aureus were present in four and six out of twenty-six samples, respectively. Following artificial contamination of melons with cocktails of Salmonella spp., E. coli and Listeria monocytogenes, it was observed that, despite the smaller number of L. monocytogenes recovered, all the pathogens were transferred from the contaminated peels to the interior of the melons. Furthermore, over storage time, significant differences were observed (p < 0.05) between the counts obtained from melon slices immediately after cutting (0 h), and after 24 and 48 h at 20 °C, with an increase of about 4 log CFU/g in all the pathogens. In conclusion, some cut melons classified as microbiologically unacceptable or unsatisfactory are being sold in local fruit shops in the Porto Metropolitan Area, Portugal. Although absent in the samples analysed, Salmonella spp. and L. monocytogenes, if present, can be transferred from the outside to the inside of the fruit by the cutting blade and, if not consumed immediately and stored at abusive temperatures, this ready-to-eat product poses a risk of infection. This pilot study, performed for the first time in Portugal under these conditions, clearly demonstrates the need for education campaigns to alert local sellers and consumers of the risk posed by cut melons.	[1]
Fujie S et al, 2022	Wild Watermelon-Extracted Juice Ingestion Reduces Peripheral Arterial Stiffness with an Increase in Nitric Oxide Production: A Randomized Crossover Pilot Study	Wild watermelon contains various nutrients, but the effect of its acute ingestion on arterial stiffness is unclear. This study aimed to investigate whether a single bout of acute ingestion of wild watermelon-extracted juice decreased arterial stiffness concomitant with an increase in nitric oxide (NO) production. Twelve healthy young female participants were tested under two conditions in a randomized, double-blind crossover study: (1) a beverage containing 90 g of wild watermelon extract and (2) a control beverage: a placebo. Pulse wave velocity (PWV), an index of arterial stiffness, blood flow, and plasma nitrate/nitrite (NOx) levels were measured in the supine position at 30, 60, and 90 min after the intake of each beverage. The changes in femoral-ankle PWV were significantly reduced after wild watermelon-extracted juice intake compared to those in the placebo group. Additionally, the changes in blood flow in the posterior tibial artery and plasma NOx levels after intake of wild watermelon-extracted juice were significantly increased compared to those in the placebo group. These data show	[2]

		that acute ingestion of wild watermelon-extracted juice reduces peripheral (lower limb) arterial stiffness and increases NO bioavailability. To confirm these associations, more detailed investigations of the nutrients that influence these effects should be conducted.	
Ramirez JL et al, 2022	Examining the consumer view of refreshing perception, relevant fruits, vegetables, soft drinks, and beers, and consumer age and gender segmentations	Consumer perspective of refreshing perception is underexplored, despite it being an emotional attribute to describe foods, beverages, hygiene products, and household items. An online survey (N = 1518) was designed to collect consumer insight into the importance of refreshing, the definition and factors related to it, and the identification of refreshing fruits, vegetables, and drinks. Nearly all participants (99.8%) cited that they have had the need to consume a food or beverage to feel refreshed, and 76.3% cited that they need this at least once per day. The factors most associated with refreshing were thirst-quenching (84.1%), temperature (86.2%), and cooling taste (86.0%). Water (86.6%), watermelons (80.8%), and cucumbers (83.5%) were the beverages/foods most frequently specified as refreshing. A second survey (N = 1050) examined refreshing perception specifically related to beer consumption and associated flavor. Beer was rated highly refreshing by 75.5% of participants, affirming its refreshing reputation. Refreshing perceived from beer was most associated with cool temperature (95.4%), flavor of the beer (88.6%), lightened mood (87.1%), and thirst-quenching (49.0%). Beers with crisp/clean flavors (87.3%) and citrus flavors (35.7%–51.7%) were most frequently specified as refreshing. There were no gender differences in the definition of refreshing and associated thirst-quenching and cold, although age differences in defining beer refreshing were significant ($p \leq .05$). There were significant gender and age differences in types of refreshing vegetables, soft drinks, beer flavours, and varieties. The study provided consumer insight into refreshing perception and the gained knowledge could be used in new product design.	[3]
Fulgoni et al, 2022	Watermelon Intake Is Associated with Increased Nutrient Intake and Higher Diet Quality in Adults and Children, NHANES 2003-2018	Watermelon is a nutrient-dense, low energy food that provides vital nutrients and contributes to overall fruit intake. Previous studies have found positive associations between watermelon and nutrient intake but few focused on raw watermelon intake or had small sample sizes. Therefore, the objective of this study was to utilize a large, nationally representative sample to determine associations between watermelon intake and nutrient intake and diet quality. Data from children (2-18 y) and adults (19+ y) who participated in the National Health and Nutrition Examination Survey (NHANES) cycles 2003-2018 were utilized in the current study. Watermelon intake was 7.51 and 7.29 g/d per capita in children and adults, respectively. In watermelon consumers, usual intake was 125 and 161 g/d in children and adults, respectively. Total diet quality was higher in watermelon consumers as compared to non-consumers as well as several subcomponent scores. Children and adult watermelon consumers had greater than 5% higher intake of dietary fibre, magnesium, potassium, and vitamin A as well as more than 5% lower intake of added sugars and total saturated fatty acids as well as higher intake of lycopene and other carotenoids. This study suggests watermelon can increase nutrient intake as well as diet quality in both children and adult Americans.	[4]

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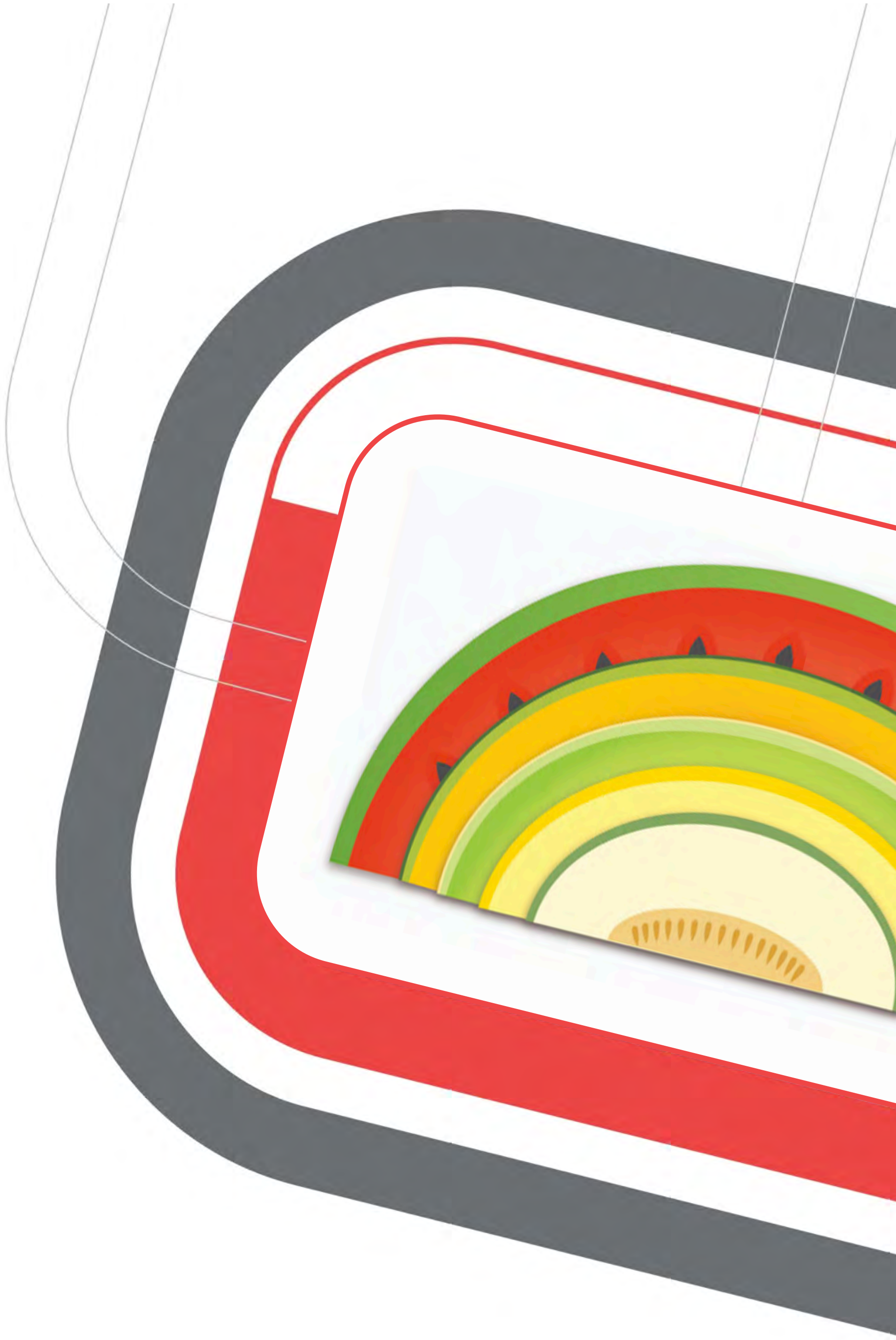

