Australian Beverages Council

Submission to FSANZ Proposal P1062
Defining Added Sugars for Claims

8th October 2023

Australian Beverages

About the Australian Beverages Council Limited

The Australian Beverages Council Limited (ABCL) is the leading peak body representing the non-alcoholic beverages industry, and the only dedicated sector representative of its kind in Australia.

The ABCL represents approximately 95 per cent of the non-alcoholic beverages industry's production volume and our member companies are some of Australia's largest drinks manufacturers. The ABCL also represents many micro, small and medium-sized companies across the country. Collectively, the ABCL's members contribute more than $7 billion to the Australian economy and employ over 50,000 people across the nation. The industry also pays $1.2 billion in taxation per annum along its supply chain, and for every direct employee in the beverages manufacturing industry, there are 4.9 jobs required elsewhere in the economy to produce and retail beverages.

The ABCL strives to advance the whole industry, as well as successfully represent the range of beverages produced by members. These include carbonated soft drinks, energy drinks, sports and electrolyte drinks, frozen drinks, bottled and packaged waters, fruit juice and fruit drinks, cordials, iced teas, ready-to-drink coffees, kombucha, flavoured milk products and flavoured plant milks.

The ABCL advocates on issues such as portion sizes, front-of-pack and nutritional labelling, responsible industry marketing and advertising, and canteen guidelines, among others. Our members are responsible and responsive, listening to consumers and innovating to stand by a commitment to provide and promote more informed choice to Australians that supports a healthy and balanced diet.

Executive Summary

The Australian Beverages Council Limited (ABCL) appreciates the opportunity to provide comments to Food Standards Australia New Zealand (FSANZ) on its Call for Submission of Proposal P1062 – *Defining added sugars for claims.*

The ABCL acknowledges and supports FSANZ continuing to set 'no added sugar(s)' claim conditions of ingredients to foods within the Food Standards Code. We recognise the Australian and New Zealand dietary guidelines recommend people limit their intake of food and drinks containing added sugar and support consumers to be able to make informed choices about sugar in their diet in line with these guidelines.

In review of the proposal, the ABCL does not support some of the proposed amendments to Schedule 4 and does not believe that some of the proposed amendments will aid consumers in making informed choices about sugar in their diet. If anything, we believe they will mislead and confuse consumers.

The ABCL and its members recommend the following:

- A blend of single strength fruit products such as fruit puree + fruit juice should be permitted to make a 'no added sugar' claim;
- A distinction be made between fruit drinks that are (i) juice + water and fruit drinks that are (ii) juice + water + added sugar;
- Fruit drinks without added sugar should be permitted to make a no added sugar claim;
- Concentrated fruit products when reconstituted with water to single strength should not be considered 'added sugar';
- Exclude low energy sugars, such as D-tagatose, from 'added sugars' given their low energy value and how the body processes low energy sugars;
- Exclude carry-over ingredients from 'added sugars' given the amount of sugar is inconsequential in the final product;
- Separate honey, malt, malt extracts, concentrated fruit juice and deionised fruit juice from sugars which are defined as 'sugar', as opposed to sugars from 'products that contain sugar'.

The ABCL strongly believes and recommends that Proposal P1062 be conducted in parallel with Proposal P1058.

ABCL Response to Questions

1. FSANZ proposes to continue to set 'no added sugar(s)' claim conditions based on the addition of ingredients to foods (see section 5.2 of the Call for submissions document).

Do you have any comments on this approach?

The ABCL supports FSANZ continuing to set 'no added sugar(s)' claim conditions of ingredients to foods within the Australia New Zealand Food Standards Code. However, the ABCL does not support some of the proposed changes and definitions as outlined elsewhere in this submission.

Our industry was surprised to be given such a short deadline for this complex topic, having had no previous consultation, and given that the results of this proposal will have broad impact elsewhere, in particular to P1058 Nutrition Labelling About Added Sugars.

2. FSANZ proposes a food displaying a 'no added sugar(s)' claim must not contain an 'added sugars' as an added ingredient including an ingredient of a compound ingredient. FSANZ proposes defining 'added sugars' for this claim condition (see section 5.2.1.4 of the Call for submissions document).

FSANZ proposes to define 'added sugars' for the purpose of 'no added sugar(s)' claim conditions to mean the following derived from any source:

I. hexose monosaccharides and disaccharides
II. starch hydrolysate
III. glucose syrups, maltodextrin and similar products
IV. products derived at a sugar refinery, including brown sugar, molasses, raw sugar, golden syrup, treacle
V. icing sugar
VI. invert sugar
VII. sugar and sugar syrups derived from plants
VIII. honey
IX. malt
X. malt extracts
XI. concentrated fruit juice, unless the food for sale is fruit juice
XII. deionised fruit juice.

Do you have any comments on this approach or the defined added sugars (see below)?

The ABCL does not support this approach to the amendments to Condition (c).

Condition (c) *For the purposes of condition (a) and (e), added sugars means any of the following derived from any source*:
(i) hexose monosaccharides and disaccharides;
(ii) starch hydrolysate;
(iii) glucose syrup, maltodextrin and similar products;
(iv) a product derived at a sugar refinery (including brown sugar, molasses, raw sugar, golden syrup, treacle);
(v) icing sugar;
(vi) invert sugar;
(vii) sugar and sugar syrup derived from plants
(viii) honey;
(ix) malt;
(x) malt extracts;
(xi) concentrated fruit juice, unless the food for sale is fruit juice;
(xii) deionised fruit juice.

The ABCL contends that only concentrated fruit products which are not able to be reconstituted should be considered added sugar. **We recommend** amending the proposed wording from "*concentrated fruit juice, unless the food for sale is fruit juice"* to *"concentrated fruit product, unless reconstituted*". This is a more holistic approach and removes the need for further conditions around fruit products.

We contend the wording of condition (c) should be clearer, and strongly assert that any fruit product which is single strength, whether from concentrate, puree, concentrated puree, paste, powder or juice, should be allowed to make no added sugar claims.

The ABCL also emphasises that grouping these ingredients in condition (c) [from (i) to (xii)] together and treating them all as sugar, will likely mean that honey, malt, malt extracts, concentrated fruit juice and deionised fruit juice will need to be declared as added sugar(s) in the NIP under P1058.

The ABCL recommends ungrouping ingredients (viii) to (xii) from sugars which are 'sugar' [(i) to (vii)] and products / ingredients that contain sugar [(viii) to (xii)]. Therefore, added sugars are those ingredients listed (i) to (vii) but do not include (viii) through to (xii), which should be listed under a separate heading, such as 'And the following products'. We agree that the presence of these products [(viii) to (xii)] in other products for sale will prevent no added sugar claims from being made.

Condition (c) will have the most impact on P1058, in that those listed in the proposed condition will be considered added sugars and will likely be considered added sugar in the NIP under P1058. Currently under Schedule 4, ingredients defined as 'sugars' do not include those listed in the proposed condition (c) from (viii) to (xii). However, making a no added sugar claim is not permitted if the product contains malt, malt extract, honey and concentrated fruit juice (unless a beverage). These two conditions rule out (viii) to (xii) from being treated as added sugars in the NIP. With the proposed amended condition, this is no longer the case, as sugars which are made

of actual 'sugar' are grouped alongside 'products that contain sugar'. Therefore, these 'products' will likely be treated as added sugar in the NIP under P1058.

Incidental Sugars

As discussed in ABCL's response to the P1058 Background Paper, sugar (and its products) used as a carrier for additives or ingredients is a useful and effective way for the active ingredient to dissolve in the finished good without contributing in any way to the overall nutritional content of the finished good. For beverages, it is often extremely difficult for manufacturers to find an alternative carrier ingredient which does not contain sugar. For example, vitamin D is spray-dried onto a maltodextrin carrier. Our industry is solely dependent on ingredient/additive manufacturers to provide viable options to use in beverages. Our industry would like to continue to add vitamins to juices and retain the 'no added sugar' claim, as having vitamins in juice provides tangible benefits to consumers.

Carry-over ingredients that may contain very small/ insignificant sources of sugar need to be considered within the overall context of no added sugar claims. A relevant example is when sugar is used to standardise gums (used in food manufacturing). An ingredient manufacturer, in producing gum, will have a specification which the ingredient needs to meet, and therefore uses a free-flowing agent (such as sugar) to meet that specification.

When these carry-over ingredients are added to the final food, the amount of sugar is inconsequential. These are often processing aids and would not be listed in the ingredients list. In Proposal P1058 'Nutritional Labelling about Added Sugars' Industry proposed that a threshold value for the treatment of incidental sugar, e.g., 0.05g per 100mL, would allow manufacturers to use ingredients which contain an insignificant amount of sugar without impacting 'no added sugar' or 'no sugar' claims. Incidental amounts equal to or less than 0.05g per 100mL would therefore not be counted under 'total sugars' or 'added sugars'. If a threshold was applied that resulted in an 'added sugar' value rounded down to zero in the NIP, then the zero value would apply equally to both added sugars and total sugars. This would enable a product to maintain a 'no added sugar' and 'no sugar' claim.

In ABCL's response to the P1058 Background Paper, this topic was discussed extensively; and not including a threshold for incidental sugar under P1062, we believe is an omission. Currently any amount of incidental sugar precludes claims, which is incongruous when the amount of incidental sugar has no nutritional impact on the product or to the consumer.

This is further unmistakable evidence to support **our strong recommendation** that both P1062 and P1058 need to be conducted in parallel.

3. FSANZ proposes 'no added sugar(s)' and 'unsweetened' claims are not permitted on foods containing the hexose monosaccharide D-tagatose, as an ingredient, consistent with existing claim conditions in the Code. As D-tagatose is a hexose monosaccharide, it is captured in the definition of 'added sugars' (see section 5.2.2 of the Call for submissions document).

Do you have any comments on this approach?

The ABCL supports the position that unsweetened claims should not be permitted in foods containing 'low energy' sweeteners such as D-tagatose. However, we support being able to make 'no added sugar' claims if using low energy sugars and believe 'low energy' and 'traditional' sugars should be treated differently.

As discussed in our submission to the P1058 Background Paper, the ABCL supports the approach where mono- and disaccharides with an energy value of less than 17 kJ/g in section S11—2(3) are not 'added sugars'. This would include D-tagatose and allow foods containing D-tagatose to make 'no added sugar' claims. Given their low energy value and how the body processes D-tagatose and other low energy sugars, the ABCL supports an approach that permits foods containing low energy sugars to make a 'no added sugar' claim. Low energy sugars should not be treated as an added sugar in the NIP.

As FSANZ has outlined in Proposal P1062, *"D-tagatose has an energy value of 11 kJ/g (compared with 17 kJ/g (4.0 kcal/g) for carbohydrates in the Code) (subsection S11—2(3) of schedule 11). D-tagatose has technological properties similar to traditional sugars, however, it differs in that it is only partially absorbed by the body resulting in its reduced energy value. About 20–25% is absorbed from the small intestine, leaving 75–80%, which is available for fermentation in the large bowel. The major fraction of D-tagatose reaches the large intestine unabsorbed (where it undergoes fermentation). D-tagatose does not promote tooth decay and has minimal effects on blood glucose and insulin levels."*

The ABCL also supports and recommends D-allulose and other low energy sugars be permitted to make 'no added sugar' claims. Having consistent regulations for all low energy sugars and permitting low energy sugars to make a 'no added sugar' claim would allow for greater innovation of new products. It would also provide consumers with a better choice of products and offer an alternative to products containing high energy added sugar.

Given D-tagatose is a non-traditional sugar, the ABCL's concern is that under P1058, non-traditional sugars will be treated in the same way as traditional sugars and would be included in the NIP as added sugar. However, they are not the same. The body metabolises them differently, so non-traditional sugars should be treated differently from traditional sugars, for the purpose of defining added sugars.

Furthermore, it is unclear how non-traditional sugars will be addressed in the future, in terms of criteria that will be used determine if no added sugars claims can be made when these sugars

are used. An example of this is D-allulose (currently under assessment by FSANZ) which has an energy value of 1kJ/g. The ABCL expects FSANZ will have, by now formulated its position on the impact this will have on no added sugar claims. The ABCL requests FSANZ is clear on the criteria that will be used to assess future non-traditional sugars and sugar claims.

This is further evidence to support **our strong recommendation** that both P1062 and P1058 need to be conducted in parallel.

4. FSANZ proposes foods containing low energy sugars (mono- and disaccharides), as ingredients, listed in subsection S11—2(3) of Schedule 11 not be permitted to display 'unsweetened' claims (see section 5.2.2 of the Call for submissions document).

Do you have any comments on this approach?

The ABCL supports this approach.

Low energy sugars should not be allowed to make 'unsweetened' claims.

However, as discussed in Question 3 and in our response to the P1058 Background Paper, **the ABCL supports products containing low energy sugars being able to make 'no added sugar' claims.**

This is further unmistakable evidence to support **our strong recommendation** that both P1062 and P1058 need to be conducted in parallel.

5. FSANZ proposes a food displaying a 'no added sugar(s)' claim must not contain the fruit products listed below as an added ingredient (including as an ingredient of a compound ingredient). FSANZ proposes to exempt fruit products which are lemon or lime fruit (see section 5.3 of the Call for submissions document).

Do you have any comments on this approach, or the fruit products listed?

- dried fruit, other than whole, cut or chopped dried fruit
- fruit juice (other than concentrated fruit juice), unless the food for sale is canned fruit or frozen fruit
- fruit juice powder
- fruit powder
- fruit pulp
- fruit purée
- concentrated fruit purée.

Condition (a) *The food for sale does not contain any of the following as an added ingredient*:
(i) added sugars;
(ii) dried fruit other than whole, cut or chopped dried fruit;
(iii) fruit juice (other than concentrated fruit juice), unless the food for sale is canned fruit or frozen fruit;
(iv) fruit juice powder;
(v) fruit powder;
(vi) fruit pulp;
(vii) fruit purée;
(viii) concentrated fruit purée;
(ix) a blend or combination of any two or more ingredients listed above.

Example:
A food for sale that contains a blend of fruit puree and fruit juice as an ingredient added during production cannot be the subject of a claim about no added sugar.

The ABCL does not support this approach.

Single strength juices and products of fruit and vegetables **(including purée and pulp**) and reconstituted juices and products of fruit and vegetables (including powder, concentrated purees, and paste) **should not be considered an added sugar**. The ABCL believes that when any fruit product is single strength, and is used in any application, it should be able to make a no added sugar claim. Having different rules apply depending on the finished food for sale, or the type of fruit product, is confusing for both manufacturers and consumers. These fruit products, at single strength, have the same sugar content as that of fresh fruit. These naturally occurring sugars are intrinsic to these fruits and should not be considered added sugar. The **ABCL recommends** that condition (a) is removed, that a more holistic approach is taken, and that 'concentrated fruit products, unless reconstituted to single strength' should not be allowed to make a no added sugar claim.

The ABCL believes the example in condition (a) is confusing and should be removed. Since this Proposal was written, FSANZ has confirmed that a mix of puree and juice will allow a no added sugar claim to be made, providing the end product (i.e., fruit juice) meets Standard 2.6.1.

If fruit drinks (that meet Standard 2.6.2) that are diluted fruit juice, i.e., fruit juice with only water added, are unable to make a no added sugar claim, they cannot be differentiated from sugar sweetened fruit drinks. This misleads consumers and could result in them choosing a sweetened fruit juice drink over an unsweetened one, thinking they are both the same. We support unsweetened fruit juice drinks retaining their ability to make a no added sugar claim to help consumers make an informed choice in this category.

The ABCL contends that, provided the fruit product is single strength in the food - obtained either by reconstitution or directly added as Not From Concentrate (NFC), it should not be counted as an added sugar. Therefore, there should be no loss of the no added sugar claim. It makes no sense that a fruit juice can make a no added sugar claim, but as soon as water is added to that fruit juice, and it becomes a fruit drink, the no added sugar claim is lost. This is confusing,

misleading, and unhelpful for consumers. Without the clear distinction between fruit drinks with 'no added sugar' and sugar sweetened fruit drinks, consumers cannot make an informed choice based on the packaging if all fruit drinks are labelled in the same manner, regardless of the presence of high energy sugars.

Here we reference the New Zealand Dietary Guidelines (NZDG): page 10 of the CFS states "For children and young people, the MoH recommends limiting intake of fruit juice to no more than one diluted glass per day, equating to a maximum of 250 mL after the juice has been diluted (MoH 2015)". This is a clear example of how unsweetened fruit drinks (which are diluted fruit juices) support consumers to make healthy food choices in support of dietary guidelines. It further provides strong grounds for unsweetened fruit drinks to retain their no added sugar claim.

Fruit Drinks are the food for sale and are required to meet the composition requirements of Standard 2.6.2, therefore fruit juice + water is the food for sale. On that basis, fruit drinks should be treated separately and made exempt from the proposed claim conditions of not allowing no added sugar claims when fruit juice is added as an ingredient to food.

Fruit paste is not listed in Condition (a). **ABCL requests FSANZ adds it to Condition (a)**.

6. FSANZ proposes a fruit product which is the food for sale (e.g. fruit juice) be permitted to make a 'no added sugar(s)' claim. This includes when the food is sold as a singular fruit (e.g. apple juice) or a blend of different fruits (e.g. blend of fruit juices), providing the food contains no 'added sugars' or other products identified in claim conditions, as added ingredients. A blend or combination of different fruit products (e.g. fruit juice and fruit purée) will not be permitted to make the claim. FSANZ also proposes to clarify that fruit does not include legumes, fungi, herbs, nuts and spices for the purpose of the claim conditions (see section 5.3 of the Call for submissions document).

Do you have any comments on this approach?

The ABCL does not support this approach.

Condition (b) *The food for sale is not a blend or combination of any two or more ingredients listed in sub-paragraphs (i) to (viii) of condition (a).*
Example:
A food for sale that is a blend of concentrated fruit juice and minced dried fruit cannot be the subject of a claim about no added sugar.

Regardless of application, if the fruit (and vegetable) component is reconstituted to single strength, then no added sugar claims should be permitted.

The example in Question 6 above (fruit juice and fruit puree) is a contradiction. As stated above, fruit juice and puree mixed together (as the food for sale) is not permitted to make a no added

sugar claim. However, we note that FSANZ, during this consultation period, has confirmed in writing that when fruit juice and puree are the food for sale and meet the requirements of Standard 2.6.1, a no added sugar claim is permitted.

Naturally occurring sugars that are intrinsic to the fruit and vegetable juice have not been added by the manufacturer. The simple concept for consumers to understand 'added sugars' is that they are sugars added by the manufacturer. We note the proposal mentions that the definition should enable consumers to make informed choices in support of dietary guidelines and should not confuse or mislead them. However, the proposed approach that fruit products which are single strength, or reconstituted to single strength, are considered added sugar, will likely confuse consumers comparing fruit and vegetable juices containing only intrinsic sugars with those 'sweetened' with additional sugar sources. Purees, such as mango, guava, and banana are the whole fruit, capturing all the goodness of the fruit, including the fibre. Therefore, purees are as nutritious as juice. Purees, where sold on their own, in any application or finished good, e.g., guava juice product; or where juice is added to them, e.g., mango puree and orange juice, should not be treated as added sugar. Treating intrinsic sugars in fruit and vegetable juices and purees as 'added sugars' does not enable consumers to make an informed choice around their intake of sugars added during manufacturing versus intrinsic sugars, nor distinguish between one product or the other.

The inconsistent treatment of intrinsic sugars in dairy versus fruit we also contend will confuse and mislead consumers. General consumer understanding is that sugars from a piece of fruit or vegetable are naturally occurring, and that understanding translates to the sugars found in single strength fruit and vegetable juice and purees. The proposed change to consider sugars in single strength juice as 'added sugars', when that juice is added as an ingredient to food or beverages, will mislead consumers to believe *other* separate sugars have been added to the beverage by the manufacturer when this is not the case. With the exclusion of milk and dairy products from the added sugar definition, the proposed change is disadvantaging one product category over the other, when both contain intrinsic sugars.

We note the US FDA does not consider single strength fruit and vegetable juices as added sugar or concentrated fruit and vegetable juices that are reconstituted to single strength (and any concentrated juice in excess is counted as added sugar)[1].

The Australian Dietary Guidelines [ADG] recognises the positive contribution juice (no added sugar) makes to a healthy dietary pattern and its role in helping many Australians meet their recommended daily fruit serves. Juice is included in the 'core food' fruit recommendations: 125mL of fruit juice with no added sugar can be included as a serve of fruit occasionally.

Condition (b) is about the mixing of two or more ingredients together, e.g., whole fruit puree and fruit juice. It makes no sense that these two ingredients, once mixed together cannot make a 'no added sugar' claim. A juice is allowed to make a no added sugar claim on its own; puree is allowed to make a no added sugar claim when sold as puree; but when the two are mixed

[1] *U.S. Food and Drug Administration (Nutrition and Supplement Facts Labels: Questions and Answers Related to the Compliance Date, Added Sugars, and Declaration of Quantitative Amounts of Vitamins and Minerals: Guidance for Industry), December 2019*

together a no added sugar claim is disallowed. This proposed condition will only create confusion among consumers. Therefore, **the ABCL strongly recommends that this condition be removed** as it is illogical. Banana puree in a tropical juice is permitted under Codex Stan 247 – 500. Some fruits (e.g., bananas, mangoes, berries, guava etc.) cannot be 'juiced' and therefore must be pureed. They are made into juice blend products are currently able to make a no added sugar claim. Compared to an apple or orange juice which is still able to make the claim, any situation where two or more fruit products are mixed together (e.g., tropical juice) can no longer make a claim, despite these being reconstituted/ single strength. **The ABCL recommends** that any fruit product which is single strength, either not from concentrate or reconstituted, should be able to claim a 'no added sugar' claim regardless of the finished juice it goes into.

The ABCL supports deionised fruit juice will be counted as added sugar as indicated in the paper.

7. FSANZ proposes 'no added sugar(s)' claims are not permitted when the concentration of sugars in the food is increased from the hydrolysis of carbohydrates during food manufacture, except when the sugars concentration in cereal-based plant milks made using hydrolysis is ≤ 1.5% (and the product otherwise meets claim conditions) (see section 5.3.2 of the Calls for submissions document).

The ABCL seeks further clarification from FSANZ regarding this proposition.

The ABCL finds the proposed threshold acceptable. However, we seek further clarification for products that have a sugars concentration of more than 1.5%. For example, how would products that have a sugars concentration of 1.7% be presented in the NIP based on Proposal P1058? Without seeing a final response to P1058, we are unable to fully support this proposed threshold.

This is further unmistakable evidence to support **our strong recommendation** that both P1062 and P1058 need to be conducted in parallel.

Furthermore, while FSANZ has acknowledged the complexity around hydrolysis technology by assigning a threshold value, the ABCL wonders if an arbitrary value is limiting to other production types and products. While the ABCL agrees there should be a distinction between incidental sugars created by hydrolysis versus the intentional/purposeful increase of sugars, if intentional, then the no added sugars claim should be lost. However, in terms of the value itself, to future proof this requirement, we postulate that the regulation could include language for 'incidental/intentional' rather than a threshold value to allow flexibility in production technologies which are difficult to control at incidental levels. **We ask FSANZ to please review this**.

8. FSANZ proposes to maintain the existing condition that a food displaying an 'unsweetened' claim must meet the conditions for a 'no added sugar(s)' claim, noting that the amended 'no added sugar(s)' claim conditions will apply (see section 5.4 of the Call for submissions document).

Do you have any comments on this approach?

The ABCL supports this approach, provided our concerns regarding the proposed no added sugar claims are addressed. In principle, the ABCL support the above, however, our concerns regarding the proposed definition of added sugar need to be taken into consideration.

In addition;

Unsweetened Claims:
*Condition (c): The food does not contain, as an ingredient or as an ingredient of a *compound ingredient, a monosaccharide or disaccharide listed in the table to subsection S11—2(3).*

See response to Question 2 regarding carry-over ingredients that may contain exceedingly small/ insignificant sources of sugar and the allowances that need to be made for these (either threshold or explicit exemption).

9. FSANZ proposes to maintain the existing condition for intense sweeteners, sorbitol, mannitol, glycerol, xylitol, isomalt, maltitol syrup or lactitol. FSANZ proposes a food containing low energy sugars (mono- and disaccharides) listed in subsection S11—2(3) of schedule 11, as an ingredient (including an ingredient of a compound ingredient), not be permitted to display an 'unsweetened' claim (see section 5.4 of the Call for submissions document).

Do you have any comments on this approach?

The ABCL supports the approach to maintain the existing condition that intense sweeteners are not permitted to display an 'unsweetened' claim. We also support the approach to disallow low energy sugars to make an 'unsweetened' claim as they are added for sweetening purposes.

However, as per our comments in question 3 and 4 and in our response to the P1058 Background Paper, we contend that D-tagatose should not be considered an added sugar but that its presence would not permit an unsweetened claim.

Low energy sugars should be explicitly excluded from the conditions of an 'added sugars' claims as per unsweetened condition (a).

This is further unmistakable evidence to support **our strong recommendation** that both P1062 and P1058 need to be conducted in parallel.

10. FSANZ is proposing a two-year transition period to allow producers, manufacturers and importers time to make any required labelling changes for products carrying 'no added sugar(s)' or 'unsweetened' claims to comply with the new claim conditions (see section 7 of the Call for submissions document).

Do you have any comments on this approach?

The ABCL does not support this approach.

Given there are multiple regulatory updates happening concurrently, plus other regulatory changes in the transition phase, **the ABCL recommends** a three-year transition and a greater than two-year stock in trade provision. As P1062 is not related to safety, the Plain English Allergen Labelling (PEAL) Proposal P1044 should be used as a precedent for a longer transition period and stock in trade provision. This additional time should not cause an issue, as there is no health or safety risk to consumers regarding the claims, and the longer overall transition period would support upcoming and ongoing packaging changes.

We also strongly recommend that P1062 and P1058 are conducted in parallel, to minimise pack/artwork changes, as these come at an exceedingly high cost to industry. The cost of a single labelling change can range from $100,000 (for a small beverage company) to $2.5 million (for a large beverage company). This does not count the cost of Scope 1, 2 and 3 raised carbon emissions from the destruction, creation and placement of new labels on pack.

This is further unmistakable evidence to support **our strong recommendation** that both P1062 and P1058 need to be conducted in parallel.

Data and evidence

FSANZ welcomes additional data and evidence from stakeholders to support its consideration of input and feedback on this proposal.

The following questions provide you with an opportunity to include or upload relevant data and evidence.

11. Do you have any data or are you aware of published data on the number of products with 'no added sugar(s)' or 'unsweetened' claims in Australia and/or New Zealand (see data used for this proposal at section 3.1 of the Call for submissions document)?

Yes / No

Please provide and editable PDF, Excel spreadsheet or Word document.
If yes, please upload your file here. Please make sure your file is under 25MB

No

12. Do you have any evidence or are you aware of published literature on consumer understanding of and responses to 'no added sugar(s)' or 'unsweetened' claims on food products (see evidence used for this proposal at section 3.2 of the Call for submissions report and Supporting Document 1)?

Yes / No

Please provide an editable PDF, Excel spreadsheet or Word document
If yes, please upload your file here. Please make sure your file is under 25MB

No

13. Do you have any data or know of any published data on the costs of labelling changes per stock keeping unit or package type (see data used for this proposal at Attachment E to the Call for submissions document)?

Yes / No

Please provide an editable PDF, Excel spreadsheet or Word document
If yes, please upload your file here
Please make sure your file is under 25MB

Yes: The ABCL conducted a survey of their members and what the impact a label change on beverages would be.[2] This data was shared with FSANZ in 2022. We attach it here.

ABCL data – the impact of a label change on beverages: A survey of ABCL members

Additional comments

Please provide any other input, data or evidence to support your submission below.
Top of Form
Comments and other input
Additional comments and input
Please upload an editable PDF, Excel spreadsheet or Word document.

1. Evidence to Support the Benefits of Juice

The ABCL would like to insert the references discussed in Question 5, as well as other literature to support juice. The literature can be found in the following appendices..

2. Vegetable juices

Vegetable juices are exempt from this proposal, but FSANZ has not explicitly provided a definition of fruit and vegetable. **ABCL requests clarification on this**. For example, tomatoes are classified as 'Fruiting Vegetables' under Schedule 22 of the Code. **We ask FSANZ to clarify if tomatoes are a fruit or a vegetable**. Can vegetable purees be added to a juice and have a 'no added sugar claim, if the final food meets Standard 2.6.1?

ABCL requests FSANZ provides clarity and a confirmation on this issue, as the information in this proposal contradicts the information FSANZ provided about single strength blends during its P1062 Webinar.

[redacted]

[2] *Australian Beverages Council Limited (The impact of a label change on beverages: A survey of ABCL members), September 2022*

Response ID ANON-JN9Z-F8DX-5

Submitted to P1062 - Defining added sugars for claims
Submitted on 2023-10-08 21:27:49

Complete your submission

Your details

What is your name?

[redacted]

What is your email address?

Email address:
[redacted]

What is your telephone number?

Telephone:
[redacted]

Which one of the following groups do you most affiliate with?

Food industry

If other, please specify:

What is the name of your organisation?

Please write N/A if this does not apply.:
Australian Beverages Council Ltd

What is your position title?

Please write N/A if this does not apply.:
[redacted]

Are you the contact person for your organisation?

Yes

If you are not the contact person for your organisation, please provide an alternative contact and details. If not applicable, please leave blank.

Contact person's name:

Email address:

Telephone:

Position title:

Have you read the P1062 – Defining added sugars for claims call for submission paper?

Yes

Confidential information

All submissions will be published, including redacted versions of confidential submissions. We will not publish material that we accept as confidential. Does your submission contain confidential information?

No. My submission does not contain confidential information.

Proposed changes to 'no added sugar(s)' claim conditions

1 FSANZ proposes to continue to set 'no added sugar(s)' claim conditions based on the addition of ingredients to foods (see section 5.2 of the Call for submissions document).

Do you have any comments on this approach?:

The ABCL supports FSANZ continuing to set 'no added sugar(s)' claim conditions of ingredients to foods within the Australia New Zealand Food Standards Code. However, the ABCL does not support some of the proposed changes and definitions as outlined elsewhere in this submission.

Our industry was surprised to be given such a short deadline for this complex topic, having had no previous consultation, and given that the results of this proposal will have broad impact elsewhere, in particular to P1058 Nutrition Labelling About Added Sugars.

2 FSANZ proposes a food displaying a 'no added sugar(s)' claim must not contain an 'added sugars' as an added ingredient including an ingredient of a compound ingredient. FSANZ proposes defining 'added sugars' for this claim condition (see section 5.2.1.4 of the Call for submissions document).

Do you have any comments on this approach or the defined added sugars (see below)?:

The ABCL does not support this approach to the amendments to Condition (c).

Condition (c) For the purposes of condition (a) and (e), added sugars means any of the following derived from any source:
(i) hexose monosaccharides and disaccharides;
(ii) starch hydrolysate;
(iii) glucose syrup, maltodextrin and similar products;
(iv) a product derived at a sugar refinery (including brown sugar, molasses, raw sugar, golden syrup, treacle);
(v) icing sugar;
(vi) invert sugar;
(vii) sugar and sugar syrup derived from plants
(viii) honey;
(ix) malt;
(x) malt extracts;
(xi) concentrated fruit juice, unless the food for sale is fruit juice;
(xii) deionised fruit juice.

The ABCL contends that only concentrated fruit products which are not able to be reconstituted should be considered added sugar. We recommend amending the proposed wording from "concentrated fruit juice, unless the food for sale is fruit juice" to "concentrated fruit product, unless reconstituted". This is a more holistic approach and removes the need for further conditions around fruit products.

We contend the wording of condition (c) should be clearer, and strongly assert that any fruit product which is single strength, whether from concentrate, puree, concentrated puree, paste, powder or juice, should be allowed to make no added sugar claims.

The ABCL also emphasises that grouping these ingredients in condition (c) [from (i) to (xii)] together and treating them all as sugar, will likely mean that honey, malt, malt extracts, concentrated fruit juice and deionised fruit juice will need to be declared as added sugar(s) in the NIP under P1058.

The ABCL recommends ungrouping ingredients (viii) to (xii) from sugars which are 'sugar' [(i) to (vii)] and products / ingredients that contain sugar [(viii) to (xii)]. Therefore, added sugars are those ingredients listed (i) to (vii) but do not include (viii) through to (xii), which should be listed under a separate heading, such as 'And the following products'. We agree that the presence of these products [(viii) to (xii)] in other products for sale will prevent no added sugar claims from being made.

Condition (c) will have the most impact on P1058, in that those listed in the proposed condition will be considered added sugars and will most likely be considered added sugar in the NIP under P1058. Currently under Schedule 4, ingredients defined as 'sugars' do not include those listed in the proposed condition (c) from (viii) to (xii). However, making a no added sugar claim is not permitted if the product contains malt, malt extract, honey and concentrated fruit juice (unless a beverage). These two conditions rule out (viii) to (xii) from being treated as added sugars in the NIP. With the proposed amended condition, this is no longer the case, as sugars which are made of actual 'sugar' are grouped alongside 'products that contain sugar'. Therefore, these 'products' will likely be treated as added sugar in the NIP under P1058.

Incidental Sugars
As discussed in ABCL's response to the P1058 Background Paper, sugar (and its products) used as a carrier for additives or ingredients is a useful and effective way for the active ingredient to dissolve in the finished good without contributing in any way to the overall nutritional content of the finished good. For beverages, it is often extremely difficult for manufacturers to find an alternative carrier ingredient which does not contain sugar. For example, vitamin D is spray-dried onto a maltodextrin carrier. Our industry is solely dependent on ingredient/additive manufacturers to provide viable options to use in beverages. Our industry would like to continue to add vitamins to juices and retain the 'no added sugar' claim, as having vitamins in juice provides tangible benefits to consumers.
Carry-over ingredients that may contain very small/ insignificant sources of sugar need to be considered within the overall context of no added sugar claims. A relevant example is when sugar is used to standardise gums (used in food manufacturing). An ingredient manufacturer, in producing gum, will have a specification which the ingredient needs to meet, and therefore uses a free-flowing agent (such as sugar) to meet that specification.

When these carry-over ingredients are added to the final food, the amount of sugar is inconsequential. These are often processing aids and would not be listed in the ingredients list. In Proposal P1058 'Nutritional Labelling about Added Sugars' Industry proposed that a threshold value for the treatment of incidental sugar, e.g., 0.05g per 100mL, would allow manufacturers to use ingredients which contain an insignificant amount of sugar without impacting 'no added sugar' or 'no sugar' claims. Incidental amounts equal to or less than 0.05g per 100mL would therefore not be counted under 'total sugars' or 'added sugars'. If a threshold was applied that resulted in an 'added sugar' value rounded down to zero in the NIP, then the zero value would apply equally to both added sugars and total sugars. This would enable a product to maintain a 'no added sugar' and 'no sugar' claim.