VM20003: NUTRITIONiQ Update

Prepared for:

Hort Innovation

July 2023

Prepared by:

Nutrition Research Australia Pty Ltd

Summary

A search of database for research over the past six months according to agreed search criteria identified nine relevant studies. Of these, seven were primary original research articles comprising of two systematic reviews with meta-analyses [1, 2]; one randomised controlled trial [3]; three papers reporting on nutrients, bioactive compounds, or sensory aspects of watermelon or watermelon-enhanced food and drink products [4-6]; and one transcriptional analysis identifying the molecular biosynthesis pathways for carotenoids in melons [7]. Also included was one literature review [8] and one editorial article summarizing papers published in a special issue focused on watermelon and cardiometabolic health [9].

Except for the transcriptional analysis, which included a variety of melons, all articles featured watermelon or extracts of watermelon. Key findings include:

- There appears to be no acute impact of citrulline supplementation on endurance performance [1].
- Consumption of watermelon and watermelon-supplements are associated with reductions in some cardiometabolic risk factors, including:
    - Consistent reductions in systolic blood pressure across five studies in one meta-analysis [2].
    - Decreased total and LDL cholesterol across two studies in meta-analysis [2].
    - There was no apparent effect of watermelon on diastolic blood pressure, heart rate, BMI, body fat, fasting insulin levels, or c-reactive protein in meta-analysis [2].
    - Meta-analysis suggested a possible increase in fasting blood sugar with consumption of watermelon. This was inconsistent between studies and largely driven by one study which accounted for most of the effect (weighting 98.54%) where post-menopausal women consumed 780mL of watermelon puree daily for 6 weeks [2].
    - Daily consumption of watermelon (compared with placebo) attenuated reductions in heart-rate variability induced with an oral glucose challenge. Decreases in heart rate variability is associated with the development of cardiovascular disease [3].
- Pre-clinical research shows that nutrients and phytochemicals found in watermelon may support male fertility, including improved sperm quality (sperm count, morphology, and motility) and hormone regulation (increases in testosterone and decreases in serum prolactin) [8]. Clinical research studies are required to determine whether these findings are translatable to humans.
- Products using watermelon or watermelon waste products (e.g. seeds, rind) include:
    - Fruit brandy [4]
    - Enhanced bakery products when combined with refined wheat flour (compared with wheat products alone) [5]
    - Watermelon-rind candy [6]
- Transcriptional analysis of molecular pathways involved in the synthesis of carotenoids may lead to methods of increasing the concentration of bioactive colour pigments in melons.

Background

To create a database of all the research conducted on melons and health, and to stay abreast of the latest clinical developments and advances in this area, our NUTRITIONiQ (NiQ) literature database service is executed every six months throughout the campaign. The NUTRITIONiQ database service conducts regular scientific searches and media monitoring that targets peer-reviewed literature, media reports, clinical trial registries and updates from bodies such as the Watermelon Promotion Board.

Findings from NiQ were initially used to inform the Melons Health Effects technical report as part of Milestone 105, with ongoing research updates conducted to ensure NRAUS stays across the latest in Melons Science and information gathered used to create ‘Fun Facts’, which may be included throughout the campaign to:

- Support key messages for resource and communication development
- Generate ideas for melon-related content
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- Be used in the website review and update

Methods

Pubmed database search was conducted on July 9th, 2023, for any new papers published since the previous search was conducted.

The previous search terms were used, including those related to melons (Watermelon or Citrullus lanatus or Muskmelon or Rockmelon or Cantaloupe or Cucumis melo var cantalupensis or Honeydew Melon or Cucumis melon var inodorus or Piel de Sapo or Crispy Pear Melon) and health (nutr* or Vitamin or Mineral or Bioactive or Health or metab* or Cardiovascular or Respiratory or inflamm* or Obesity or Body weight or diab* or Cognitive or Cognition or Macular or Eyesight or eye sight or vision or Cancer or Exercise or Sports performance or Bone or Renal or kidney or Hepatic or liver or Neural or nervous system or neonat* or Maternal or fetal* or Pregnancy or Gastrointestinal or "Gut health" or microbio*). Results were limited to those since the previous search (July 9th, 2022).

Results

The search returned 48 articles for screening. From those, nine relevant full text articles were retrieved. These have been summarized, with the abstracts for each article provided in **Table 1.** Almost all the research identified was related to watermelon, with no relevant returns for rockmelon, honeydew melon, or Piel de Sapo melons. One study was included which analysed the genetic transcription of orange- and yellow-fleshed melons, which used a specialty species that had been developed by the research group conducting the research. While not directly on melons represented within the VM20003 project, findings from this project will are potentially applicable to the development of bioactive-enhanced melons. The effects of watermelon on health outcomes have been summarised, as well as findings from nutrient and biochemical analyses.

Health effects of watermelon

Sports Performance

A systematic literature review (SLR) and meta-analysis including nine studies and 330 participants found no direct effect of citrulline supplements on endurance performance. Studies were included in this review if they included either a loading or bolus dose of citrulline, and included measures of exercise endurance, including time-to-completion or time-to-failure in continuous sub-maximal intensity exercise. Neither loading nor bolus doses of citrulline had any effect on endurance. Of note, there was an extremely low level of between-group heterogeneity within this study, with most participants falling between the ages of 18 and 30, and only two of the nine studies including a mix of men and women, while no studies were conducted exclusively in women. Authors suggest that future research should be conducted using chronic supplementation of ≥7 days and including women in future studies.

Cardiometabolic health

One systematic review and one randomised controlled trial investigated the effect of watermelon consumption on risk factors of cardiovascular health. Overall, the studies showed positive effects of watermelon and watermelon supplements on cardiometabolic risk, however, some caution may be needed in relation to fasting blood sugar. The SLR included nine studies with 330 participants. Eight of the nine studies included participants at high risk of cardiometabolic disease. Interventions included diced watermelon (2 cups daily), watermelon puree (710 mL or 980 mL daily), watermelon powder (2-6g daily), and watermelon extract (2-6g daily), and outcomes included blood pressure, blood lipid profile, glycaemic markers (fasting glucose and fasting insulin), heart rate, body mass index, body fat %, and c-reactive protein. The RCT included 18 healthy young non-smoking adults who had BMIs in the ‘healthy’ range (18.5-25.0 kg/m^2 in a cross-over design. The intervention compared the heart rate variability and metabolic parameters of participants given an oral glucose challenge after the participants had consumed either 500 mL watermelon or placebo juice daily for two weeks.

> ***Heart Rate Variability*** measures the amount of fluctuation there is in the time between heart beats. Decreases in the heart rate variability is strongly associated with the development of cardiometabolic disease and can be an early indicator or predictor of disease development.

Summary of cardiometabolic outcomes

Blood Pressure: Meta-analysis of five studies showed a significant decrease in systolic blood pressure with a moderate effect size, with no effect on diastolic pressure [2]. The effects on SBP were highly consistent across all the included studies.

Lipid Profile: There were significant decreases in both total and LDL- cholesterol [6]. While statistically significant, these findings are based on only two studies, and should be interpreted with caution.

Glycaemic markers: Authors reported that watermelon significantly increased fasting blood glucose in the meta-analysis, with no significant effect on fasting insulin levels [8]. The increase in fasting glucose was entirely driven by the effect of just one of two included studies which reported both glucose and insulin, with the study weighting meaning that one study accounted for 98.6% of the analysis. In this study by Shanely et al (2019) [10], post-menopausal women consumed 710mL of watermelon puree each day for 6 weeks. In the second study by Lum et al, participants consumed 2 cups diced watermelon daily for 4 weeks which had no effect on fasting blood glucose levels.

Interestingly, although not significant, the directions of effect sizes between the two studies differed from each other for both glucose and insulin responses, which could potentially reflect a different effect of the whole vs pureed fruit on glycaemic response (**Figure 1**).

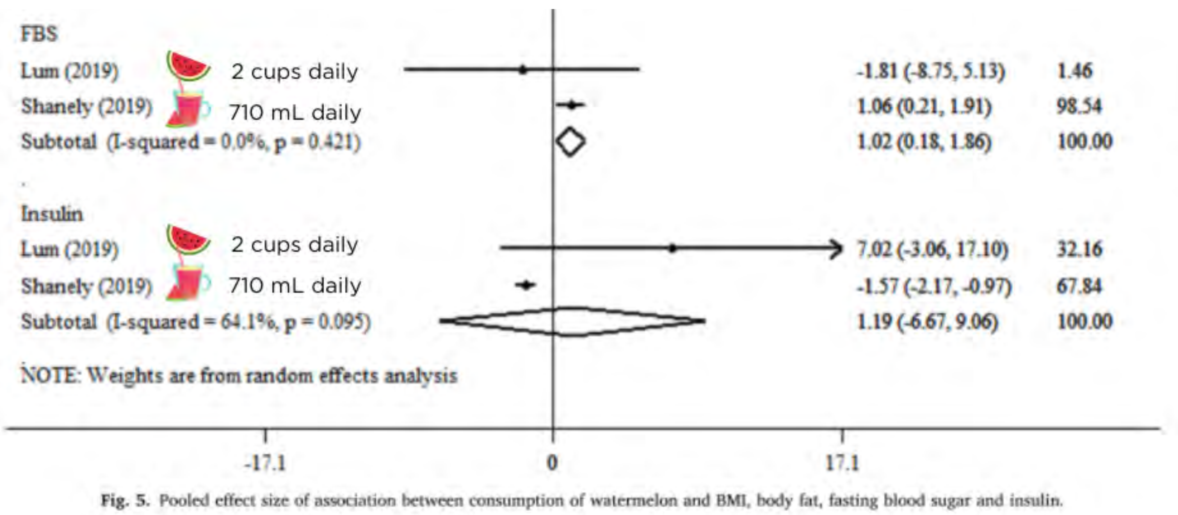

Figure 1. Inverse directions of effect for glycaemic outcome measures in response to whole vs pureed watermelon interventions could indicate effects of food matrix. Figure adapted from Karimi et al [2].

Heart rate variability: In the placebo group, administration of the oral glucose challenge induced a decrease in heart rate variability, an effect which was attenuated when the glucose challenge was given after the participants had consumed 500mL watermelon juice daily for two weeks [3]. There was no difference in effect for metabolic outcomes between the intervention and placebo periods.

Male Fertility

A narrative literature review article put forth the hypothesis that watermelon consumption should have beneficial effects on male fertility [8]. Based on pre-clinical evidence conducted mainly in rodent models, watermelon or supplements derived from watermelon are proposed to improve male reproductive health in the following parameters:

- Increased antioxidant activity in the testes
- Increased semen quality (increased sperm count, increased sperm motility, improved semen morphology)
- Improved hormone regulation (increased testosterone, decreased serum prolactin)
- Increased libido

Proposed biological mechanisms include:

- Presence of vitamins needed as cofactors for cellular architecture and cellular differentiation (thiamine, riboflavin, niacin, folate)
- Effect of antioxidants present in watermelon including flavones, carotenoids (including lycopene), and vitamin C. Increased antioxidant activity is proposed to improve sperm morphology and viability
- Phenols present in watermelon have been shown to chelate arsenic, increasing its removal from the body
- Increased blood flow and vascular function in the pelvic region resulting from citrulline and arginine present, which increases the endogenous production of nitric oxide.

It is unclear what the mechanism for increased testosterone levels may be, but authors propose that it may be related to changes in the structure and functioning of the testes resulting in increased testosterone function. Although of interest, it should be noted that that no human intervention studies were included in the review, thus these should be interpreted cautiously to inform future research and cannot be relied upon for clinical recommendations.

Nutrient or bioactive analysis of watermelon or watermelon products

Fruit Brandy

Research from Ambindei et al presented experimental research determining the optimum factors for the development of a fruit brandy, which included watermelon as one of the key ingredients [4]. Of potential interest to this project, the final product contained polyphenols, vitamin C, and organic acids (vitamin C 80-100mG/L; polyphenols 22.77-42.77 mqGAE/100g).

Enhanced bakery products using watermelon flour

Jaroszewska et al showed that refined wheat flour can be fortified with watermelon flour, with the resultant flour showing improved baking qualities, including improvements on development and baking time, and softening and stability of the dough [5]. Although there is a high amount of phenolic compounds in the watermelon flour, the presence of polyphenols in the final product was extremely low and there was no effect on the measured antioxidant capacity.

Watermelon Rind Candy

Nutrient and sensory analysis of a product developed from watermelon rind demonstrated the production of a shelf-stable dried snack with a taste and texture determined to be acceptable by a panel evaluating its sensory characteristics.

Table 1: Summary of new published studies on Melons from January 2023 to July 2023 based on search criteria.