In ABCL's response to the P1058 Background Paper, this topic was discussed extensively; and not including a threshold for incidental sugar under P1062, we believe is an omission. Currently any amount of incidental sugar precludes claims, which is incongruous when the amount of incidental sugar has no nutritional impact on the product or to the consumer.

This is further clear evidence to support our strong recommendation that both P1062 and P1058 need to be conducted in parallel.

3 FSANZ proposes 'no added sugar(s)' and 'unsweetened' claims are not permitted on foods containing the hexose monosaccharide D-tagatose, as an ingredient, consistent with existing claim conditions in the Code. As D-tagatose is a hexose monosaccharide, it is captured in the definition of 'added sugars' (see section 5.2.2 of the Call for submissions document).

Do you have any comments on this approach?:

The ABCL supports the position that unsweetened claims should not be permitted in foods containing 'low energy' sweeteners such as D-tagatose. However, we support being able to make 'no added sugar' claims if using low energy sugars and believe 'low energy' and 'traditional' sugars should be treated differently.

As discussed in our submission to the P1058 Background Paper, the ABCL supports the approach where mono- and disaccharides with an energy value of less than 17 kJ/g in section S11—2(3) are not 'added sugars'. This would include D-tagatose and allow foods containing D-tagatose to make 'no added sugar' claims. Given their low energy value and how the body processes D-tagatose and other low energy sugars, the ABCL supports an approach that permits foods containing low energy sugars to make a 'no added sugar' claim. Low energy sugars should not be treated as an added sugar in the NIP.
As FSANZ has outlined in Proposal P1062, "D-tagatose has an energy value of 11 kJ/g (compared with 17 kJ/g (4.0 kcal/g) for carbohydrates in the Code) (subsection S11—2(3) of schedule 11). D-tagatose has technological properties similar to traditional sugars, however, it differs in that it is only partially absorbed by the body resulting in its reduced energy value. About 20–25% is absorbed from the small intestine, leaving 75–80%, which is available for fermentation in the large bowel. The major fraction of D-tagatose reaches the large intestine unabsorbed (where it undergoes fermentation). D-tagatose does not promote tooth decay and has minimal effects on blood glucose and insulin levels."

The ABCL also supports and recommends D-allulose and other low energy sugars be permitted to make 'no added sugar' claims. Having consistent regulations for all low energy sugars and permitting low energy sugars to make a 'no added sugar' claim would allow for greater innovation of new products. It would also provide consumers with a better choice of products and offer an alternative to products containing high energy added sugar.

Given D-tagatose is a non-traditional sugar, the ABCL's concern is that under P1058, non-traditional sugars will be treated in the same way as traditional sugars and would be included in the NIP as added sugar. However, they are not the same. The body metabolises them differently, so non-traditional sugars should be treated differently from traditional sugars, for the purpose of defining added sugars.
Furthermore, it is unclear how non-traditional sugars will be addressed in the future, in terms of criteria that will be used determine if no added sugars claims can be made when these sugars are used. An example of this is D-allulose (currently under assessment by FSANZ) which has an energy value of 1kJ/g. The ABCL expects FSANZ will have, by now formulated its position on the impact this will have on no added sugar claims. The ABCL requests FSANZ is clear on the criteria that will be used to assess future non-traditional sugars and sugar claims.

This is further evidence to support our strong recommendation that both P1062 and P1058 need to be conducted in parallel.

4 FSANZ proposes foods containing low energy sugars (mono- and disaccharides), as ingredients, listed in subsection S11—2(3) of Schedule 11 not be permitted to display 'unsweetened' claims (see section 5.2.2 of the Call for submissions document).

Do you have any comments on this approach?:

The ABCL supports this approach.

Low energy sugars should not be allowed to make 'unsweetened' claims.

However, as discussed in Question 3 and in our response to the P1058 Background Paper, the ABCL supports products containing low energy sugars being able to make 'no added sugar' claims.

This is further clear evidence to support our strong recommendation that both P1062 and P1058 need to be conducted in parallel.

5 FSANZ proposes a food displaying a 'no added sugar(s)' claim must not contain the fruit products listed below as an added ingredient (including as an ingredient of a compound ingredient). FSANZ proposes to exempt fruit products which are lemon or lime fruit (see section 5.3 of the Call for submissions document).

Do you have any comments on this approach or the fruit products listed?:

Condition (a) The food for sale does not contain any of the following as an added ingredient:
(i) added sugars;
(ii) dried fruit other than whole, cut or chopped dried fruit;
(iii) fruit juice (other than concentrated fruit juice), unless the food for sale is canned fruit or frozen fruit;
(iv) fruit juice powder;
(v) fruit powder;
(vi) fruit pulp;
(vii) fruit purée;
(viii) concentrated fruit purée;

(ix) a blend or combination of any two or more ingredients listed above.

Example:
A food for sale that contains a blend of fruit puree and fruit juice as an ingredient added during production cannot be the subject of a claim about no added sugar.

The ABCL does not support this approach.

Single strength juices and products of fruit and vegetables (including purée and pulp) and reconstituted juices and products of fruit and vegetables (including powder, concentrated purees, and paste) should not be considered an added sugar. The ABCL believes that when any fruit product is single strength, and is used in any application, it should be able to make a no added sugar claim. Having different rules apply depending on the finished food for sale, or the type of fruit product, is confusing for both manufacturers and consumers. These fruit products, at single strength, have the same sugar content as that of fresh fruit. These naturally occurring sugars are intrinsic to these fruits and should not be considered added sugar. The ABCL recommends that condition (a) is removed, that a more holistic approach is taken, and that 'concentrated fruit products, unless reconstituted to single strength' should not be allowed to make a no added sugar claim.

The ABCL believes the example in condition (a) is confusing and should be removed. Since this Proposal was written, FSANZ has confirmed that a mix of puree and juice will allow a no added sugar claim to be made, providing the end product (i.e., fruit juice) meets Standard 2.6.1.

If fruit drinks (that meet Standard 2.6.2) that are diluted fruit juice, i.e., fruit juice with only water added, are unable to make a no added sugar claim, they cannot be differentiated from sugar sweetened fruit drinks. This misleads consumers and could result in them choosing a sweetened fruit juice drink over an unsweetened one, thinking they are both the same. We support unsweetened fruit juice drinks retaining their ability to make a no added sugar claim to help consumers make an informed choice in this category.

The ABCL contends that, provided the fruit product is single strength in the food - obtained either by reconstitution or directly added as Not From Concentrate (NFC), it should not be counted as an added sugar. Therefore, there should be no loss of the no added sugar claim. It makes no sense that a fruit juice can make a no added sugar claim, but as soon as water is added to that fruit juice, and it becomes a fruit drink, the no added sugar claim is lost. This is confusing, misleading, and unhelpful for consumers. Without the clear distinction between fruit drinks with 'no added sugar' and sugar sweetened fruit drinks, consumers cannot make an informed choice based on the packaging if all fruit drinks are labelled in the same manner, regardless of the presence of high energy sugars.

Here we reference the New Zealand Dietary Guidelines (NZDG): page 10 of the CFS states "For children and young people, the MoH recommends limiting intake of fruit juice to no more than one diluted glass per day, equating to a maximum of 250 mL after the juice has been diluted (MoH 2015)". This is a clear example of how unsweetened fruit drinks (which are diluted fruit juices) support consumers to make healthy food choices in support of dietary guidelines. It further provides strong grounds for unsweetened fruit drinks to retain their no added sugar claim.

Fruit Drinks are the food for sale and are required to meet the composition requirements of Standard 2.6 2, therefore fruit juice + water is the food for sale. On that basis, fruit drinks should be treated separately and made exempt from the proposed claim conditions of not allowing no added sugar claims when fruit juice is added as an ingredient to food.

Fruit paste is not listed in Condition (a). ABCL requests FSANZ adds it to Condition (a).

6 FSANZ proposes a fruit product which is the food for sale (e.g. fruit juice) be permitted to make a 'no added sugar(s)' claim. This includes when the food is sold as a singular fruit (e.g. apple juice) or a blend of different fruits (e.g. blend of fruit juices), providing the food contains no 'added sugars' or other products identified in claim conditions, as added ingredients. A blend or combination of different fruit products (e.g. fruit juice and fruit purée) will not be permitted to make the claim. FSANZ also proposes to clarify that fruit does not include legumes, fungi, herbs, nuts and spices for the purpose of the claim conditions (see section 5.3 of the Call for submissions document).

Do you have any comments on this approach?:

The ABCL does not support this approach.

Condition (b) The food for sale is not a blend or combination of any two or more ingredients listed in sub paragraphs (i) to (viii) of condition (a).

Example:
A food for sale that is a blend of concentrated fruit juice and minced dried fruit cannot be the subject of a claim about no added sugar.

Regardless of application, if the fruit (and vegetable) component is reconstituted to single strength, then no added sugar claims should be permitted.

The example in Question 6 above (fruit juice and fruit puree) is a contradiction. As stated above, fruit juice and puree mixed together (as the food for sale) is not permitted to make a no added sugar claim. However, we note that FSANZ, during this consultation period, has confirmed in writing that when fruit juice and puree are the food for sale and meet the requirements of Standard 2.6.1, a no added sugar claim is permitted.

Naturally occurring sugars that are intrinsic to the fruit and vegetable juice have not been added by the manufacturer. The simple concept for consumers to understand 'added sugars' is that they are sugars added by the manufacturer. We note the proposal mentions that the definition should enable consumers to make informed choices in support of dietary guidelines and should not confuse or mislead them. However, the proposed approach that fruit products which are single strength, or reconstituted to single strength, are considered added sugar, will likely confuse consumers comparing fruit and vegetable juices containing only intrinsic sugars with those 'sweetened' with additional sugar sources.

Purees, such as mango, guava, and banana are the whole fruit, capturing all the goodness of the fruit, including the fibre. Therefore, purees are as nutritious as juice. Purees, where sold on their own, in any application or finished good, e.g., guava juice product; or where juice is added to them, e.g., mango puree and orange juice, should not be treated as added sugar. Treating intrinsic sugars in fruit and vegetable juices and purees as 'added sugars' does not enable consumers to make an informed choice around their intake of sugars added during manufacturing versus intrinsic sugars, nor distinguish between one product or the other.

The inconsistent treatment of intrinsic sugars in dairy versus fruit we also contend will confuse and mislead consumers. General consumer understanding is that sugars from a piece of fruit or vegetable are naturally occurring, and that understanding translates to the sugars found in single strength fruit and vegetable juice and purees. The proposed change to consider sugars in single strength juice as 'added sugars', when that juice is added as an ingredient to food or beverages, will mislead consumers to believe other separate sugars have been added to the beverage by the manufacturer when this is not the case. With the exclusion of milk and dairy products from the added sugar definition, the proposed change is disadvantaging one product category over the other, when both contain intrinsic sugars.

We note the US FDA does not consider single strength fruit and vegetable juices as added sugar or concentrated fruit and vegetable juices that are reconstituted to single strength (and any concentrated juice in excess is counted as added sugar).

The Australian Dietary Guidelines [ADG] recognises the positive contribution juice (no added sugar) makes to a healthy dietary pattern and its role in helping many Australians meet their recommended daily fruit serves. Juice is included in the 'core food' fruit recommendations: 125mL of fruit juice with no added sugar can be included as a serve of fruit occasionally.

Condition (b) is about the mixing of two or more ingredients together, e.g., whole fruit puree and fruit juice. It makes no sense that these two ingredients, once mixed together cannot make a 'no added sugar' claim. A juice is allowed to make a no added sugar claim on its own; puree is allowed to make a no added sugar claim when sold as puree; but when the two are mixed together a no added sugar claim is disallowed. This proposed condition will only create confusion among consumers. Therefore, the ABCL strongly recommends that this condition be removed as it is illogical. Banana puree in a tropical juice is permitted under Codex Stan 247 – 500. Some fruits (e.g., bananas, mangoes, berries, guava etc.) cannot be 'juiced' and therefore must be pureed. They are made into juice blend products are currently able to make a no added sugar claim. Compared to an apple or orange juice which is still able to make the claim, any situation where two or more fruit products are mixed together (e.g., tropical juice) can no longer make a claim, despite these being reconstituted/ single strength. The ABCL recommends that any fruit product which is single strength, either not from concentrate or reconstituted, should be able to claim a 'no added sugar' claim regardless of the finished juice it goes into.

The ABCL supports deionised fruit juice will be counted as added sugar as indicated in the paper

7 FSANZ proposes 'no added sugar(s)' claims are not permitted when the concentration of sugars in the food is increased from the hydrolysis of carbohydrates during food manufacture, except when the sugars concentration in cereal-based plant milks made using hydrolysis is ≤ 1.5% (and the product otherwise meets claim conditions) (see section 5.3.2 of the Calls for submissions document).

Do you have any comments on this approach?:

The ABCL seeks further clarification from FSANZ regarding this proposition.

The ABCL finds the proposed threshold acceptable. However, we seek further clarification for products that have a sugars concentration of more than 1.5%. For example, how would products that have a sugars concentration of 1.7% be presented in the NIP based on Proposal P1058? Without seeing a final response to P1058, we are unable to fully support this proposed threshold.

This is further clear evidence to support our strong recommendation that both P1062 and P1058 need to be conducted in parallel.

Furthermore, while FSANZ has acknowledged the complexity around hydrolysis technology by assigning a threshold value, the ABCL wonders if an arbitrary value is limiting to other production types and products. While the ABCL agrees there should be a distinction between incidental sugars created by hydrolysis versus the intentional/purposeful increase of sugars, if intentional, then the no added sugars claim should be lost. However, in terms of the value itself, to future proof this requirement, we postulate that the regulation could include language for 'incidental/intentional' rather than a threshold value to allow flexibility in production technologies which are difficult to control at incidental levels.

We ask FSANZ to please review this.

8 FSANZ proposes to maintain the existing condition that a food displaying an 'unsweetened' claim must meet the conditions for a 'no added sugar(s)' claim, noting that the amended 'no added sugar(s)' claim conditions will apply (see section 5.4 of the Call for submissions document).

Do you have any comments on this approach?:

The ABCL supports this approach, provided our concerns regarding the proposed no added sugar claims are addressed. In principle, the ABCL support the above, however, our concerns regarding the proposed definition of added sugar need to be taken into consideration.

In addition;

Unsweetened Claims:
Condition (c): The food does not contain, as an ingredient or as an ingredient of a *compound ingredient, a monosaccharide or disaccharide listed in the table to subsection S11—2(3).

See response to Question 2 regarding carry-over ingredients that may contain very small/ insignificant sources of sugar and the allowances that need to

be made for these (either threshold or explicit exemption).

9 FSANZ proposes to maintain the existing condition for intense sweeteners, sorbitol, mannitol, glycerol, xylitol, isomalt, maltitol syrup or lactitol. FSANZ proposes a food containing low energy sugars (mono- and disaccharides) listed in subsection S11—2(3) of schedule 11, as an ingredient (including an ingredient of a compound ingredient), not be permitted to display an 'unsweetened' claim (see section 5.4 of the Call for submissions document).

Do you have any comments on this approach?:

The ABCL supports the approach to maintain the existing condition that intense sweeteners are not permitted to display an 'unsweetened' claim. We also support the approach to disallow low energy sugars to make an 'unsweetened' claim as they are added for sweetening purposes.

However, as per our comments in question 3 and 4 and in our response to the P1058 Background Paper, we contend that D-tagatose should not be considered an added sugar but that it's presence would not permit an unsweetened claim.

Low energy sugars should be explicitly excluded from the conditions of an 'added sugars' claims as per unsweetened condition (a).

This is further clear evidence to support our strong recommendation that both P1062 and P1058 need to be conducted in parallel.

10 FSANZ is proposing a two-year transition period to allow producers, manufacturers and importers time to make any required labelling changes for products carrying 'no added sugar(s)' or 'unsweetened' claims to comply with the new claim conditions (see section 7 of the Call for submissions document).

Do you have any comments on this approach?:

The ABCL does not support this approach.

Given there are multiple regulatory updates happening concurrently, plus other regulatory changes in the transition phase, the ABCL recommends a three-year transition and a greater than two year stock in trade provision. As P1062 is not related to safety, the Plain English Allergen Labelling (PEAL) Proposal P1044 should be used as a precedent for a longer transition period and stock in trade provision. This additional time should not cause an issue, as there is no health or safety risk to consumers regarding the claims, and the longer overall transition period would support upcoming and ongoing packaging changes.

We also strongly recommend that P1062 and P1058 are conducted in parallel, to minimise pack/artwork changes, as these come at a very high cost to industry. The cost of a single labelling change can range from $100,000 (for a small beverage company) to $2.5 million (for a large beverage company). This does not count the cost of Scope 1, 2 and 3 raised carbon emissions from the destruction, creation and placement of new labels on pack.

This is further clear evidence to support our strong recommendation that both P1062 and P1058 need to be conducted in parallel.

Data and evidence

11 Do you have any data or are you aware of published data on the number of products with 'no added sugar(s)' or 'unsweetened' claims in Australia and/or New Zealand (see data used for this proposal at section 3.1 of the Call for submissions document)?

No

If yes, please upload your file here.:
No file uploaded

12 Do you have any evidence or are you aware of published literature on consumer understanding of and responses to 'no added sugar(s)' or 'unsweetened' claims on food products (see evidence used for this proposal at section 3.2 of the Call for submissions report and Supporting Document 1)?