AUTHOR/YEAR	TITLE	ABSTRACT	REF
ORIGINAL RESEARCH			
Ambindei, W. A., et al. 2023	Optimization of the pulp ratio of Ananas comosus, Citrullus lanatus and Psidium guajava and fermentation time in the production of a "fruit brandy"	Brandy, produced by the distillation of wine, is highly consumed in Cameroon, most of which is imported, whereas this region harnesses a vast diversity of fruits, which could be exploited in producing wines and spirits. These fruits have interesting health virtues and are prone to rapid postharvest losses. This study is aimed at producing brandy from a combination of pineapple (Ananas comosus), watermelon (Citrullus lanatus) and guava (Psidium guajava), with an objective to optimize the ratio of fruit pulps and fermentation time to produce wine, then brandy of acceptable taste and flavour. A D-optimal 3-component, 1-factor experimental design was used to obtain the best wine formulation to be distilled. The factors retained were: the volumes of Pineapple (A), watermelon (B) and guava (C) and the fermentation time (D) was considered as a process factor. Based on the experimental design using Design Expert 11 software, 24 wine samples were formulated. After statistical analyses, the pH, alcohol content and viscosity were considered for mathematical modelling due to their significant impacts during fermentation (pH and viscosity) and distillation (alcohol content). Optimization for wine production gave a fruit formulation of 69, 19 and 12% of pineapple, watermelon and guava respectively, with a fermentation time of 11 days. Distillation of this wine gave an ethanol output of 72%, from which two distinct Brandy was obtained: one (E (1)) in which dilution was done with clarified wine, and the second (E(2)) with distilled water and a roasted bark of Cupressus sempervirens (cypress) added to it. After six weeks of aging at ambient temperature, physicochemical characteristics showed a vitamin C content of 100 and 80 mg/L, polyphenols content of 22.77 and 42.77 mqGAE/100 g, and a titratable acidity of 1.42 and 0.45 meq.g of tartaric acid respectively for E (1) and E(2). After sensory analysis, brandy sample E(1) was preferred.	[4]
Diao, Q., et al. 2023	Transcriptome analysis reveals association of carotenoid metabolism pathway with fruit colour in melon.	Flesh colour is an important quality of melon (Cucumis melo L.) and is determined mainly by carotenoid content, awarding them with colours, aromas, and nutrients. enhancing the nutritional and health benefits of fruits and vegetables for humans. In this study, we performed transcriptomic analysis of two melon inbred line "B-14" (orange-flesh) and "B-6" (white-flesh) at three developmental stages. We observed that the β-carotene content of inbred line "B-6" (14.232 µg/g) was significantly lower than that of inbred line "B-14" (0.534 µg/g). RNA-sequencing and quantitative reverse transcription PCR analyses were performed to identify differentially expressed genes (DEGs) between the two inbred lines at different stages; the DEGs were analysed using the Gene Ontology (GO) and Kyoto Encyclopedia of Genes and Genomes databases (KEGG). We identified 33 structural DEGs in different developmental periods of the two lines that were related to carotenoid metabolism. Among them, PSY, Z-ISO, ZDS, CRTISO, CCD4, VDE1, and NCED2 were highly correlated with carotenoid content. Thus, this study provides a basis for molecular mechanism of carotenoid biosynthesis and flesh colour in melon fruit.	[7]

Harnden, C. S., et al. 2023	Effects of citrulline on endurance performance in young healthy adults: a systematic review and meta-analysis.	BACKGROUND: Citrulline is a popular dietary supplement, primarily thought to exert ergogenic effects on exercise performance through the enhancement of nitric oxide (NO) synthesis and ammonia buffering. However, recent findings surrounding citrulline's effect on endurance performance have been inconsistent. A systematic review and meta-analysis of the relevant literature have yet to be undertaken. AIM: To determine if acute ingestion of citrulline has an ergogenic effect on endurance performance in young healthy adults. METHODS: A systematic search of three databases was undertaken to find peer-reviewed randomized controlled trials (RCTs) published in English investigating the effects of citrulline supplementation on endurance performance in young healthy adults. Two independent investigators completed a three-phased screening procedure against pre-determined eligibility criteria. Included studies evaluated loading or bolus dosage regimes of citrulline in participants aged 18 or over that were at least recreationally active. Outcome measures focused on time-to-completion (TTC) or time-to-exhaustion (TTE) in continuous submaximal intensity exercise. Cochrane's Risk of Bias 2 (RoB 2) tool was used to assess the risk of bias in individual studies. Meta-analysis was conducted using a fixed-effects model to pool the weighted estimate of standardized mean differences (SMD) across studies. A chi-squared test assessed heterogeneity between studies. This review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. RESULTS: Nine studies (n = 158 participants) met the eligibility criteria; five reported TTE outcomes ($I(2) = 0\%$, $\chi(2) = 0.37$, df = 4, $P = 0.99$) and four reported TTC outcomes ($I(2) = 0\%$, $\chi(2) = 0.46$, df = 3, $P = 0.93$), both with a low between-study heterogeneity. The results of the meta-analyses showed no significant difference in the endurance performance measures, TTE (pooled SMD = 0.03 [-0.27, 0.33]) and TTC (pooled SMD = -0.07 [-0.50, 0.15]), after acute ingestion of citrulline supplementation or a control in young healthy adults. DISCUSSION: The current evidence suggests no significant benefit of citrulline supplementation for endurance performance. However, the small evidence base requires further research to fully evaluate this topic. Recommendations include a focus on female populations; higher continuous doses of citrulline over seven days; and TTC outcome measures over longer distances to simulate competition.	[1]
Jaroszewska, A., et al. 2023	Mineral, Nutritional, and Phytochemical Composition and Baking Properties of Teff and Watermelon Seed Flours.	Demonstrated limitations in the mineral and nutritional composition of refined flours have led to calls for the possibility of enriching them with health-promoting supplements, such as high-value non-cereal seeds. Teff and watermelon seeds have been found suitable to produce gluten-free flour, but so far, their potential to enrich conventional baking flours has not been comprehensively studied. Hence, the present study aimed at farinographic evaluation of dough based on refined wheat flour with additions of whole white teff (TF) and watermelon seed (WSF) and pomace (DWSF) flours (tested levels 10%, 20%, and 30%), as well as possibly extensive chemical characterization of the plant material tested, including LC-MS/MS, GC-MS, total phenolics, flavonoids, melatonin, and antioxidant	[5]

		potential. Most of the rheological traits were improved in the flour mixtures compared to the base white flour: development time and quality number (above 1.6-fold increase), softening and stability time (up to 1.3-fold change), and water absorption (up to 6%). Overall, the best results were achieved after the addition of watermelon seed pomace. The DWSF material was characterized by the highest levels of P, Mg, Na (7.5, 1.7, 0.4 g/kg, respectively), and Fe and Zn (124 and 27 mg/kg), while TF was the richest in Ca (0.9 g/kg) and Mn (43 mg/kg). Protein and fat levels were significantly higher in watermelon seeds compared to teff (about double and up to 10-fold, respectively). Phytochemical analyses highlighted the abundance of phenolics, especially flavones, in TF, WSF and DWSF flours (244, 93, and 721 mg/kg, respectively). However, the value of total polyphenols was low in all materials (<2 mg GAE/g), which also correlates with the low antioxidant potential of the samples. Watermelon seed pomace was characterized by significantly higher melatonin concentration (60 µg/kg) than teff (3.5 µg/kg). This study provides new information on the chemical composition and application opportunities of teff and watermelon seeds.	
Karimi, E., et al. 2023	Watermelon consumption decreases risk factors of cardiovascular diseases: A systematic review and meta-analysis of randomized controlled trials.	This meta-analysis was conducted to examine the effects of watermelon supplementation on cardiovascular diseases (CVDs) risk factors in randomized controlled trials (RCTs). The comprehensive search was done in Cochrane Library databases, ISI Web of Science, PubMed, and Scopus up to March 2022. A random-effect model was used for computing weighted mean differences (WMD). Standard methods were applied to examine publication bias, sensitivity analysis, and heterogeneity. Of the 8962 identified studies, 9 RCTs were included in the final analysis. Watermelon consumption significantly decreased systolic blood pressure (SBP), total cholesterol (TC) and low-density lipoprotein (LDL). In addition, watermelon consumption led to a significant increase in fasting blood sugar (FBS). However, there was not any significant difference in other outcomes of interest including diastolic blood pressure (DBP), heart rate (HR), BMI, body fat, and serum levels of arginine, insulin, and CRP after watermelon supplementation. The current findings provide promising evidence of the antihypertensive effect of watermelon. However, due to the lack of evidence in human research, the result regarding the remaining outcomes needs to be used with caution. Further RCTs with longer follow-ups and larger sample sizes should be done to confirm the current findings.	[2]
Matthews, R., et al. 2023	The Effect of Watermelon Juice Supplementation on Heart Rate Variability and Metabolic Response during an Oral Glucose Challenge: A Randomized, Double-Blind, Placebo-	Heart rate variability (HRV) provides a simple method to evaluate autonomic function in health and disease. A reduction in HRV may indicate autonomic dysfunction and is strongly associated with aspects of cardiometabolic disease, including hyperglycaemia. Reduced nitric oxide (NO) bioavailability is also implicated in the development of cardiometabolic disease and autonomic dysfunction. Watermelons are natural sources of L-arginine and L-citrulline, substrates used for NO synthesis. Watermelon consumption can improve NO bioavailability. We conducted a randomized, double-blind, placebo-controlled crossover trial to test the effects of 2 weeks of daily watermelon juice (WMJ) supplementation on HRV in response to an oral glucose challenge (OGC) in healthy young adults. We also performed indirect calorimetry to assess if our intervention altered the metabolic response to the	[3]

	Controlled Crossover Trial.	OGC. WMJ supplementation preserved high-frequency power (HF) (treatment effect, p = 0.03) and the percentage of successive differences that differ by more than 50 ms (pNN50) (treatment effect, p = 0.009) when compared to the placebo treatment. There was no difference in resting energy expenditure or substate oxidation according to treatment. We report that WMJ supplementation attenuates OGC-induced reductions in HRV. Future work should emphasize the importance of NO bioavailability in autonomic dysfunction in cardiometabolic disease.	
Rezagholizade-Shirvan, A., et al. 2023	Evaluation of physicochemical, antioxidant, antibacterial activity, and sensory properties of watermelon rind candy.	Watermelon (Citrullus lanatus) is consumed all over the world that contains many seeds and rind, which is discarded. These by-products contain phytochemical compounds with great nutritional potential. This study aims to evaluate physicochemical properties and sensory values of watermelon rind candy. In this study in order to make the waste of watermelon a more sustainable and value-added food product, the watermelon rind was dried using an osmotic dehydration technique which comprises gradual impregnation of syrup (50 and 70% w/w - 1 to 5 h) before drying at 40 and 60 °C in 8 and 10 h. Various variables such as moisture content, chemical composition, water loss, solid gain, rehydration water, acidity, pH, antioxidant activity, antibacterial activity, residual toxins, phenolic and flavonoid contents during osmotic dehydration of watermelon were investigated. Results showed by rising temperatures, dehydration becomes more severe. Increasing the temperature in both osmotic samples in a concentrated solution (70%) and in osmotic samples with a dilute solution (50%) can enhance the mass transfer, water loss, solid absorption, as well as dehydration intensity. However, antioxidant activity, phenolic and flavonoid content significantly decreased after osmotic dehydration. TPC decreased from 35.83 mg/100 g to 27.45 mg/100 g and TFC of the watermelon rind (8.71 ± 0.01 mg/100 g) decreased to 2.63 ± 0.02 mg/100 g and antioxidant activity after the osmotic process decreased from 61% to 40%. Also, osmotic dehydration had no significant impact on acidity and pH. The watermelon rind dehydrated sample (osmosis temperature: 40 °C, osmotic solution concentration: 70%, immersion duration: 5 h) was the best choice of panellists due to the highest score in the sensory evaluation including taste, texture, and overall acceptability. By determining the hardness of the watermelon rind candy and comparing it with the results of texture analysis of other dried products, it can be concluded that this product can be used as a healthy snack with longer shelf-life properties.	[6]
REVIEW OR OPINION			
Figueroa, A. and A. Wong 2023	Editorial for the Special Issue Benefits of Supplementation with L-arginine, Citrulline and Watermelon on	The endothelium is crucial in controlling blood pressure and preventing cardiovascular diseases… [Editorial].	[9]

	Vascular and Metabolic Health.		
Rotimi, D. E. and R. M. Asaleye (2023).	"Impact of Watermelon (Citrallus lanatus) on Male Fertility.	Plants have been used in various regions of the world to treat various medical conditions including male infertility. The review aims to evaluate the pharmacological effects of watermelon consumption in improving male fertility and sexual function. Watermelon is a popular fruit consumed around the world for its diverse nutritional and health-promoting qualities. This study showed the mechanism via which watermelon enhances male fertility as it was reported for improving semen quality, reversing erectile dysfunction, enhancing testicular redox status, as well as improving gonadotropin secretion. These activities have been linked to their constituents as it contains vitamins and phytochemicals such as phenols and certain flavonoids that contribute to their antioxidant properties. Watermelon has also been noted to possess antimicrobial, anti-helminthic, antioxidant, antidiabetic, anti-inflammatory, and antihypertensive properties that may contribute to its therapeutic use.	[8]

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VM20003: NutritioniQ Update

Prepared for:

Hort Innovation
January 2024

Prepared by:

FOODiQ Global

Summary

The aim of this literature update is to provide updates to the science presented in the Melons and Human Health report and provide updates to information where required. PubMed was searched for articles published from the last date of the search performed for the Melons and Human Health report, using the same search strategy as previously outlined. Only human research studies have been included in this update.

Seven full text articles were retrieved and included in this current update. As with previous reports, intervention trials covered mainly watermelon, which was used in five of the seven studies. Findings from this NiQ update provide further evidence that watermelon consumption has beneficial effects on cardiometabolic risk factors.

The key findings for this literature update are consistent with the findings in the Melons and Human Health report for their effects on cardio health, anticancer effects and antibacterial effects.

Background

To create a database of all the research conducted on Melons and health, and to stay abreast of the latest clinical developments and advances in this area, our NUTRITIONiQ (NiQ) literature database service is executed every six months throughout the campaign. The NUTRITIONiQ database service conducts regular scientific searches and media monitoring that targets peer-reviewed literature, media reports, and clinical trial registries.