No

If yes, please upload your file here.:
No file uploaded

13 Do you have any data or know of any published data on the costs of labelling changes per stock keeping unit or package type (see data used for this proposal at Attachment E to the Call for submissions document)?

Yes

If yes, please upload your file here:
The impact of a label change on beverages - an ABCL member survey 5Sept2022.pdf was uploaded

Additional comments

Comments and other input

Additional comments and input:

1. Evidence to Support the Benefits of Juice
The ABCL would like to insert the references discussed in Question 5, as well as other literature to support juice. The literature is attached here.

2. Vegetable juices
Vegetable juices are exempt from this proposal, but FSANZ has not explicitly provided a definition of fruit and vegetable. ABCL requests clarification on this. For example, tomatoes are classified as 'Fruiting Vegetables' under Schedule 22 of the Code. We ask FSANZ to clarify if tomatoes are a fruit or a vegetable. Can vegetable purees be added to a juice and have a 'no added sugar claim, if the final food meets Standard 2.6.1?

ABCL requests FSANZ provides clarity and a confirmation on this issue, as the information in this proposal contradicts the information FSANZ provided about single strength blends during its P1062 Webinar.

Please upload additional files here.:
Moore LL Beverages 2023 Fr Juice BMI diet qual in biracial cohort (003).pdf was uploaded

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Very satisfied

Do you have any feedback you would like to provide to FSANZ regarding this new platform?

No

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RESEARCH ARTICLE Open Access

A longitudinal study of fruit juice consumption during preschool years and subsequent diet quality and BMI

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Abstract

Background: The role of fruit juice in pediatric dietary guidelines continues to be controversial, particularly with respect to concerns about unhealthy dietary habits and the potential promotion of excessive weight gain. The objective of the current study was to determine the association between preschool fruit juice consumption and the following outcomes during childhood and adolescence: whole and total fruit intake, diet quality, likelihood of meeting current dietary recommendations, and BMI change.

Methods: The data were previously collected from 100 children enrolled in the Framingham Children's Study at 3–6 years of age and subsequently followed for 10 years. Dietary data were collected annually using multiple sets of 3 day diet records. Compliance with dietary recommendations was estimated based on *2015–2020 Dietary Guidelines for Americans* and diet quality was measured using the associated Healthy Eating Index (HEI). Mixed linear and logistic regression models were used for statistical analyses.

Results: Preschool children (3–6 years) who drank ≥1.0 (vs. < 0.5) cup of 100% fruit juice/day consumed 0.9 cups/day more total fruit ($p < 0.0001$) and 0.5 cups/day more whole fruit ($p < 0.0001$) during adolescence (14–18 years). Total HEI scores during adolescence for those with the highest preschool juice intakes were almost 6 points higher than those with the lowest fruit juice intakes ($p = 0.0044$). Preschoolers consuming < 0.5 cups/day of fruit juice had sharply declining whole fruit intake throughout childhood compared with those preschoolers consuming ≥1.0 cups/day who had stable intakes of whole fruit throughout childhood. Those children who consumed ≥0.75 cups/day of fruit juice during preschool (vs. less) were 3.8 times as likely to meet *Dietary Guidelines* for whole fruit intake during adolescence ($p < 0.05$). Finally, in multivariable models, there was no association between fruit juice consumption and BMI change throughout childhood.

Conclusion: These data suggest that preschool consumption of 100% fruit juice is associated with beneficial effects on whole fruit intake and diet quality without having any adverse effect on BMI during childhood and into middle adolescence.

Keywords: Fruit juice, Fruit intake, Diet quality, Children, Adolescence

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Background

Fruit is a widely recognized source of a significant number of beneficial nutrients including vitamins, minerals, phytochemicals, and dietary fiber that have been associated with lower risks of cardiovascular disease and obesity [1]. For children and adolescents aged 2–18 years, guidelines from United States Department of Agriculture (USDA) recommend daily fruit intakes of 1–2 cups depending on age, sex, and physical activity level [2]. It is also recommended that at least half of daily total fruit intake for both children and adults be derived from whole fruit [3]. Data from *National Health and Nutrition Examination Surveys (NHANES)* show that fruit juice consumption among preschoolers peaked in the early 2000s [4] and then subsequently declined while whole fruit consumption slightly increased [5]. However, most children (particularly after the preschool years) still fail to consume the recommended amount of total fruit per day. Cross-sectional analyses of NHANES data from 2005 to 2010 show that whole and total fruit consumption declines with increasing age. For example, 4–8-year olds ate significantly more whole and total fruit than 9–13-year olds, who in turn consumed more than 14–18-year olds, whose mean total fruit intakes were half of the recommended amount [6].

The role of 100% fruit juice in total fruit intake amongst children, especially younger children, continues to be controversial [7]. Longstanding concerns about juice intake include its lower fiber content (compared with whole fruit), caloric density, and potential promotion of dental caries. Current American Academy of Pediatrics (AAP) guidelines recommend avoiding fruit juice in infants less than 1 year of age and encourage consumption of whole fruit rather than fruit juice throughout childhood and adolescence [8]. After 1 year of age, the AAP concurs that fruit juice may comprise up to half of the recommended total daily fruit intake but also recommends that intakes among 1 to 3-year old children should be limited to 4 oz (oz) per day and among those 4 to 6 years of age to 4–6 oz. per day.

Some earlier investigators have suggested that to address the rising rates of obesity, fruit juice should be eliminated from federal nutrition programs [9]. The AAP concurs that fruit juice restriction may be an effective strategy for reducing of energy imbalance in young children [8]. However, there is little evidence to support a link between juice consumption and childhood obesity. One early study found that preschoolers who consumed > 12 oz of fruit juice per day were at increased risk for excess weight gain [10] while another study published the same year found no such association [11]. Several reviews of the evidence in children have concluded that there is no independent or systematic contribution of 100% fruit juice to clinically-significant weight gain or obesity risk in children [12–14]. On the other hand, fruit juice is known to have beneficial antioxidant capacity [15] and children who consume it have been shown to have higher intakes of important micronutrients such as vitamins C and B6, potassium, riboflavin, magnesium, iron, and folate compared with non-consumers [16].

Most studies that have examined the association between fruit juice consumption and diet quality in children have been cross-sectional [13]. Whether fruit juice consumption in early childhood affects overall fruit intake and diet quality in later childhood and adolescence remains largely unknown. In this study, we have used data from the Framingham Children's Study (FCS) in which children were enrolled at 3–6 years of age and followed for approximately 10 years to investigate the relation between greater consumption of 100% fruit juice during preschool and subsequent intakes of whole and total fruit, the overall likelihood of meeting dietary guidelines, overall diet quality, and change in BMI throughout childhood.

Methods

These analyses are based on previously collected data. The FCS was a longitudinal study that enrolled 106 children from two-parent families with a 3–6 year-old child in 1987. The families were third and fourth generation descendants of subjects in the original Framingham Heart Study [17]. Of the original 106 families, 100 provided dietary data for the children at baseline (preschool) and throughout follow-up (adolescence). Diet, physical activity and other lifestyle factors were evaluated annually by means of interviews, questionnaires, and clinical measurements over a period of 10 years [18–20].

Dietary data

Dietary data were collected annually using multiple sets of 3-day diet records. During early years of the study (prior to age 10), parents completed the diaries for the children, with input from other caregivers inside and outside of the family. A study nutritionist instructed each family in the completion of the diet record including accurate estimation of portion size. Nearly 90% of subjects completed diet records for eight or more of the 11 years in the study. Dietary data were analyzed for nutrient intake using the Nutrition Data System for Research (NDSR) of the University of Minnesota [21]. Mean servings per day at each age in the 30 USDA food groups were calculated by linking NDSR food codes with Pyramid Serving data files of the Continuing Survey of Food Intake by Individuals [22]. For our calculation of fruit juice, only 100% fruit juices and 100% juice blends such as 100% cranberry juice blends (i.e., blended with other 100% juices) were included. Part-juice beverages and tomato juice were excluded from fruit juices. Intake

of whole fruit (including cut fruit) and juices are expressed as USDA-defined cup-equivalents per day. The most common types of juice beverages in the preschool years were apple and orange juices.

Outcome variables

Each child's intake of whole and total fruit throughout childhood was examined to determine whether the child met the recommendations for fruit intake at each age. Based on *Dietary Guidelines for Americans* (DGA) recommendations, the following levels were considered to meet guidelines for total fruit intake: 1 cup for 2–3 year-olds, 1–1½ cups for 4–8 years, 1½ cups for 9–13 years old, and 1½ cups for 14–18 year-old girls and 2 cups for 14–18 year-old boys [3]. Diet quality was based on the 2015 Healthy Eating Index (HEI-2015) total score which is designed to measure conformance with the 2015 USDA DGAs. HEI-2015 is comprised of 13 component scores with a maximum total score of 100. Two fruit outcomes are included: whole fruit and total fruit intake. As an overall measure of diet quality, the HEI-2015 has been shown to be both reliable and valid [23].

Each child's height and weight were recorded at each annual clinic exam. Weight (to the nearest 1/4 pound) was measured using a standard counterbalance scale, and height was measured (to the nearest 1/4 in) using a measuring bar on the same scale. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared.

Statistical analysis

Children were categorized into four age groups: preschool (3–6 years old) and three follow-up ages (7–9, 10–13, and 14–17 years old). These age groups were chosen to reflect the child's growing level of independence with respect to food and beverage choices as well as emerging peer influence on those choices. The youngest age group includes children in preschool/kindergarten when parents exert the greatest control over food choices. The second and third age groups include early elementary school and middle school ages, respectively, while the oldest children were those in their high school years who have the greatest level of independence in food choices. For analyses related to the association between 100% fruit juice consumption and subsequent total and whole fruit intakes, preschool fruit juice intake was categorized as < 0.5 cups, 0.5- < 1.0 cups, and ≥ 1.0 cups. To increase power for some analyses, categories of juice intake were collapsed to include < 0.75 cups vs. ≥0.75 cups. Mixed linear regression models for repeated measures data was used to examine the association between juice consumption at 3–6 years of age and total and whole fruit intake as well as HEI scores throughout childhood. Logistic regression modeling was used to estimate the likelihood of meeting dietary guidelines throughout childhood and adolescence. Potential confounding by age, sex, parental education, mother's BMI, energy intake, physical activity, and television and video viewing time was explored. Only sex was found to confound the results for dietary outcomes and thus was retained in these final models. For the BMI analysis, the final model included age, sex, maternal education, maternal BMI, physical activity, and TV and video viewing time.

Results

The baseline characteristics of children according to the three categories of preschool fruit juice intake are shown in Table 1. Children who consumed one or more cups of 100% fruit juice per day were slightly younger and had lower energy-adjusted intakes of dietary fat but higher intakes of carbohydrates. In addition, these children consumed more potassium, magnesium, vitamin C, and dietary folate. Finally, education level for the mothers was highest among those consuming the most fruit juice.

Figure 1 shows age-specific median intakes of total fruit, whole fruit and fruit juice. During preschool, average total fruit intake was slightly less than 1.5 cups/day; this amount steadily declined to less than a cup per day by mid-adolescence. The median intakes of whole fruit and 100% fruit juice both declined slightly with age.

In Fig. 2, children were categorized according to consumption level of 100% fruit juice during preschool years: < 0.5, 0.5- < 1.0, and ≥ 1.0 cups/day. At the end of follow-up (14–17 years of age), children who drank ≥1.0 cups of 100% fruit juice per day (vs. < 0.5 cups/day) during preschool consumed 0.9 cups/day more of total fruit ($p < 0.0001$) (Fig. 2a) and 0.5 cups/day more whole fruit ($p < 0.0001$) (Fig. 2b). Preschool children drinking 0.5- < 1.0 cups/day (vs. < 0.5 cups/day) also consumed significantly more total fruit ($p = 0.0057$) (Fig. 2a) and whole fruit per day ($p = 0.0009$) (Fig. 2b) at 14–17 years of age. Preschoolers consuming < 0.5 cups/day of 100% fruit juice had sharply declining whole fruit intakes starting at age seven compared with those children who consumed more fruit juice at baseline.

In Table 2, preschool children who consumed ≥0.75 (vs. < 0.75) cups/day of 100% fruit juice were much more likely to meet DGA recommendations for whole and total fruit intake. At end of follow-up (14–17 years of age), children who drank ≥0.75 cups/day of fruit juice during preschool (vs. less) were 3.8 times as likely to meet current recommended intakes for whole fruit and total fruit intake ($p < 0.05$).

Figure 3 shows the relation between preschool fruit juice consumption and diet quality throughout childhood as measured by the HEI-2015 total score. First, it

Table 1 Baseline characteristics of children aged 3 6 years according to preschool consumption of fruit juice

	Categories of 100% fruit juice intake per day						
	< 0.5 cup		0.5 < 1 cup		≥1 cup		
Characteristics	*n* = 35		*n* = 35		*n* = 30		
	Mean	SD	Mean	SD	Mean	SD	*p trend*
Age (years)	5.2	0.49	5.3	0.59	4.7	0.84	0.0038
BMI (kg/m^2)	16.3	1.4	16.0	0.92	16.5	1.1	0.1350
Activity (Caltrac counts/hour)	11.3	1.8	10.7	2.0	10.6	1.9	0.3077
Energy (kilocalories)	1519	210	1639	313	1623	240	0.1196
% energy from protein	13.6	1.8	13.7	1.8	13.2	2.0	0.5113
% energy from fat	35.9	3.2	34.4	3.9	31.5	3.8	<.0001
% energy from carbohydrate	52.0	4.1	53.6	4.8	57.0	5.3	0.0002
Calcium (mg/day)	740	212	825	210	748	236	0.2123
Magnesium (mg/day)	180	40	204	43	206	42	0.0232
Potassium (mg/day)	1676	369	1983	412	2150	399	<.0001
Vitamin C (mg/day)	67.7	26.5	89.1	32.0	125.9	49.0	<.0001
Folic acid (mcg/day)	177.8	47.0	194.8	49.6	237.6	64.4	<.0001
Milk (cup equivalents/day)	1.50	0.61	1.53	0.62	1.42	0.67	0.7629
Added sugar (tsp equivalents/day)	15.8	4.2	16.3	6.1	14.5	4.4	0.3620
Sugar sweetened beverages, cups/day	0.76	0.48	0.76	0.61	0.60	0.47	0.3695
Whole fruit (cup equivalents/day)	0.52	0.40	0.65	0.44	0.62	0.34	0.3688
Total Fruit juice (cup equivalents/day)	0.40	0.20	0.84	0.17	1.63	0.62	<.0001
100% fruit juice (cup equivalent/day)	0.30	0.16	0.73	0.14	1.51	0.59	<.0001
Healthy Eating Index 2015 Score	48.0	2.0	52.4	6.1	55.0	6.7	0.0002
Number (column percent)							
Gender (% male)	24	(69%)	23	(66%)	14	(47%)	0.0781
Mother's education (% college)	7	(20%)	14	(40%)	15	(50%)	0.0116

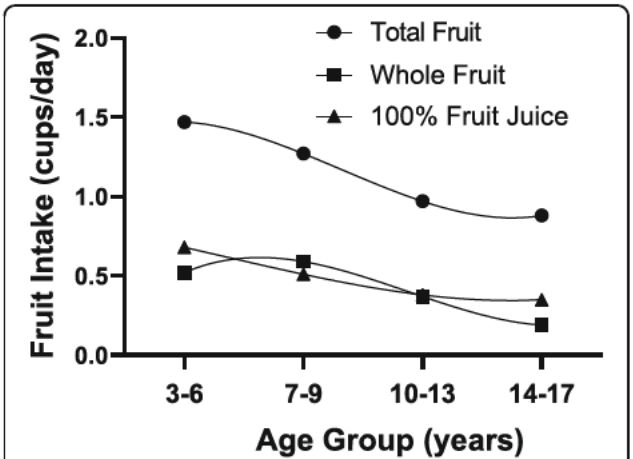

Fig. 1 Median intakes of total fruit, whole fruit, and 100% fruit juice throughout childhood (ages 3 17 years) in the Framingham Children's Study

is evident that diet quality as measured by the HEI declines steadily throughout childhood. However, children with higher fruit juice intakes during preschool had the highest HEI scores at all ages. At the end of follow-up (14–17 years old), HEI total scores for those with the highest preschool juice intakes (≥1.0 cups/day) were almost 6 points higher than those with the lowest preschool fruit juice intakes (< 0.5 cups/day) ($p = 0.0044$).

Finally, Fig. 4 shows that 100% fruit juice consumption had no effect on change in BMI throughout childhood after adjusting for age, sex, maternal education, baseline BMI, physical activity, and TV and video viewing time.

Discussion

The results of the current study provide evidence that higher intake of 100% fruit juice during the preschool years is associated with better diet quality throughout childhood. Findings also confirm that whole fruit consumption declined from early childhood through adolescence in this cohort. These data suggest that preschoolers who consumed more fruit juice in the early

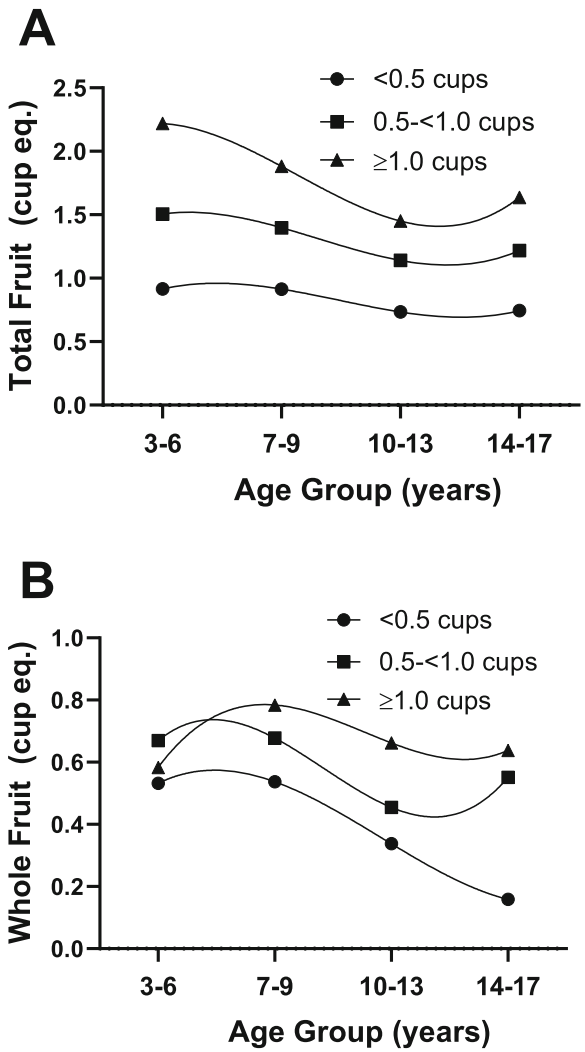

Fig. 2 Total (Panel **a**) and whole (Panel **b**) fruit consumption throughout childhood (ages 3 17 years) according to preschool (ages 3 6 years) fruit juice consumption. Results are adjusted for sex

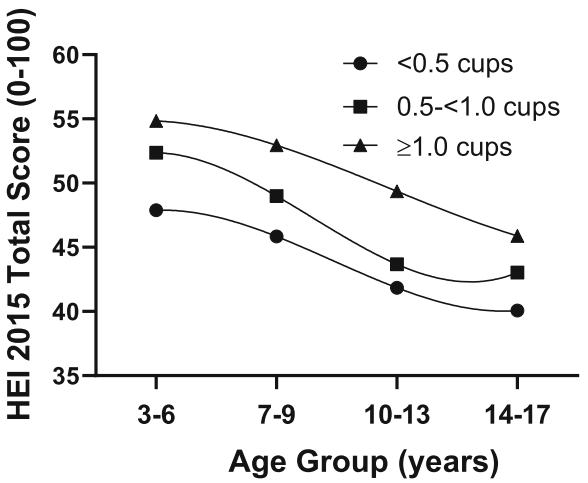

Fig. 3 Total Healthy Eating Index 2015 (HEI 2015) scores throughout childhood (ages 3 17 years) according to preschool (ages 3 6 years) fruit juice consumption. Results are adjusted for sex

years of childhood also consumed more whole fruit at the same time and continue to consume more whole fruit into adolescence.

These data directly address an existing gap in evidence identified by the AAP and others about whether fruit juice consumption promotes healthy eating behaviors and greater intake of whole fruit [8, 24]. This study also suggests that 100% fruit juice consumption during preschool is associated with a higher overall diet quality from preschool into adolescence as measured by the HEI-2015. Additionally, the current results suggest that the nutritional benefits of moderate intakes of fruit juice (above current recommendations) during early childhood are not accompanied by excessive weight gain. Therefore, these results provide no support for the recommendation to eliminate 100% fruit juice from federal child nutrition programs.

These findings are consistent with and extend the results of previous cross-sectional studies of the association between 100% fruit juice consumption and diet quality. Successive analyses of NHANES subjects from

Table 2 Likelihood of meeting total and whole fruit *Dietary Guidelines* by preschool 100% fruit juice intake

Fruit Juice Intake (ages 3 6)	Ages 7 9		Ages 10 13		Ages 14 17	
	OR*	95% CI	OR	95% CI	OR*	95% CI
Likelihood of Meeting Total Fruit Guidelines						
< 0.75 cups/day	1.00		1.00		1.00	
≥0.75 cups/day	5.71	(2.36, 13.84)	2.14	(0.80, 5.74)	3.83	(1.37, 10.77)
Likelihood of Meeting Whole Fruit Guidelines						
< 0.75 cups/day	1.00		1.00		1.00	
≥0.75 cups/day	1.95	(0.83, 4.58)	1.92	(0.68, 5.41)	3.80	(1.07, 13.46)

*Adjusted for sex.

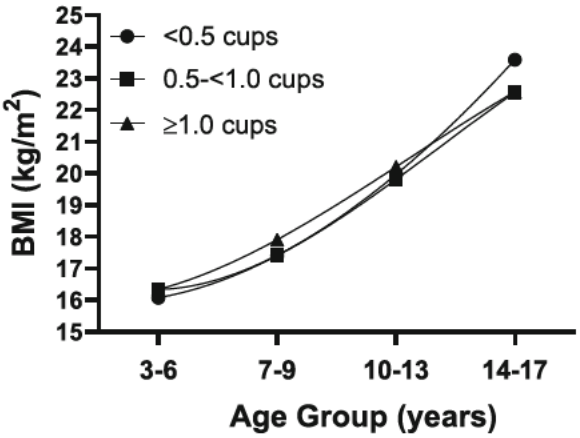

Fig. 4 BMI (kg/m2) throughout childhood (ages 3 17 years) according to preschool (ages 3 6 years) fruit juice consumption. Results are adjusted for age, sex, maternal education, baseline BMI, physical activity, and TV and video viewing time

early childhood through adolescence have shown positive associations between orange juice [25] and other 100% fruit juices [26, 27] and the intake of key micronutrients and overall diet quality as measured by HEI scores. To the best of our knowledge, the current results are the first to show a longitudinal association of preschool fruit juice consumption and subsequent intake of total and whole fruit as well as higher overall diet quality.

A 2017 meta-analysis of 8 prospective studies that found no clinically significant association between 100% fruit juice and weight gain among children 1–6 years of age and no association at all with weight gain from 7 to 18 years of age [28]. The data in the current study were collected during a time of peak fruit juice consumption among U.S. children [4, 5] as well as the period in which the prevalence of obesity was rising rapidly [29]. Current AAP recommendations for preschool children are to limit intake of 100% fruit juice to no more than 6 oz. per day at 4–6 years of age [8]. The 3–6 year-old children with the highest fruit juice intakes in this study consumed more than 8 oz. per day, allowing us to evaluate potential adverse effects of higher juice consumption on change in BMI in these children. However, no such adverse effect on weight gain was detected.

There is a clear imperative to increase total fruit and whole fruit consumption in younger populations, particularly adolescents. Recent data from Youth Risk Behavior Surveillance System suggests that only 8.5% of high school students meet the current USDA recommendation for fruit intake [30]. Intakes of fruit and vegetables have been found to be associated with beneficial cardiometabolic outcomes in adolescents [31–33]. There is also evidence to suggest that dietary intake patterns are established early in life, track throughout childhood [19], and continue into adulthood [34]. Further, childhood diet appears to be associated with the development and progression of CVD in adulthood [35]. Consequently, the finding that early fruit juice consumption may promote higher intakes of total fruit and whole fruit suggests that moderate juice consumption during the preschool years may have long-term benefits for chronic disease risk.

There are several notable strengths of this longitudinal study. The FCS provides detailed and repeated measures of diet which allow for substantial precision around the estimated effects. Additionally, the intensive level of follow-up from early childhood over 10 years may help to reduce the likelihood of reporting error and/or bias. On the other hand, there are some limitations that must be acknowledged including the small sample size and the homogeneity of the study population. The families in this study are descendants of the original Framingham Heart Study cohort and as such, they are largely of middle-class Caucasian ancestry. There is always the potential for biased reporting of dietary intake in any study. These data, however, were collected over a decade starting in 1987, at a time when there was no negative publicity about juice consumption. The positive association between maternal education and juice intake in the FCS families contrasts with the inverse association between juice consumption and socio-economic status observed a decade later in NHANES [36]. Nonetheless, we found no evidence of confounding of the current results by parental education.

Conclusions

This longitudinal study adds important evidence addressing the current controversies surrounding the consumption of fruit juice during the preschool years. Early childhood diet plays a crucial role in the establishment of life-long dietary patterns. This study demonstrates that early juice consumption is an important determinant of overall fruit intake and better diet quality in later childhood years without having any adverse effect on energy balance. Thus, this study provides important new evidence that should be considered in the development of future guidelines on fruit juice consumption in early childhood.

Abbreviations

HEI: Healthy Eating Index; USDA: United States Department of Agriculture; NHANES: National Health and Nutrition Examination Surveys; FCS: Framingham Children's Study; NDSR: Nutrition Data System for Research; DGA: Dietary Guidelines for Americans; AAP: American Academy of Pediatrics; BMI: Body Mass Index

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Availability of data and material
The datasets analyzed in the current study are available from the corresponding author on reasonable request.

Conflict of interests
Authors have none to report.

Authors' contributions
LW participated in the literature review and interpretation of analyses and wrote the first draft of the manuscript. PDJ participated in the interpretation of analyses and editing of the manuscript. MRS carried out the analyses, interpreted results, and edited the manuscript. MLB participated in interpreting results, evaluating background literature, and editing the manuscript. LLM designed and oversaw all analyses and interpretation of results, and critically reviewed the final manuscript. All authors read and approved the final version of the manuscript.

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Ethics approval and consent to participate
These secondary analyses as well as the original data collection were conducted with the approval of the Boston University Medical Campus Institutional Review Board.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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Publisher's Note

Evidence to Support Juice

Based on the research referenced below, not permitting 'no added sugar' claims to fruit juice (including puree and blended juices) could lead to more confusion amongst consumers and to an even lower consumer intake of fruit and vegetable juices. Based on all the nutritious benefits of juice, that would be unfavourable to the consumer.

This latest evidence (from IFU and NRAUS) confirms the ADG position, that juice is part of the 'core food' fruit group and can make a positive contribution to the Australian diet and is associated with markers of healthy diets:

• **Juice makes a significant contribution to daily micronutrient intakes of juice consumers,** for example, 57% to vitamin C, around 17% to folate and 14-16% to potassium intakes;
• **Juice makes a relatively low contribution to daily energy intakes of juice consumers (5%), total sugar intake (20%) and zero contribution to added sugar intake,** as the sugar in juice is naturally occurring;
• **Juice consumption is associated with multiple markers of a healthy diet**, including **higher total diet quality scores** and **lower discretionary food consumption;** and
• **Juice consumption is associated with healthy lifestyle behaviours**, such as greater levels of physical activity, with consumer research indicating that health is a key motivator for choosing juice.

One of the key roles of juice is to help Australians meet their minimum recommended daily fruit serves:
• **Including juice (125mL) as a serve of fruit significantly increased** the percentage of the Australian population who **met their daily fruit recommendations from 10% to 24%** (2011-12 National Nutrition and Physical Activity Survey); and
• In some groups, such as **young adults aged 19-30**, the effect was even greater with the inclusion of juice **increasing compliance from 4% to 18%.**

This is an important consideration as fruit and vegetable intakes remain low:
• 95% of children do not meet their minimum recommended daily fruit and vegetable serves;
• 52% of adults do not meet their minimum recommended daily fruit serves; and
• 94% of adults do not meet their minimum recommended daily vegetable serves.

IFU Literature

The IFU (International Fruit and Vegetable Juice Association) have recently published a systematic review on the goodness of juice and purees: "Health effects of 100% fruit and vegetable juices (FVJs): evidence from human intervention Studies". The review aimed to shed light on the potential impact of 100% FVJs on human health, comprehensively assessing the role each type of juice may have in specific health outcomes for a particular target population, as reported in dietary interventions. FVJs contain notable amounts of free sugars, but also vitamins, minerals, and secondary compounds with

proven biological activities like (poly)phenols and carotenoids. The effects of a wide range of FVJs (orange, grapefruit, mandarin, lemon, apple, white, red, and Concord grape, pomegranate, cranberry, chokeberry, blueberry, other minor berries, sweet and tart cherry, plum, tomato, carrot, beetroot, and watermelon, among others) were evaluated on a series of outcomes (anthropometric parameters, body composition, blood pressure and vascular function, lipid profile, glucose homeostasis, biomarkers of inflammation and oxidative stress, cognitive function, exercise performance, gut microbiota composition and bacterial infections), providing a thorough picture of the contribution of each FVJ to a health outcome. Some juices demonstrated their ability to exert potential preventive effects on some outcomes while others on other health outcomes, emphasizing how the differential composition in bioactive compounds defines juice effects. 100% FVJs appear to have beneficial effects on some cardiometabolic health outcomes, cognition, and exercise performance, or neutral effects on anthropometric parameters and body composition.

The full publication is attached here.

NRAUS Literature/Abstract

NRAUS (Nutrition Research Australia) has recently conducted a review on fruit and vegetable juices too: "Health effects of drinking 100% fruit and/or vegetable juice: An umbrella review of systematic reviews and meta-analyses". The review should be published by December 2023 (or January 2024 at the latest). The review found that low fruit and vegetable intakes are major modifiable determinants of disease. 100% juice may facilitate intake and deliver essential nutrients and bioactive compounds. Ten meta-analyses (MAs) (19.6%) reported health benefits (blood pressure, vascular function, inflammation, stroke mortality), three MAs (5.9%) reported adverse risks (CVD mortality, prostate cancer, type 2 diabetes risk), while majority (74.5%) reported no effect (blood lipids, body composition, liver function, metabolic health, cancers, and inflammation). Findings confirm there are health benefits associated with 100% juice consumption, with limited harms and some potential benefits. The balance of evidence does not justify recommendations that exclude or limit 100% juice intake, but continues to support the inclusion of 100% juice as a core food in dietary guidelines. Juice was found to have a similar nutrition profile to the fruit. It was recognised that the nutrients do not work in isolation, but they work together. **The polyphenols and bioactive nutrients in juice reduce the uptake and absorption of the free sugars in juice.** It is important to stop taking a 'simple systems' approach to food. Food and the way the nutrients work in the body is very complex, with all the nutrients working together.

The abstract is attached here.

Juice Products ASSOCIATION

FOR IMMEDIATE RELEASE: [redacted]

New Biracial Study Finds Pre-teen Girls that Drink Fruit Juice Have Better Diets with No Adverse Effect on Weight

Washington, DC – A new study was recently published on-line in *Beverages* by Dr. Lynn L. Moore, a Professor of Medicine, at the Boston University Chobanian and Avedisian School of Medicine. Moore and her colleagues found that pre-teen girls who drank 100% fruit juice had long term positive dietary benefits with no adverse effect on weight, throughout adolescence, regardless of race.

"While total fruit intake and particularly whole fruit intake may have increased in recent years, among younger children, this is not the case for older children," said Dr. Moore, "In fact, teens generally consume only about half the recommended amounts of whole fruit per day. This study showed that teen girls who drank 100% juice were about twice as likely to meet Dietary Guideline recommendations for whole fruit as girls who didn't drink any juice." In this study, there were some racial differences in fruit consumption—black girls tended to consume 100% juice at a consistent level throughout adolescence despite drops in total fruit and especially whole fruit intakes. Thus, 100% fruit juice made an especially important contribution to total fruit intake among adolescents who consumed little whole fruit."

In this study higher intakes of 100% fruit juice during preadolescence were associated with higher intakes of both whole fruit and total fruit as well as better quality diets throughout adolescence. The girls, both black and white, who drank the highest amount of juice (≥1.25 cups per day) also had the lowest BMI levels while those with the highest BMIs were the nonfruit juice consumers. By the end of adolescence (ages 19-20 years), girls who consumed 1.25 or more cups per day of 100% fruit juice during adolescence had a BMI that was 1.7 kg/m^2 lower (24.1 kg/m^2 vs. 25.8 kg/m^2) compared to girls who did not drink fruit juice.

The study tracked multiple sets of 3-day diet records, as well as height and weight data, for more than 2,100 girls, over a 10-year period as part of the prospective National Heart, Lung and Blood Institute's National Growth and Health Study. There were approximately equal numbers of black and white girls. Whole and total fruit consumption was compared with recommendations from the Dietary Guidelines for Americans (DGA) at each age, and diet quality was measured using Healthy Eating Index (HEI) scores.

Among the study's results were the following:

- Higher intakes of 100% fruit juice during preadolescence in girls was associated with higher intakes of both whole fruit and total fruit, regardless of race.

- Both white and black girls who consumed 100% fruit juice during preadolescence were also more than 2 times as likely to meet current Dietary Guideline recommendations for whole fruit, and total fruit intake throughout adolescence than those who did not drink juice.

- Fruit juice consumption was not associated with excess weight gain and in this research, those children who drank the most juice, had the lowest Body Mass Index (BMI) during adolescence.

- This study confirms findings from previous studies suggesting that juice drinking in the preteen and teen years may promote better diet quality and higher intakes of whole fruit without having an adverse effect on weight.

"This research shows juice drinking may actually encourage higher whole fruit and total fruit intake. Even children drinking more than 1 cup of fruit juice a day, had better diet quality and lower BMI's than those drinking no juice at all," noted Dr. Moore.

Co-author and Chair of the Department of Pediatrics, University of Colorado School of Medicine, Dr. Stephen R. Daniels, states "Fruit juice, in appropriate quantities, has a useful role in a healthful diet for adolescents. Fruit juice can contribute to achieving adequate intake of fruit which is a challenge for many adolescents."