This NiQ research update captures systematic reviews, randomised controlled trials, and observational research conducted and published since July 7th, 2023, to capture literature published since the 'Melons and Human Health' and subsequent NIQ update reports were completed. This ensures FOODiQ stays across the latest in Melon Science and information gathered will be used to create 'Fun Facts', which may be included throughout the campaign to:

- Support key messages for resource and communication development

- Generate ideas for melon-related content
- Provide cutting-edge science for EDM updates

Methods

Medline database search was conducted on December 18th, 2023, for any new papers published since the previous search was conducted.

Search terms included those relating to melons (Watermelon or Citrullus lanatus or Muskmelon or Rockmelon or Cantaloupe or Cucumis melo var cantalupensis or Honeydew Melon or Cucumis melon var inodorus or Piel de Sapo or Crispy Pear Melon) and those related to health outcomes of interest (nutr* or Vitamin or Mineral or Bioactive or Health or metab* or Cardiovascular or Respiratory or inflamm* or Obesity or Body weight or diab* or Cognitive or Cognition or Macular or Eyesight or eye sight or vision or Cancer or Exercise or Sports performance or Bone or Renal or kidney or Hepatic or liver or Neural or nervous system or neonat* or Maternal or f?tal* or Pregnancy or Gastrointestinal or "Gut health" or microbio*). Searches were restricted to new articles published since previous search (July 9th, 2023)

Results

The search returned 84 articles for screening. From those, seven relevant full text articles were retrieved. These have been summarized with the abstracts for each article provided in **Table 1.** Almost all the research identified was related to watermelon, one with bitter melon and one for rockmelon, with no relevant returns for, honeydew melon, or Piel de Sapo melons.

Key Findings:

Cardiometabolic/cardiovascular factors

- The consumption of blended watermelon has shown promising effects on various cardiometabolic risk factors. Studies indicate improvements in BMI (Body Mass Index), BMIP (BMI Percentile), body fat composition, and HbA1c levels. These findings suggest that incorporating watermelon into one's diet may offer potential benefits for managing these risk factors [3].
- While there's a noted lack of human studies specifically addressing the antihypertensive effects of watermelon, the current findings from pre-

clinical research still shows promise. This hints at the possibility of watermelon contributing to lowering blood pressure, although further human-focused research is needed to solidify these observations [2].

Anticancer factors

- The research suggests that the extract derived from bitter melon could possess properties that impede the cellular uptake of glucose, leading to cytotoxicity specifically targeted at MCF-7 cells in breast cancer [4].
- Watermelon rind extract shows changes in cell activities related to programmed cell death and cell migration showing the potential anticancer properties [6].

Antibacterial/Anti-viral factors

- Given its rich abundance of naturally occurring bioactive compounds and enhanced effectiveness against S. mutans, watermelon extract stands as a viable resource for producing stannous nanoparticles providing an antibacterial effect. This presents a non-toxic alternative to the utilization of potentially hazardous chemicals [7].
- The presence of phytochemicals, particularly phytoestrogens like polyphenols, flavonoids, and prenylated compounds in wild watermelon juice, contributes significantly to inhibiting various stages of viral replication. Depending on their molecular structures, these compounds demonstrate distinct capacities to impede different phases of viral growth. These naturally occurring substances offer valuable insights for potential strategies aimed at developing antiviral therapies in the future [1].

Table 1: Summary of new published studies on Melons from July 2023 to December 2023 based on search criteria.

AUTHOR/YEAR	TITLE	ABSTRACT	REF
ORIGINAL RESEARCH			
Daughtry et al, 2023	Blenderized watermelon consumption decreases body mass index, body mass index percentile, body fat and HbA1c in children with overweight or obesity	Objectives: Childhood obesity increases risk factors related to metabolic diseases. Watermelon's bioactive components can help reduce these risk factors. However, no study has investigated the effects of whole watermelon including both the flesh and rind or have assessed the impacts of any form of watermelon on children with overweight or obesity. The goal of this study was to examine the effects of whole-blenderized watermelon (BWM) consumption on cardiometabolic risk factors. Methods: A randomized, cross-over clinical design was implemented. Boys and girls ages 10-17 years with overweight or obesity (BMI ≥ 85th percentile) consumed one cup of BWM or an isocaloric sugar-sweetened beverage (control) every day for 8 weeks with a 4-week washout between trials. Anthropometrics, dietary, biochemical and clinical measures were obtained before and at the end of each trial. Results: A total of 17 participants completed the study. Eight weeks of BWM intake significantly decreased BMI ($p = 0.032$), BMI percentile (BMIP) ($p = 0.038$), body fat percentage ($p = 0.036$), and haemoglobin A1c (HbA1c) ($p = 0.012$) compared to the sugar-sweetened beverage. Sugar-sweetened beverage consumption increased BMIP ($p = 0.014$) compared to baseline. No significant differences were observed for inflammation, blood glucose, insulin, lipids, liver function enzymes, and satiety hormones. Conclusions: The results support that BWM consumption improved some cardiometabolic risk factors including BMI, BMIP, body fat, and HbA1c. Watermelon is a potential alternative to unhealthful snacks for improving anthropometry and some risk factors related to obesity in children.	[3]
Kauturu et al, 2023	Bitter melon extract suppresses metastatic	Breast cancer is one of the most commonly diagnosed cancers among women, however the complete cure for metastatic breast cancer is lacking due to poor	[4]

	breast cancer cells (MCF-7 cells) growth possibly by hindering glucose uptake	prognosis. There has been an increasing trend of dietary modifications including consumption of natural food for the prevention of cancer. One of the popular natural foods is bitter melon. Bitter melon grows in tropical and subtropical areas. Some of the beneficial effects of bitter melon towards disease including cancer have been reported at the whole body/organismal level. However, specific cellular mechanisms by which bitter melon exerts beneficial effects in breast cancer are lacking. In this study, we used a human metastatic breast cancer cell line, MCF-7 cell, to study if bitter melon alters glucose clearance from the culture medium. We co-cultured MCF-7 cells with bitter melon extract in the presence and absence of supplemented insulin and subsequently measured MCF-7 cells viability. In this study, we report a noble finding that bitter melon extract exerts cytotoxic effects on MCF-7 cells possibly via inhibition of glucose uptake. Our findings show that insulin rescues MCF-7 cells from the effects of bitter melon extract.	
Gomes et al, 2023	Nanoparticles Loaded with a Carotenoid-Rich Extract from Cantaloupe Melon Improved Hepatic Retinol Levels in a Diet-Induced Obesity Preclinical Model	The study evaluated the effect of the carotenoid-rich extract from cantaloupe melon (CE) nanoencapsulated in porcine gelatin (EPG) on hepatic retinol concentration and liver damage scores in Wistar rats with obesity induced by high glycemic index and high glycemic load diet (HGLI diet). For 17 days, animals were fed the HGLI diet. They were divided into three groups and treated for 10 days [HGLI diet + water, HGLI diet + CE (12.5 mg/kg), and HGLI diet + EPG (50 mg/kg)]. The groups were evaluated for dietary intake, retinol, weight variation, hematological parameters, fasting glucose, lipid profile, hepatic retinol concentration, AST/ALT ratio, FIB-4 (Fibrosis-4 Index for Liver Fibrosis), and APRI (AST to Platelet Ratio Index) scores to evaluate the effects on the liver. Animals treated with EPG showed a lower dietary intake ($p < 0.05$). No significant weight change was detected in the evaluated groups ($p > 0.05$). The EPG-treated group had significantly higher concentrations ($p < 0.05$) of hepatic retinol [266 (45) μg/g] than the untreated group [186 (23.8) μg/g] and the one treated with CE [175 (8.08) μg/g]. Liver damage assessment scores did not show significant differences, but the lowest means were observed in the group treated with EPG. The nanoencapsulation of the extract rich in beta-carotene promoted reduced food consumption and increased hepatic retinol without causing significant changes in liver	[5]