Moore LL, Zhou X, Wan L, Singer MR, Bradlee ML, Daniels SR. Fruit Juice Consumption, Body Mass Index, and Adolescent Diet Quality in a Biracial Cohort. *Beverages*. 2023; 9(2):42. https://doi.org/10.3390/beverages9020042

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The Juice Product Association is the trade association representing the fruit and juice products industry. You can follow the organization on Instagram, Twitter and Facebook at #SipSmarter. For more information, please visit www.sipsmarter.org.

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Health effects of 100% fruit and vegetable juices: evidence from human subject intervention studies

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Abstract

The health effects of 100% fruit and vegetable juices (FVJ) represent a controversial topic. FVJ contain notable amounts of free sugars, but also vitamins, minerals, and secondary compounds with proven biological activities like (poly)phenols and carotenoids. The review aimed to shed light on the potential impact of 100% FVJ on human subject health, comprehensively assessing the role each type of juice may have in specific health outcomes for a particular target population, as reported in dietary interventions. The effects of a wide range of FVJ (orange, grapefruit, mandarin, lemon, apple, white, red, and Concord grapes, pomegranate, cranberry, chokeberry, blueberry, other minor berries, sweet and tart cherry, plum, tomato, carrot, beetroot, and watermelon, among others) were evaluated on a series of outcomes (anthropometric parameters, body composition, blood pressure and vascular function, lipid profile, glucose homeostasis, biomarkers of inflammation and oxidative stress, cognitive function, exercise performance, gut microbiota composition and bacterial infections), providing a thorough picture of the contribution of each FVJ to a health outcome. Some juices demonstrated their ability to exert potential preventive effects on some outcomes while others on other health outcomes, emphasising how the differential composition in bioactive compounds defines juice effects. Research gaps and future prospects were discussed. Although 100% FVJ appear to have beneficial effects on some cardiometabolic health outcomes, cognition and exercise performance, or neutral effects on anthropometric parameters and body composition, further efforts are needed to better understand the impact of 100% FVJ on human subject health.

Keywords: **Juice: Nutrition: Health properties: Food bioactives: phytochemicals**

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Introduction

The health effects of 100% fruit and vegetable juices (FVJ) represent a controversial topic to date. Despite the plant origin of 100% FVJ and the role of fruit and vegetable consumption in preventing non communicable diseases[1], scientific evidence is less robust, and the debate is focused almost exclusively on the sugar content of FVJ. Indeed, although 100% FVJ have no added sugars, they still have a total sugar content that depends on the fruit or vegetable from which they are made (approximately 16 24 g/200 ml serving size)[2]. Considering international (for example, WHO) and national recommen dations, 100% FVJ should be consumed in moderate amounts. According to the WHO guidelines, total daily free sugar intake should be reduced to less than 10% of energy intake (50 g/d for a 2000 kcal/8368 kJ diet), with sugars from FVJ being classified as free sugars[3]. While the adverse effects of excess added sugars are well established, the contribution of naturally occurring sugars, such as in fruits and fruit juices, to the increased prevalence of non communicable diseases is unclear and deserves further discussion[2,4]. Overall, limiting 100% FVJ only because of their sugar content is not a balanced but a reductionist approach that may lead to possibly unfounded evaluations.

In a recent review, Ruxton and Myers (2021)[2] showed that 100% fruit juices (FJ) have a nutritional composition closer to whole fruits than to classic sugar sweetened beverages (SSB), primarily due to their micronutrient and phytochemical content. In terms of micronutrients, Mitchell *et al.* (2020)[6] found that 100% FJ contribute to vitamin C, folate, magnesium, and potassium intakes in the USA, UK and Brazil. These findings are supported by Brauchla *et al.* (2021)[7], who observed a dramatic decline in vitamin C intake over a 20 year period (1999 2018) in a US nationally representative survey, likely driven by a decreasing FJ consumption. Similarly, according to NHANES data, 100% FJ intake was associated with better nutrient intake and diet quality in adults[8] and improved nutrient adequacy in children and adolescents (2 18 years)[9]. Regarding phytochem icals, the HELENA study showed that FVJ were among the top three food contributors of dietary (poly)phenols in European adolescents (12·5 17·5 years)[10]. Similar results have been reported for European adults, where FJ are sources of specific phenolic compounds[11]. (Poly)phenols or phenolic compounds are phytochemicals with proven biological activity widespread in all plant products, and (poly)phenol rich diets are associated with reduced risk of various diseases[12,13,14]. Ho *et al.* (2020)[15] reported that 100% FJ contribute to dietary (poly)phenol intake,

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making them complementary to commonly consumed (poly) phenol rich sources (for example, some fruits, coffee, tea, cocoa, etc.), and that some FJ (dark coloured ones) might provide many of the same benefits as whole fruits. Indeed, a recent systematic reviews and meta analysis (SRMA) on randomised controlled trials (RCT) providing quantitative data on the (poly)phenol content in 100% FJ has demonstrated how anthocyanins, but not total (poly)phenols, may mediate the potential beneficial effects of some 100% FJ on total and LDL cholesterol (LDL C)[16]. The contribution of other bioactive phytochemicals available in specific FVJ, such as carotenoids (tomato; carrot; citrus; etc.) and betalains (beetroot), may also account for the potential benefits of 100% FVJ. Therefore, it is essential to address the discussion on the health effects of 100% FVJ from a comprehensive point of view, taking into account the juice as a whole, as a food product naturally containing sugars, but also other beneficial compo nents, such as vitamins, minerals and phytochemicals.

Current dietary guidelines are primarily based on observa tional studies or systematic reviews/meta analyses of observa tional studies. This literature is key to understanding the health prospects of FVJ, but it presents a great heterogeneity of outcomes as the classification of FVJ is often ambiguous: although some authors distinguish between 100% FVJ and other types of juices (nectars), many epidemiological studies do not consider the compositional differences among 100% FVJ, nectars and even most SSB that typically contain only small amounts of FVJ[17]. Assessing together all the FVJ derived products may lead to misunderstandings as it is clear that the composition of sugars, micronutrients, and phytochemicals varies among these prod ucts, as does their potential contribution to human subject health[2]. On the other hand, while merging all the different 100% FVJ ('one size fits all' approach) is essential to provide sound dietary recommendations for the general population, an accurate assessment of the biological effects of these juices needs certain specificity. It seems reasonable to expect that juices from different botanical species (and compositions in secondary bioactive compounds, Fig. 1) may lead to different effects on a specific health outcome, so the assessment of the contribution of 100% FVJ to human subject health should be addressed for every juice and outcome.

The aim of this review was to shed light on the potential impact on human subject health of 100% FVJ. A brief overview of the contribution of 100% FVJ to main health outcomes was provided, considering mainly epidemiological studies. The core of this literature review focused on assessing the effects of FVJ on a wide range of outcomes through intervention studies conducted in human subjects and using 100% pure juice or purées (when available). To provide a complete picture of the research question, no limit was set with regard to the botanical species and health outcomes considered, neither by population setting or publication year. Discussion is provided by juice type, addressing the most relevant publications for any FVJ and health outcome: when only a few articles for a specific juice and outcome were available, they were all reported; however, when several articles were available for a specific outcome, the most representative papers (by experimental design and sample size) were selected as examples, together with available systematic reviews on the topic. When available, the phytochemical composition was reported to better understand the potential compounds behind the observed effects. When some relevant studies were on juice drinks but not on 100% fruit juice (for example, as for many studies on berry juices), they were included by specifying that the juice was not 100% FJ. Lastly, a thorough picture of the contribution of each FVJ to a health outcome was provided, considering the evidence available and research gaps and future needs were discussed.

General evidence from 100% fruit and vegetable juices as reported in observational studies and literature reviews

Most of the studies on the effects of 100% FVJ are related to cardiometabolic health and obesity, as they are closely associated with an increased sugar intake[17]. Comparison among different beverages derived from FVJ is essential to really understand the contribution of each juice beverage to cardiometabolic health in different population settings. In this sense, in the EPIC NL prospective cohort study with 35,000 participants (aged 20 70 years at enrolment), Scheffers *et al.* (2021)[18] found that substituting 100% FJ for SSB was associated with lower cardiometabolic risk, whereas replacing 100% FJ for fruit was not associated with differences in the risk of cardiovascular diseases (CVD), stroke, and type 2 diabetes (T2D). Authors concluded that 100% FJ did not appear to be different from whole fruit in relation to cardiometabolic risk[18]. Cross sectional data from about 8500 participants in the US Nurses' Health Study indicated that the intake of SSBs was associated with adverse levels of multiple cardiometabolic biomarkers, whereas the association was less consistent for FJ[19]. Similar results were found for the Framingham Heart Study, as SSB consumption was associated with adverse changes in lipoprotein concentrations and increased incidence of dyslipidemia, while regular con sumption of 100% FJ up to 1·5 daily servings was not linked to adverse effects on lipoproteins or dyslipidaemia[20]. Elsahoryi *et al.* (2021)[21] found that a high overall intake of fruits, vegetables and FJ was inversely associated with blood pressure (BP) in the PRIME study, a prospective study including about 10,600 men from France and Northern Ireland, while sub type analysis did not show any effect of FJ on BP.

Previous results on cardiometabolic risk biomarkers are in line with two recent SRMA of prospective cohort studies and RCT assessing the incidence of cardiovascular diseases and showing that 100% FVJ are among the fruit and vegetable sources associated with greater cardiovascular benefits[22,23]. Indeed, researchers[22,23] indicated that 100% FVJ intake was not linked to higher CV risk and that a non linear inverse dose response relationship was shown between 100% FVJ consumption and CVD, especially for the risk of stroke. In the case of T2D, no association between intake of 100% FVJ and risk of T2D in Japanese adults (40 59 years), who had no previous history of diabetes, was observed[24]. These findings were in line with a SRMA of RCT that reported a neutral effect of 100% FJ on glycaemic control[25]. Since this point would benefit from a more accurate discussion, but it is not the aim of this review, the following meta analysis on the effect of FVJ on glycaemic management are suggested: Choo *et al.* (2018)[26], D'Elia *et al.* (2020)[23] and Murphy *et al.* (2017)[25]. Lastly,

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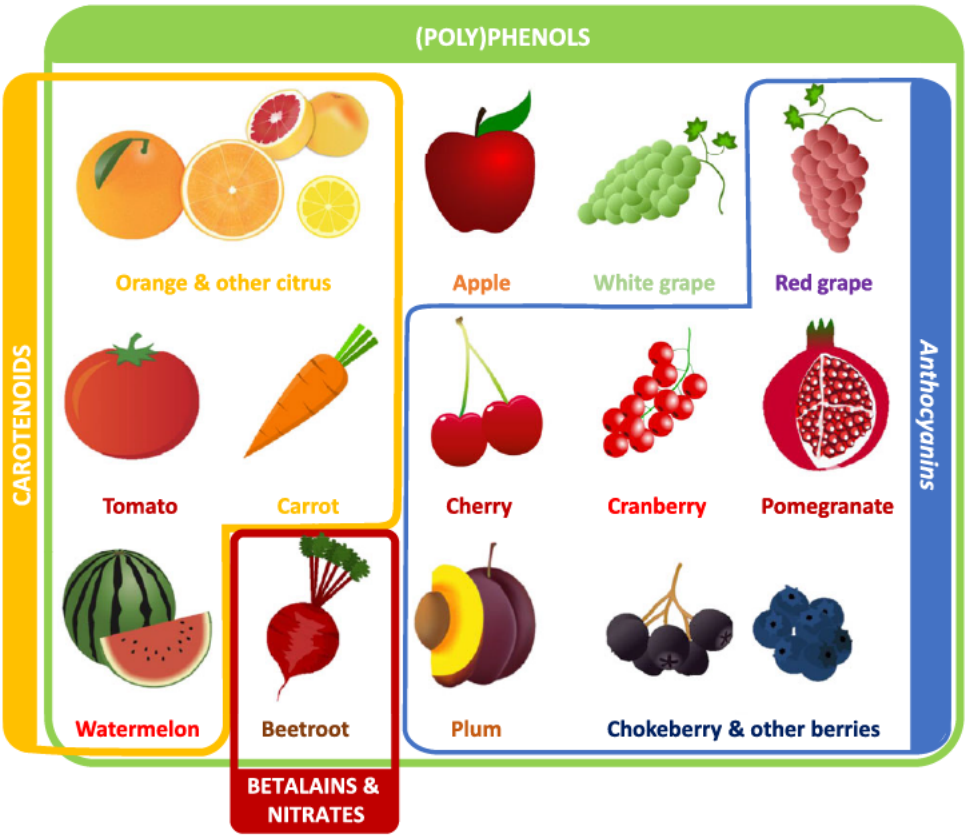

Fig. 1. Main families of non nutrient bioactive compounds in the FVJ assessed. Anthocyanins are a class of coloured polyphenols

regarding body weight, the results of a systematic review by Crowe White *et al.* (2016)[27] did not suggest an association between 100% FJ and weight status or adiposity in children (1 18 years) after controlling for total energy intake. Auerbach *et al.* (2017)[28], in a meta analysis of eight prospective cohort studies, also did not find an association of 100% FJ with clinically significant weight gain in children.

In general, this information on obesity and cardiometabolic outcomes is in agreement with a recent review by Ruxton and Myers (2021)[2], who reported that moderate consumption of 100% FJ (75 224 ml/d) did not increase the risk of T2D, poor glycaemic control, obesity or CVD, and that pure juices may confer health benefits in terms of vascular function and reduced BP. Authors thus concluded that 100% FJ appear to offer more benefits than risks within a balanced diet. A similar position was also reported by Auerbach *et al.* (2018)[29], highlighting that adverse health effects are not conclusive and dietary recommen dations allowing moderate consumption of 100% FVJ are supported by the available evidence. Indeed, although 100% FVJ can be a source of fructose increasing the risk of suffering from metabolic syndrome when consumed excessively, juice con sumption at moderate amounts (between 75 and 150 ml/d) may show protective effects on the incident of metabolic syndrome[30].

Two other emerging research fields related to FVJ are mental health and gut microbiota. Głąbska *et al.* (2020)[31], in a recent systematic review of observational studies, reported that FVJ were among the fruit and vegetable sources associated with a possible beneficial influence on mental health. Similarly, Pontifex *et al.* (2020)[32] supported the potential beneficial effects of (poly)phenols present in citrus fruits and juices on brain health, even though more has to be investigated. On the other hand, Henning *et al.* (2017)[33], in an intervention study designed to better understand the health benefits of an FVJ based diet, showed an alteration in the intestinal microbiota associated with weight loss among other physiological improve ments. However, despite the prospects of FVJ on gut microbiota, comprehensive literature reviews on this topic are still lacking.

Evidence of the health effects of 100% fruit and vegetable juices as reported in human subject intervention studies

Citrus juices

Citrus fruits and their juices are rich in micronutrients such as vitamin C, folate, potassium and magnesium, as well as in bioactive (poly)phenols[34,35,36]. Citrus are the main dietary source of flavanones, a flavonoid subclass. Flavanones in citrus fruit occur primarily in a glycosylated form, and the dominant flavanone glycosides are hesperidin in sweet orange and tangerine, naringin and neohesperidin in sour orange, naringin in grapefruit, and hesperidin and eriocitrin in lemon and lime[37,38]. Citrus juices have been associated with different protective features, as they may have a role in reducing the risk of T2D[34] and in the inflammatory response[35]. They are among the most studied FVJ as they also represent the major group of FVJ consumed by Western populations, orange juice being the most consumed 100% juice worldwide.

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Orange juice. Most of the literature on the health effects of juices is related to orange juice, and the number of targets addressed is quite broad. Some representative studies have been presented in Table 1.

Regarding body weight, Rangel Huerta *et al.* (2015)[39], in a randomised crossover double blind 12 week study, investigated the effects of consuming 500 ml/d of orange juice containing either normal (589 mg/l) or high (1490 mg/l) concentrations of flavanones (normal polyphenol juice (NPJ) and high polyphe nol juice (HPJ), respectively) in 100 non smoking adults who were overweight or obese. In both juices, hesperidin was the main flavanone, accounting for 89% and 78% of the polyphenol content for NPJ and HPJ, respectively. Potassium (460 and 1065 mg/500 ml, in NPJ and HPJ, respectively) and vitamin C (210 and 235 mg/500 ml, in NPJ and HPJ, respectively) were the main minerals and vitamins. Results showed a reduction in body weight, BMI and waist circumference following consumption of both juices. These reductions could be explained by the decrease in energy intake during the study, but not by the flavanone content of each treatment, which did not entail differences in the urinary excretion of flavanone metabolites between treatments[39]. A similar experimental protocol (12 week intervention, 500 ml/d, 100% orange juice, 324 mg/l hesperitin), where orange juice was supplemented as part of a reduced calorie diet, did not inhibit weight loss in seventy eight patients with obesity, as compared with the control group (a reduced calorie diet without orange juice)[40]. Another 12 week study showed no effect of 250 ml/d of orange juice (542 mg/l hesperidin) on body weight in men who were overweight[41]. Together, these studies showed no adverse effect of orange juice on body weight management, in agreement with two recent meta analyses of RCT on the effect of orange juice on anthropometric measures in healthy or unhealthy/at risk adults[42,43].