		damage scores. Thus, EPG is a candidate for future clinical studies to evaluate the beneficial effects of treating diseases involving vitamin A deficiencies.	
Rajagopal et al, 2023	The Antibacterial Effectiveness of Citrullus lanatus-Mediated Stannous Nanoparticles on Streptococcus mutans	Introduction Dental caries is a prevalent oral health issue caused by the colonization of Streptococcus mutans in the oral cavity. Citrullus lanatus, commonly known as watermelon, is rich in bioactive compounds that possess antibacterial potential. In this study, we aimed to synthesize stannous chloride (SnCl2) nanoparticles (NPs) mediated by Citrullus lanatus extract and investigate their antibacterial effectiveness against Streptococcus mutans. Materials and method Stannous nanoparticles (SnNPs) synthesized by the green method were achieved by using the watermelon extract. Dilute stannous chloride solution was obtained by adding 0.45 g of stannous (Sn) chloride (Cl) powder to 60 mL of water, which was subjected to an orbital shaker with the watermelon extract. The nanoparticles obtained were subjected to characterization using antimicrobial testing, Fourier transform infrared (FTIR) spectroscopy, energy-dispersive X-ray (EDAX) analysis, and scanning electron microscopy (SEM). Agar well diffusion method was used against specific strains of S. aureus, S. mutans, and Escherichia coli. Results The novel nanoparticles demonstrated promising antibacterial activity against S. mutans providing 10 mm of inhibitory action. Conclusion Due to its abundance of naturally occurring bioactive chemicals and improved efficacy against S. mutans, watermelon extract can be utilized to create stannous nanoparticles as opposed to the use of toxic chemicals. They can also be employed as oral administration systems.	[7]
REVIEW or OPINION			
Morimoto et al, 2023	Anti-Influenza Virus Activity of Citrullus lanatus var. citroides as a Functional Food: A Review	Influenza is an acute respiratory illness caused by the influenza virus, in response to which vaccines and antiviral drugs are administered. In recent years, the antiviral effects of plants and foods have garnered attention. This review is the first to summarize the therapeutic properties of wild watermelon (Citrullus lanatus var. citroides) against influenza from a phytochemical viewpoint. Wild watermelon is a wild plant with significant potential as a therapeutic candidate in antiviral strategies, when focused on its multiple anti-influenza functionalities. Wild watermelon juice inhibits viral growth, entry, and replication. Hence, we highlight the possibility of utilizing wild	[1]

		watermelon for the prevention and treatment of influenza with stronger antiviral activity. Phytochemicals and phytoestrogen (polyphenol, flavonoids, and prenylated compounds) in wild watermelon juice contribute to this activity and inhibit various stages of viral replication, depending on the molecular structure. Wild plants and foods closely related to the original species contain many natural compounds such as phytochemicals, and exhibit various viral growth inhibitory effects. These natural products provide useful information for future antiviral strategies.	
Karimi et al, 2023	Watermelon consumption decreases risk factors of cardiovascular diseases: A systematic review and meta-analysis of randomized controlled trials	This meta-analysis was conducted to examine the effects of watermelon supplementation on cardiovascular diseases (CVDs) risk factors in randomized controlled trials (RCTs). The comprehensive search was done in Cochrane Library databases, ISI Web of Science, PubMed, and Scopus up to March 2022. A random-effect model was used for computing weighted mean differences (WMD). Standard methods were applied to examine publication bias, sensitivity analysis, and heterogeneity. Of the 8962 identified studies, 9 RCTs were included in the final analysis. Watermelon consumption significantly decreased systolic blood pressure (SBP), totalcholesterol (TC) and low-density lipoprotein (LDL). In addition, watermelon consumption led to a significant increase in fasting blood sugar (FBS). However, there was not any significant difference in other outcomes of interest including diastolic blood pressure (DBP), heart rate (HR), BMI, body fat, and serum levels of arginine, insulin, and CRP after watermelon supplementation. The current findings provide promising evidence of the antihypertensive effect of watermelon. However, due to the lack of evidence in human research, the result regarding the remaining outcomes needs to be used with caution. Furter RCTs with longer follow-ups and larger sample sizes should be done to confirm the current findings.	[2]
Reddy et al, 2023	From Fruit Waste to Medical Insight: The Comprehensive Role of Watermelon Rind Extract on Renal Adenocarcinoma	Cancer researchers are fascinated by the chemistry of diverse natural products that show exciting potential as anticancer agents. In this study, we aimed to investigate the anticancer properties of watermelon rind extract (WRE) by examining its effects on cell proliferation, apoptosis, senescence, and global gene expression in human renal cell adenocarcinoma cells (HRAC-769-P) in vitro. Our metabolome data analysis of WRE exhibited untargeted phyto-constituents and targeted citrulline (22.29 µg/mg). HRAC-	[6]

Cellular and Transcriptomic Dynamics	769-P cells were cultured in RPMI-1640 media and treated with 22.4, 44.8, 67.2, 88.6, 112, 134.4, and 156.8 mg·mL-1 for 24, 48, and 72 h. At 24 h after treatment, (88.6 mg·mL-1 of WRE) cell proliferation significantly reduced, more than 34% compared with the control. Cell viability decreased 48 and 72 h after treatment to 45% and 37%, respectively. We also examined poly caspase, SA-beta-galactosidase (SA-beta-gal), and wound healing activities using WRE. All treatments induced an early poly caspase response and a significant reduction in cell migration. Further, we analyzed the transcript profile of the cells grown at 44.8 mg·mL-1 of WRE after 6 h using RNA sequencing (RNAseq) analysis. We identified 186 differentially expressed genes (DEGs), including 149 upregulated genes and 37 downregulated genes, in cells treated with WRE compared with the control. The differentially expressed genes were associated with NF-Kappa B signaling and TNF pathways. Crucial apoptosis-related genes such as BMF, NPTX1, NFKBIA, NFKBIE, and NFKBID might induce intrinsic and extrinsic apoptosis. Another possible mechanism is a high quantity of citrulline may lead to induction of apoptosis by the production of increased nitric oxide. Hence, our study suggests the potential anticancer properties of WRE and provides insights into its effects on cellular processes and gene expression in HRAC-769-P cells.

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VM20003: NutritioniQ Update

Prepared for:

Hort Innovation
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Prepared by:

FOODiQ Global

Summary

The aim of this literature update is to provide updates to the science presented in the Melons and Human Health report and provide updates to information where required. PubMed was searched for articles published from the last date of the search performed for the Melons and Human Health report, using the same search strategy as previously outlined. Only human research studies have been included in this update.