Considering vascular health, daily consumption of flavanone rich orange juices may be able to reduce BP, while red orange juice might affect endothelial function (contrary to 'blonde' or common orange, red or 'blood' orange contains anthocyanins). Consumption of an orange juice with normal levels of flavanones (NPJ, 589 mg/l) for 12 weeks reduced both systolic and diastolic BP in adults who were overweight/obese, while the decrease after consuming a juice with higher flavanone content (HPJ, 1490 mg/l) was not significant[39]. Contrarily, an effect of the flavanone content on BP has been described in a 12 week randomised parallel double blind placebo controlled trial evaluating the effects of hesperidin in orange juice on BP in 129 mildly hypertensive individuals[44]. Consumption of 500 ml/d of orange juice containing 690 mg/l of hesperidin, or enriched orange juice containing 1200 mg/l of hesperidin, decreased both systolic BP and pulse pressure in a dose dependent manner with the hesperidin content of the beverage administrated and in comparison to a control drink. Furthermore, a single dose of enriched orange juice (500 ml) but no other treatments reduced systolic BP. These functional changes were backed by changes in the plasma concentrations of hesperetin metabolites[44]. Similarly, Morand *et al.* (2011)[45] showed that lower levels of diastolic BP were reached after consumption of both orange juice, naturally rich in hesperidin, and an hesperidin enriched control drink. Nevertheless, other authors have reported a lack of effect of orange juice on BP. Hollands *et al.* (2018) compared 4 week consumption of 500 ml/d of 'blood' orange juice (134 mg/l of hesperidin + 100 mg/l of anthocyanins) or 'blonde' orange juice (208 mg/l of hesperidin, without anthocyanins) in 41 predominantly individuals who were overweight and found no effect of any juice on BP. In a 2 week study, consumption of 400 ml/d of 'blood' orange juice (802 mg/l of hesperidin + 24 mg/l of anthocyanins) did not change BP in 15 non smoking adults who were overweight or obese and who had baseline pressure within a healthy range[47]. The low amounts of flavanones provided[46], the intervention duration, and the baseline values in the study population[47] might be behind the lack of effect reported. The inter individual variability in the metabolism of flavanones may also condition the effect of orange juice consumption on systolic BP[48]. On the other hand, in the case of endothelial function,[47] a favourable effect (2% increase in flow mediated dilation (FMD)) of blood orange juice (400 ml/d for 2 weeks) was demonstrated compared with a control drink. The result correlated with a higher urinary excretion of hesperetin metabolites[47]. A similar improve ment in FMD was reported following 7 d consumption of red orange juice (500 ml/d, 319 mg/l of hesperidin and 71 mg/l of anthocyanins) in 19 non diabetic subjects with increased cardiovascular risk, while there was no effect in healthy subjects[49]. The result of the ongoing HESPER HEALTH study, which evaluates the role of orange juice in vascular health[50], will help to better establish the effect of orange juice intake on FMD.

Regarding lipid profile, a recent SRMA of fifteen RCT in healthy or unhealthy at risk adults investigated the effectiveness of orange juice intake on primary cardiometabolic markers, including lipid profile[43]. The results suggested that orange juice intake might be associated with reduced serum total cholesterol (TC) concentration. But, despite this extensive evidence, several works have failed to find an effect of orange juice consumption on lipid profile. Hollands *et al.* (2018)[46], comparing 4 week consumption of 500 ml/d of blood orange juice (containing anthocyanins) or blonde orange juice (without anthocyanins), found no effect of the orange juice pre and post supplementa tion on the lipid profile of forty one predominantly overweight individuals. In particular, the hypothesised improvement in LDL C with blood orange juice (because of its anthocyanin content) did not occur, nor was there any change in TC, HDL cholesterol (HDL C) and triacylglycerols (TG). As suggested by the authors, the study population was only minimally hyperlipidaemic (5·1 mmol/l TC), and an effect in individuals with higher TC (for example, >6·0 mmol/l) cannot be precluded. However, 12 week consumption of 250 ml/d of orange juice did not affect circulating lipids in thirty six men with overweight and elevated fasting serum TC (5 7 mmol/l)[41]. Nevertheless, in the orange juice group, those with the highest TG concentration pre intervention showed the greatest reduction after 12 weeks of supplementation[41]. Li *et al.* (2020)[47] also reported that the lipid profile (TC, LDL C, HDL C, and TGs) was unaffected by blood orange juice (400 ml/d for 2 weeks) in subjects with normal lipid levels. The same conclusions were found following either consumption of NPJ or HPJ (normal or high polyphenol concentration orange juice, respectively), except for TG and

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Table 1. Characteristics of some representative studies investigating the health effects of 100% orange juice

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bioactive compounds	Control/Placebo group	Main findings	Reference
Orange (blood orange)	RT, CO, 21 d	$n = 16$ (F), NW, 20 27 years	600 l/d	450 mg vitamin C, 21 mg cyanidin 3 glucoside	Diet devoid of blood orange juice	No changes in PAC, MDA, 11 dehydro TXB2, DNA damage	Riso *et al.*, 2005[57]
Orange, control drink + placebo (CDP), control drink + hesperidin (CDH)	RCT, CO, O + DB, 4 week	$n = 24$ (M), healthy, OW, 56 (SD 1) year	500 ml/d	292 mg hesperidin, 47·5 mg narirutin	CDP: isoenergetic control drink containing starch; CDH: isoenergetic control drink containing 292 mg of hesperidin	OJ and CDH: ↓ DBP and sVCAM 1, improved endothelial function; OJ: ↓ uric acid	Morand *et al.*, 2011[45]
Orange (Red orange)	RCT, SB, CO, 1 week	$n = 31$ (16 F, 19 intervention), OW/OB non diabetic subjects with increased cardiovascular risk + healthy nonobese control subjects, 48 (SD 13) year CVR group, 35 (SD 8) year control group	500 ml/d	210 mg GAE total (poly)phenols, 160 mg hesperidin, 22 mg narirutin, 36 mg cyanidin 3 glucoside anthocyanins	Control drink made up of water, orange aroma, colourants (azorubin and tartrazine), sucrose, citric acid	↓ FMD, hs CRP, IL 6, TNF α; no changes in plasma protein carbonyl concentrations	Buscemi *et al.*, 2012[49]
Orange	RCT, DB, CO, 8 week	$n = 37$ (24 F), healthy, OW, 67 (SD 5) years	500 ml/d	305 mg flavanones, 275 hesperidin, 30 mg narirutin	Isoenergetic low flavanone control drink (37 mg/500 ml)	Better global cognitive function compared with the control drink	Kean *et al.*, 2015[58]
Orange (normal or high concentrations of (poly)phenols, NPJ and HPJ, respectively)	RT, DB, CO, two 12 week periods	$n = 100$, OB, 18 65 years	500 ml/d	NPJ: 299 mg flavanones (237 mg hesperidin); HPJ: 745 mg flavanones (582 mg hesperidin)	Comparison of both interventions	Both NPJ and HPJ: ↑ glucose, urine hesperetin and naringenin metabolites; ↓ BW, BMI, WC, insulin, leptin; no changes in LDL c, TC, HDL c, HOMA IR; NPJ: ↓ SBP and DBP, TAG, apoB; HPJ: ↑ Apo A I, SOD activity	Rangel Huerta *et al.*, 2015[39]
Orange (juice with added orange pomace fibre)	RCT, DB, CO, single dose	$n = 24$ (M), healthy, OW/OB, 51 (SD 7) years	240 ml	272 mg flavonoids + with 5·5 g of added orange pomace fibre	Colour/flavour/energy matched beverage without flavonoids	Acute improvements in cognitive function and subjective alertness up to 6 h post consumption	Alharbi *et al.*, 2016[59]
Orange (without pulp (OJ), OJ with orange pomace fibre (OPF), juice made from lightly blended whole orange fruit (WOF))	RCT, DB, CO, post prandial single dose with four treatments	$n = 36$ (M), with ≥1 cardiometabolic risk factor, OW, 48 (SD 1) years	240 ml	OJ: 129 mg total flavonoids + 0·7 g fibre; OPF: 272 mg + 5·5 g; WOF: 453 mg + 6·3 g	Isoenergetic control drink without (poly)phenols	OPF delayed the time to reach the peak glucose concentration compared with Control and OJ, and of insulin compared with Control after breakfast	Dong *et al.*, 2016[52]
Orange	RCT, SB, parallel, 12 week	$n = 36$ M, elevated serum cholesterol, OW/OB, 49 (SD 4) years	250 ml/d	135 mg hesperidin, 15 mg narirutin	Colour/flavour/energy matched beverage	No changes in BW, LDL c, TC, HDL c, TAG, HOMA IR	Simpson *et al.*, 2016[41]
Orange consumed with a reduced calorie diet	RCT, parallel, 12 week	$n = 78$ (54 F, 39 intervention), OB, 36 (SD 1) years	500 ml/d	162 mg hesperitin, 7·7 mg naringenin	Reduced calorie diet without orange juice	↓ TC and LDL c, insulin, HOMA IR, hs CRP	Ribeiro *et al.*, 2017[40]

Table 1. (*Continued*)

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bioactive compounds	Control/Placebo group	Main findings	Reference
Orange (anthocyanin rich blood orange juice)	RCT, OL, two arm CO, 4 week	*n* = 41 (21 F), WC men >94 cm and women >80 cm, 52 (SD 14) years	500 ml/d	50 mg anthocyanins, 67 mg of hesperidin	Blonde orange juice without anthocyanins, 104 mg/500 ml of hesperidin	No changes in LDL c, TC, HDL c, TAG, glucose, fructosamine, NO, hs CRP, SBP, DBP, carotid femoral and brachial ankle PWV	Hollands *et al.*, 2018[46]
Orange, cvs. 'Bahia' and 'Cara Cara'	RCT, CO, 7 d	*n* = 21 (10 F), healthy, NW, 18 45 years	500 ml/d		Isoenergetic control drink containing water, sucrose, and vitamin C	Bahia and Cara Cara orange juice affected the gut microbiota composition differently	Brasili *et al.*, 2019[61]
Orange	nonRCT, temporal series intergroup design, 120 d (60 d experimental period with OJ)	*n* = 10 (F), healthy, NW/OW, 28 (SD 8) years	300 ml/d		No control	↑ SCFAs, *Lactobacillus* spp., *Bifidobacterium* spp., total anaerobic bacteria; ↓ blood glucose, insulin, HOMA IR, TAG, TC, LDL c	Delgado *et al.*, 2019[62]
Orange (blood orange)	RCT, SB, CO, 2 week	*n* = 15 (10 F), healthy, OW/OB, 28 (SD 6) years	400 ml/d	321 mg hesperidin, 38 mg narirutin, 10 mg anthocyanins	Sugar matched, low flavonoid drink	↑ FMD; no changes in BP, LDL c, TC, HDL c, and TAG	Li *et al.*, 2020[47]
Orange	RCT, SB, parallel, two arm, 8 week	*n* = 40 (24 F), with depressive symptom, NW, 22 (SD 2) years	380 ml/d	600 ±5·4 mg flavonoids/380 ml	Isoenergetic flavonoid low orange cordial (108±2·6 mg flavonoids)	↑ BDNF, folate; changed in microbiota composition potentially related to an improvement in depression	Park *et al.*, 2020[63]
Orange (without pulp (OJ), OJ with orange pomace fibre (OPF), whole orange fruit (WOF))	RCT, CO, single dose with three treatments (both studies)	*n* = 17 (11 F), healthy, NW, 39 (SD 3) years (study 1) *n* = 45 (21 F), healthy, NW, 25 (SD 4) years (study 2)	OJ: 250 g; OPF: 257 g; WOF: 227 g		No control	In both studies: OPF significantly attenuated glucose C_{max} compared with OJ; glucose T_{max} significantly delayed in OPF compared with OJ and WOF; insulin T_{max} significantly delayed in OPF compared with OJ and WOF	Guzman *et al.*, 2021[53]
Orange, natural hesperidin content (OJ) or enriched (EOJ)	RCT, DB, parallel, 12 weeks	*n* = 129, with pre or stage 1 hypertension, 18 65 years	500 ml/d	OJ: 345 mg hesperidin; EOJ: 600 mg hesperidin	Colour/flavour/energy matched beverage without hesperidin	EOJ: ↓ SBP, PP; OJ and EOJ: ↓ DBP, homocysteine	Valls *et al.*, 2021[44]

Juices were 100% juice unless otherwise stated. Abbreviations: 11 dehydro TXB2, 11 Dehydrothromboxane B2; Apo A, apolipoprotein A; Apo B, apolipoprotein B; BDNF, brain derived neurotrophic factor; BMI, body mass index; BP, blood pressure; BW, body weight; C_{max}, maximal glucose concentration; CDH, hesperidin control drink; CDP, placebo control drink; CO, crossover; CVR, cardiovascular risk; DB, double blind; DBP, diastolic blood pressure; EOJ, enriched orange juice; F, female; FMD, flow mediated dilation; GAE, gallic acid equivalent; HDL c, HDL cholesterol; HOMA IR, homeostasis model assessment insulin resistance; HPJ, high concentrations of (poly)phenols; hs CRP, high sensitivity CRP; IL 6, interleukin 6; LDL c, LDL cholesterol; M, male; MDA, malondialdehyde; NO, nitric oxide; NPJ, normal concentrations of (poly)phenols; NW, normal weight (BMI: 18,5 24,9 kg/m^2); OB, obesity (BMI: >30 kg/m^2); OJ, orange juice; OL, open label; OPF, orange pomace fibre; OW, overweight (BMI: 25 30 kg/m^2); PAC, A type proanthocyanidins; PP, pulse blood pressure; RCT, randomised controlled trial; RT, randomised trial; SB, single blind; SBP, systolic blood pressure; SCFAs, short chain fatty acids; SOD, superoxide dismutase; T_{max}, time to reach the maximal glucose concentration; TAG, triglycerides; TC, total cholesterol; TNF α, tumour necrosis factor α; WC, waist circumference; WOF, whole orange fruit; ↓, decreased level; ↑ increased level

apoB (the major component of LDL C), which decreased significantly only after the intake of NPJ when compared with baseline[39]. Differently, when orange juice was consumed concomitantly to a reduced energy diet for 12 weeks, it helped to reduce TC and LDL C in individuals with obesity and a normal lipid profile compared with the control group[40]. Therefore, orange juice consumption may impact the lipid profile but only for specific target populations, particularly in subjects with high TG concentrations.

The effect of orange juice supplementation on glucose insulin homeostasis and the prevention of T2D onset has been broadly studied. Dietary supplementation of 500 ml/d of blood or blonde orange juice for 4 weeks did not change glycaemia in subjects with overweight[46]. Similarly, orange juice, as part of a reduced calorie diet, did not increase glucose levels over time in patients with obesity, whereas it improved insulin sensitivity[40]. The decrease in insulin levels and the reduction of homeostasis model assessment insulin resistance (HOMA IR) were noted only after 8 weeks of intervention[40]. However, Simpson *et al.* (2016)[41] and Rangel Huerta *et al.* (2015)[39] found no change in HOMA IR index after a 12 week orange juice intervention in individuals who were overweight and with elevated fasting serum cholesterol and individuals who were overweight/obese, respectively, despite the amounts of orange juice administered were different (250 ml versus 500 ml per day). On the other hand, orange juice consumption may have positive effects on reducing uric acid levels in healthy adults[45].

The SRMA of RCT by Motallaei *et al.* (2021)[43] suggested that orange juice intake might be associated with improved insulin sensitivity, although the quality of the evidence was low to moderate and further well designed studies are needed to confirm this finding. Indeed, the contradictory nature of the available evidence has been highlighted and investigated by Prof. Williamson's group[34]. In a recent review of epidemio logical and intervention studies on the effect of orange juice consumption on risk of developing T2D, it was stated that orange juice might improve fasting glucose, fasting insulin and insulin sensitivity after 4 to 12 weeks of orange juice consumption. Inter individual variability in the metabolism of flavanones seems to be one of the main drivers affecting the physiological responses to chronic consumption in humans[34]. This review also concluded that the acute effect of orange juice consumption on post prandial glycaemic response is relatively small[34], as it may depend on the hesperidin and sugar content of the juice[51]. Fibre content may also play a role in the post prandial glycaemic response. Dong *et al.* (2016)[52] found that consuming 240 ml of orange juice added with pomace fibre (5·5 g) significantly reduced the maximal change in glucose concen trations reached after meal ingestion in men with increased cardiometabolic risk. Similar results have been recently shown by Guzman *et al.* (2021)[53].

Motallaei *et al.* (2021)[43] also investigated how orange juice intake might be associated with other cardiometabolic markers such as inflammatory markers (C reactive protein (CRP), interleukin 6 (IL 6), and vascular cell adhesion molecule 1 (VCAM 1)), although no significant associations were found. However, two recent meta analyses have accounted for the beneficial effect of 100% orange juice and hesperidin in orange juice on inflammation[54,55]. In this sense, some works indicated positive effects of orange juice consumption on inflammatory markers[40] and genes[56]. On the other hand, markers related to oxidative stress have also been considered. Both NPJ and HPJ protected against DNA damage and lipid peroxidation and modified several antioxidant enzymes in non smoking subjects who were overweight/obese [39]. In contrast, no change in plasma protein carbonyl concentrations, measured as a biomarker of oxidative stress, was observed following red orange juice intake in subjects with increased cardiovascular risk[49]. Similarly, con sumption of 600 ml/d of blood orange juice for 21 d did not modify plasma antioxidant status and lipid peroxidation, but it improved lymphocyte DNA resistance to oxidative stress in healthy women[57]. The 600 ml portion provided approximately 450 mg of vitamin C, 21 mg of cyanidin 3 glucoside, 0·4 mg of β cryptoxanthin, 0·12 mg of lutein, 0·11 mg of zeaxanthin and 0·1 mg of lycopene, and higher plasma concentrations of these components were recorded after juice intake[57]. The recent meta analysis by Cara *et al.* (2022)[55] also suggested a positive effect of 100% orange juice on malondialdehyde (MDA) levels, although the results were not statistically significant.