Two research articles were identified and included within the current report; as per previous updates, both papers related to watermelon only. The two papers demonstrate innovative uses and processing techniques that may potentially enhance the value and nutritional quality of watermelon products. The first paper highlights the potential of using watermelon rind as a supplement in high-fiber pasta, improving its nutritional profile without compromising consumer acceptability. The second paper shows that pasteurization, combined with sulfites and acidification, preserves the nutritional and sensory qualities of watermelon juice better than reconstitution from vacuum-concentrate. These findings offer practical insights for maximizing the utilization and processing efficiency of watermelon products

Background

To create a database of all the research conducted on Melons and health, and to stay abreast of the latest clinical developments and advances in this area, our NUTRITIONiQ (NiQ) literature database service is executed every six months throughout the campaign. The NUTRITIONiQ database service conducts regular scientific searches and media monitoring that targets peer-reviewed literature, media reports, and clinical trial registries.

This NiQ research update captures systematic reviews, randomised controlled trials, and observational research conducted and published since July 7th, 2023, to capture literature published since the 'Melons and Human Health' and subsequent NIQ update reports were completed. This ensures FOODiQ stays across the latest in Melon Science and information gathered will be used to create 'Fun Facts', which may be included throughout the campaign to:

- Support key messages for resource and communication development
- Generate ideas for melon-related content
- Provide cutting-edge science for EDM updates
- Be used in communications with melon growers.

Methods

Medline database search was conducted on July 5th, 2024, for any new papers published since the previous search was conducted.

Search terms included those relating to melons (Watermelon or Citrullus lanatus or Muskmelon or Rockmelon or Cantaloupe or Cucumis melo var cantalupensis or Honeydew Melon or Cucumis melon var inodorus or Piel de Sapo or Crispy Pear Melon) and those related to health outcomes of interest (nutr* or Vitamin or Mineral or Bioactive or Health or metab* or Cardiovascular or Respiratory or inflamm* or Obesity or Body weight or diab* or Cognitive or Cognition or Macular or Eyesight or eye sight or vision or Cancer or Exercise or Sports performance or Bone or Renal or kidney or Hepatic or liver or Neural or nervous system or neonat* or Maternal or f?tal* or Pregnancy or Gastrointestinal or "Gut health" or microbio*). Searches were restricted to new articles published since previous search (December 18th, 2023)

Results

The search returned 87 articles for screening, none of which reported on health outcomes. Two articles focused on optimizing the nutritional properties of watermelon products (rind and juice). These findings may highlight new research and development opportunities. The abstracts for these articles are listed in **Table 1**.

Key Findings:

Hi-fibre pasta supplemented with watermelon rind

> Authors found that supplementing a high-fibre pasta with watermelon rind resulted in a higher soluble fibre, nutritional quality and antioxidant capacity, with a lower predicted glycaemic index. Supplementing with watermelon rind did impact the texture and cooking properties of the finished pasta; however, consumer testing showed no difference in the acceptability of the pasta. This highlights a potential area for the watermelon industry to provide a value-added product utilising byproducts of watermelon processing (i.e. rind).

Thermal processing of watermelon juice

> This study compared fresh, pasteurized, and reconstituted watermelon juices (from vacuum-concentrate) treated with sulfites and acidification. It evaluated their chemical profiles, including phenolics, amino acids, carotenoids, sugars, organic acids, and volatile compounds. Pasteurization preserved most compounds and enhanced typical watermelon aromas without creating off-flavors. In contrast, reconstitution reduced key

nutrients and volatiles. The study concluded that sulfite and acidification could maintain the nutritional and quality parameters of pasteurized watermelon juice, while vacuum concentration and reconstitution negatively impacted these aspects. The findings aim to improve thermal processing methods for better nutrient and flavor retention.

Table 1: Summary of new published studies on Melons from December 18th 2023 to July 5th 2023 based on search criteria.

AUTHOR/YEAR	TITLE	ABSTRACT	REF
Long et al, 2024	Quality of high-fibre pasta supplemented with watermelon rind powder with different particle sizes	**Research background:** Watermelon rind, a by-product of watermelon juice processing, contains large amounts of dietary fibre and phenols with antioxidant capacity. The use of agro-industrial by-products would both improve economic benefits and reduce environmental emissions. The aim of this research is to examine the effect of the particle size of watermelon rind powder on the quality of high-fibre pasta. **Experiment approach:** The nutritional, physical and physicochemical quality of three samples of watermelon rind powder, sieved through three sieves with aperture size of 400, 210 and 149 μm, were analysed. Durum wheat semolina with watermelon rind powder mass fraction of 10 % were mixed and used to make pasta. Nutritional, textural and cooking quality, sensory acceptability, in vitro glycaemic index and antioxidant bioaccessibility of high-fibre pasta with added watermelon rind powder of different particle sizes were evaluated and compared. **Results and conclusions:** When the sieve aperture size was reduced from 400 to 149 μm, the soluble dietary fibre and total phenolic contents of watermelon rind powder were increased by 35 and 15 %, respectively, while its insoluble dietary fibre content was decreased by 21 %. Decrease in sieve aperture size from 410 to 149 μm reduced phenolic bioaccessibility of the fortified pasta from 63 to 57 %, but enhanced its predicted glycaemic index from 50 to 69. It also decreased the pasta hardness by 13 %, but improved its elongation rate and tensile strength by 13 and 40 %, respectively. The finer the particles of the watermelon rind powder, the longer the optimal cooking time, the higher the water absorption index, and the lower the cooking loss of the supplemented pasta. Consumers did not notice any significant differences in the overall acceptability among all pasta samples. **Novelty and scientific contribution:** The particle size of the watermelon rind powder had a major effect on nutritional value, texture and cooking quality	(1)

		of the fortified pasta. In particular, the predicted glycaemic index and antioxidant bioaccessibility of high-fibre pasta were significantly affected by the particle size of the dietary fibre material used in the recipe.	
Cândido da Silva et al, 2024	Impact of sulfite use and acidification on chemical quality components in thermally processed watermelon juices	The present study compared pasteurized and reconstituted (from vacuum-concentrated) watermelon juices with sulfite use (~40 mg/L) and acidification (pH = 4.2) to fresh watermelon juices. The products were evaluated for phenolics, free amino acids, carotenoids, sugars, organic acids, and alcohols by high-performance liquid chromatography-HPLC and the volatile profile by headspace-gas chromatography/mass spectrometry(HS-GC/MS). Pasteurization had no significant impact on most of the chemical components. Furthermore, it potentiated typical watermelon aromas (E,E)-2,6-nonadienal, (Z)-3-nonen-1-ol, 4-hexen-1-ol, (E,Z)-3,6-nonadien-1-ol, 6-amino-2-methyl-2-heptanol, (E)-6-nonenal, (E)-2-nonenal, pentanal, nonanal and 1-nonanol), without off-flavor compounds formation. On the other hand, the reconstituted juice showed reduced amino acids (serine, glutamine, and tryptophan), phenolics (epicatechin gallate, myricetin, and cis-resveratrol), carotenoids (lycopene, β-carotene, and violaxanthin) and most volatile compounds. Our results showed that sulfite and acidification could maintain watermelon juice's nutritional and quality parameters after pasteurization. The vacuum concentration and reconstitution processes negatively impacted the evaluated compounds. Our findings contribute to improving thermal processes in watermelon juices for better preservation of nutrients, flavor, and bioactive compounds.	(2)

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