Other health outcomes such as cognitive function have also been investigated. Kean *et al.* (2015)[58], in a randomised double blind placebo controlled trial in thirty seven healthy older adults (66·7; SD 5·3 years), showed a significantly better global cognitive function after 8 weeks of 500 ml/d of high flavanone 100% orange juice (610 mg/l flavanones, 90% hesperidin) compared with an isoenergetic low flavanone control drink. In another study, consumption of 240 ml of orange juice with added orange pomace fibre containing 917 mg/l hesperidin and 5·5 g fibre was associated with acute improvements in cognitive function and subjective alertness up to 6 h post consumption in healthy middle aged males (51; SD 6·6 years), relative to an energy matched placebo drink[59]. In young adults (18 30 years), 500 ml/d of citrus juice (mainly orange including grapefruit juice, containing 140 mg/l flavonoids, of which 84 mg/l was hesperidin) enhanced cerebral blood flow. However, the results did not show a clear association between increased cerebral blood flow and behavioural benefits[60]. Moreover, a recent review on the impact of citrus (poly)phenols, mainly from orange juice, on brain functions accounted for positive effects on reduction of depression risk and cognitive ability linked to schizophrenia[31].

Orange juice could play a role in gut microbiota modulation. In a randomised crossover 7 d study, Brasili *et al.* (2019)[61] found that 500 ml/d consumption of two different orange juices belonging to 'Bahia' or 'Cara Cara' cultivars, significantly changed the gut microbiota composition in twenty one healthy individuals. Interestingly, the authors observed that the two juices, characterised by different vitamin C content, flavanones and carbohydrates, affected the modulation of the microbiota profile differently. Changes in metabolome were also cultivar specific[61]. In another study carried out in ten healthy young women that consumed 300 ml of commercial pasteurised orange juice for 2 months, orange juice positively modulated the composition and metabolic activity of gut microbiota, increasing the population of *Bifidobacterium* spp. and *Lactobacillus* spp.[62]. Changes in microbiota composition following

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flavonoid rich orange juice (600 mg flavonoids/380 ml daily dose, for 8 weeks) were also linked to a potential improvement in depression status in young adults[63].

In conclusion, orange juice shows no adverse effect on body weight and other anthropometric markers, as supported by recent meta analyses. It could lower systolic BP and improve endothelial function, notably due to the hesperidin content. It did not adversely affect the lipid profile and may help reduce high plasma TG concentrations. Similarly, it did not modify glycaemia and insulin sensitivity, neither could it improve the latter. The role of orange juice in oxidative stress and inflammation is not clear. Last, its effect on cognitive function and microbiota modulation showed interesting prospects, although these observations are still preliminary. Further studies should investigate the potential role of hesperidin and other bioactives in orange juices. Indeed, more attention should be paid on characterisation of the carotenoid and fibre content in orange juices. For instance, it has been reported that the bioavailability of β cryptoxanthin is greater from pasteurised orange juice than from fresh oranges, while higher fibre amounts may limit carotenoid bioavailability[64]. To draw more robust conclusions, a detailed phytochemical profiling is needed, and future research must consider the numerous confounding factors that may condition the physiological response, from the orange juice characteristics to the drivers of the inter individual variability both in the metabolism and the response (responders/non responders) to phytochemicals[34,54].

Grapefruit, mandarin and lemon juice. In comparison to orange juice, only a few studies have addressed the impact of grapefruit, mandarin and lemon juices on human subject health (Table 2). Some works have investigated the potential interaction of grapefruit juice with medication pharmacokinetics, particularly calcium channel blockers as antihypertensive therapy, but these were not reported as they go beyond the aim of this review.

Habauzit *et al.* (2015)[65], in a 6 month randomised controlled crossover double blind trial in forty eight healthy post menopausal women, found that 340 ml/d of either blonde grapefruit juice (626 mg/l of naringenin glycosides) or isoenergetic control drink matched for the macro and micronutrients of the juice, but without naringenin glycosides, did not affect body weight and other anthropometric measures. Considering vascular function, no effect on BP and endothelial function (for example, FMD) was observed following grapefruit juice consumption. However, grapefruit flavanones significantly lowered arterial stiffness compared with the control drink[65]. This effect has been recently attributed to the ability of grapefruit juice flavanones to modulate the expression of genes regulating inflammation, cell interactions and vascular function[66]. Considering glucose metabolism, inflammatory biomarkers and oxidative stress, they were not affected by grapefruit juice[65]. A similar lack of effect on body composition, BP and glucose homeostasis was achieved by Silver *et al.* (2011)[67] on subjects with obesity, although higher increases in serum HDL C concentrations in the grapefruit juice group relative to the grapefruit group were observed. Anyway, the evidence on grapefruit is still limited.

There is also a scarcity of available information on the health effects of mandarin or clementine juices in human subject settings. To date, just a few studies have been published. One dealt with children with obesity[68], where mandarin juice consumption (35 mg of vitamin C, 30 mg/l of low flavanone content, and 700 μg/l of carotenoids) within a 4 week hypoenergetic diet significantly decreased fasting insulin and HOMA IR index when compared with those who were not supplemented. Treatment reduced some markers of oxidative stress (MDA and carbonyl groups) while increasing the level of circulating antioxidants (vitamin C, α tocopherol and glutathione)[68]. Another intervention assessed the effect of β cryptoxanthin rich Satsuma mandarin juice supplementation (4 mg) in comparison to a β cryptoxanthin deprived Satsuma mandarin juice (0 mg) on pulse wave velocity[69]. A total of 117 participants completed this 12 week parallel intervention and, although serum β cryptoxanthin concentration increased in the treatment group, there were no differences between the treatment and control groups. Nonetheless, supplementation of both juices led to decreases in brachial ankle pulse wave velocity (PWV) and the levels of oxidative stress biomarkers, reducing the cardiovascular risk[69]. Despite the lack of effect of β cryptoxanthin in Satsuma mandarin juice at the cardiovascular level, a previous work showed that the 8 week intake of juice fortified with β cryptoxanthin might have stimulatory effects on bone formation and inhibitory effects on bone resorption in humans and, in particular, in post menopausal women[70].

Unlike orange, grapefruit and mandarin, lemon juice is not consumed alone, and there are no 100% lemon juices commercially available. Nevertheless, lemon juice can be used to prepare lemon based drinks or to acidulate some other juices to create 100% juices, being a way to increase the level of some bioactive compounds in the final beverage[71,72]. Freitas *et al.* (2021)[73], in a randomised crossover trial, investigated the effect of drinking 250 ml lemon juice (50% lemon juice, 50% spring water), black tea or spring water (control) with 100 g of bread on glycaemia and subsequent energy intake. No beverage affected the energy intake, but results showed that lemon juice significantly delayed and reduced peak postprandial blood glucose concentrations compared with water. Authors suggested that lemon juice, which lowered the pH of the meal, slowed down starch digestion through premature inhibition of salivary α amylase[73]. Therefore, lemon juice may help to control the glycaemic response, although further research is needed to confirm this aspect. In addition, the role of lemon flavanones should be explored in the light of the evidence collected for orange flavanones. Last but not least, a recent prospective randomised controlled open trial assessed the effects of fresh lemon juice supplementation (60 ml twice per day) to a standard diet on time to stone recurrence in 203 patients with recurrent idiopathic calcium oxalate nephrolithiasis[74]. Results suggested that lemon juice supplementation might prevent stone recurrence in patients with calcium oxalate nephrolithiasis. Nevertheless, adherence to the treatment was an issue as it also increased the frequency of gastrointestinal disorders[74].

Apple juice

Apples provide good amounts of fibre, in particular pectin, and a variety of (poly)phenols. Juice processing, specifically clarification, notably reduces the fibre and pectin content. In addition,

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Table 2. Characteristics of some representative studies investigating the health effects of grapefruit, mandarin and lemon juices

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bioactive compounds	Control/Placebo group	Main findings	Reference
Grapefruit	RCT, OL, parallel, three arm, 12 weeks	*n* = 68 (22 intervention), OB, 40 (SD 8) years	Restricted diet with 127 g juice	40 mg naringin	Water	↑ HDL c; no changes in BP, fasting glu cose, insulin, HOMA, and body com position	Silver *et al.*, 2011[67]
Grapefruit	RCT, DB, CO, 6 months	*n* = 48 (F), healthy, NW/ OW, 58 (SD 4) years	340 ml/d	213 mg naringenin glycosides	Drink matched for the nutrients of the juice but without naringe nin glycosides	↓ PWV; no changes in BW, other anthropometric measures, BP, FMD, FG, HOMA IR, insulin, hs CRP, ICAM 1, IL 6, vWF, FRAP	Habauzit *et al.*, 2015[65]
Mandarin (β crypto xanthin rich juice)	Non RCT, parallel, four arm, 56 d	*n* = 90 (71 F, 36 meno pausal women), hea thy, 27 65 years	200 ml/d	β cryptoxanthin rich Satsuma mandarin juice (1·5, 3·0, or 6·0 mg/d)	Placebo	Juice fortified with β cryptoxanthin has stimulatory effects on bone formation and inhibitory effects on bone resorp tion	Yamaguchi *et al.*, 2006[70]
Mandarin	RCT, OL, longi tudinal, parallel, 4 weeks	*n* = 40 (23 F, 20 inter vention), OB, 12 (SD 2) years	500 ml/d	hesperidin 10 mg, naringenin 5 mg	No juice supple mentation	↓ fasting insulin, HOMA IR, MDA, car bonyl groups; ↑ vitamin C, α tocoph erol, GSH	Codoner Franch *et al.*, 2010[68]
Mandarin (β crypto xanthin rich juice)	RCT, DB, parallel, 12 weeks	*n* = 117 (45 F, 59 inter vention), NW, 41 (SD 11) years	125 ml/d	β cryptoxanthin rich Satsuma mandarin juice (4 mg)	β cryptoxanthin deprived Satsuma mandarin juice (0 mg)	No differences between interventions. Both juices on time: ↓ brachial ankle PWV, MDA oxidised LDL, adiponectin; ↑ BMI, BP, FG, fasting insulin, HOMA IR, GGT	Nakamura *et al.*, 2017[69]
Lemon	RT, CO, 3d	*n* = 18 (11 F), healthy, NW, 33 (SD 10) years	250 ml (50% lemon juice)		Spring water or tea	Delayed and reduced peak post prandial blood glucose concentration compared with water	Freitas *et al.*, 2021[73]
Lemon	RCT, SB, OL, prospective	*n* = 158, patients with recurrent idiopathic calcium oxalate neph rolithiasis, NW/OW, 45 (SD 13) years	120 ml/d		No supplementa tion	Fresh lemon juice supplementation to a standard diet prevents stone recur rence in patients with calcium oxalate nephrolithiasis; ↑ frequency of gastro intestinal disorders	Ruggenenti *et al.*, 2021[74]

Juices were 100% juice unless otherwise stated. Abbreviations: BMI, body mass index; BP, blood pressure; BW, body weight; CO, crossover; DB, double blind; FG, fasting blood glucose; FMD, flow mediated dilation; FRAP, ferric reducing ability of plasma; GGT, &x01B4; glutamyl transpeptidase; GSH, glutathione; HOMA IR, homeostasis model assessment insulin resistance; hs CRP, high sensitivity CRP; ICAM 1, intercellular adhesion molecule 1; IL 6, interleukin 6; MDA, malondialdehyde; NW, normal weight (BMI: 18,5 24,9 kg/m^2); OB, obesity (BMI: >30 kg/m^2); OL, open label; OW, overweight (BMI: 25 30 kg/m^2); PWV, pulse wave velocity; RCT, randomised controlled trial; RT, randomised trial; SB, single blind; vWF, von Willebrand factor; ↓, decreased level; ↑ increased level

the concentration of (poly)phenols varies considerably between the peel and flesh of the apple. The compounds most found in apple peel are chlorogenic acids, flavan 3 ols (catechin, epicatechin and proanthocyanidins), phloridzin and quercetin derivatives. While quercetin derivatives are found exclusively in apple peel, the other compounds are also in the apple flesh but at much lower concentrations, except for chlorogenic acids, which are higher in the flesh than in the peel[75]. Apple pomace has been widely associated with cardiometabolic health benefits[76], while the information on apple juice is relatively scarce considering the commercial importance of apple juices. A recent review has tried to bridge this gap[77] and some relevant articles are presented in Table 3.

Barth *et al.* (2012)[78], in a randomised parallel study, investigated the effect of a (poly)phenol rich cloudy apple juice (total phenol content: 1070 mg/l) or an isoenergetic control drink (without (poly)phenols) on obesity associated metabolic and endocrine parameters in males with obesity. After 4 weeks at 750 ml/d, cloudy apple juice had no significant effect on BMI and waist circumference, while it significantly reduced percent body fat compared with the control drink. This effect was related to the IL 6 174 G/C polymorphism as body fat reduction was detectable only in C/C carriers but not in G/C or G/G ones[78]. Genetic polymorphisms were considered key to the better understanding of the effect of cloudy apple juice on fat reduction; although, it was not related to other obesity related parameters. In agreement with this study, a randomised five arm crossover study reported no changes in body weight and waist to hip ratio in healthy individuals who followed a 4 week restricted diet supplemented with 500 ml/d of either cloudy or clear apple juice compared with whole apples (550 g/d), apple pomace (22 g/d) and the control (diet without supplementation)[79]. The cloudy and clear apple juice contained 290 and 216 mg polyphenols per litre, respectively, where chlorogenic acid, procyanidin dimers and epicatechin were the major compounds in both juices; in addition, the cloudy juice had a pectin content of 0·94 g/l while it was almost absent in clear juice[79]. Therefore, although the literature shows promising results coming from animal studies[80], the available information through human subject interventions with apple juice do not account for improvements in anthropometric parameters and body composition, except when specific genotypic differences are considered.

Considering cardiometabolic biomarkers, BP, TC and HDL C were not affected by cloudy or clear apple juice in healthy subjects[79]. However, cloudy apple juice showed a similar not significant ($p = 0{\cdot}064$) trend to the whole apple and apple pomace in lowering TC and LDL C, while these parameters increased with clear apple juice compared with whole apple and pomace, but not to the control[79]. Similarly, Barth *et al.* (2012)[78] found no changes in blood lipids upon cloudy apple juice consumption. Results from a meta analysis of the effects of flavan 3 ol containing products on blood lipids and including the two previous studies indicated that intake of apple products was associated with reduced TC and LDL C levels[81]. Therefore, as the impact of apple juice on blood lipids is still contradictory, further research would be appreciated.

In the case of glucose insulin homeostasis, cloudy or clear apple juice did not show any effect on glucose metabolism markers (including insulin), in line with the consumption of whole apples or apple pomace[79]. On the other hand, Soriano Maldonado *et al.* (2014)[82] conducted a randomised crossover study in healthy adults for 4 weeks comparing two cloudy apple juices: a vitamin C rich juice (vitamin C and total polyphenol content: 60 and 510 mg/l, respectively) and a polyphenol rich juice (22 and 993 mg/l, respectively). An increase in insulin and HOMA index was observed after polyphenol rich cloudy apple juice consumption but not in the vitamin C rich cloudy apple juice group. Glucose and blood lipids did not change between treatments[82].

Considering inflammatory markers, no significant changes were found in a panel of systemic and vascular inflammation markers and adipokines after cloudy apple juice consumption by individuals with obesity[78]. Apple consumption, regardless of form (whole, pomace, clear or cloudy juice), did not change high sensitivity CRP (hs CRP) levels in healthy volunteers[79]. The same results were reported by Soriano Maldonado *et al.* (2014)[82], where the vitamin C rich or polyphenol rich cloudy apple juice did not change inflammation related parameters compared to the baseline. Examining biomarkers of oxidative stress, clear and cloudy apple juices did not modify the antioxidant status with respect to the control in healthy individuals[79]. These results were in line with the data collected for the polyphenol rich cloudy apple juice compared to the vitamin C rich one, as no modifications in plasma antioxidant activity were registered[82]. On the contrary, antioxidant activity significantly increased after vitamin C rich juice, but this increase was not related to the plasma vitamin C levels. In addition, consuming the polyphenol rich juice reduced total glutathione levels in peripheral blood mononuclear cells[82].

A thorough acute intervention study was conducted to assess the effect of fructose from fruit sources in the increase in uric acid concentration, as it is well known that the intake of large amounts of fructose raises circulating urate[83]. Participants ingested two servings (small or large) of apple segments and apple juice, or a glucose and a fructose control beverage. Plasma uric acid levels increased after consumption of all fructose containing treatments, without differences between apple segments and juices[83]. More attention should be paid to this point, as hyperuricemia (high levels of uric acid) represents the main risk factor for gout, the most common inflammatory form of arthritis in men[84].

Finally, no changes in microbiota composition were observed after consumption of apple juice, clear or cloudy, by healthy volunteers for 4 weeks[79]. Similar results were achieved after cloudy apple juice intake by patients with T2D for the same time period: although small decreases were found in numbers of Enterococci and Firmicutes, the overall microbiota profile did not change when compared with the isoenergetic control beverage[85].

Few high quality studies have been conducted on apple juice despite its market share. No significant effects of apple juice on human subject health have been discovered. Apple juice only showed a moderate effect in reducing body fat depending on gene polymorphisms. This is a point worth mentioning as inter individual variability may be key to better evaluating the beneficial effects of apple juice. Indeed, as a notable

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Table 3. Characteristics of some representative studies investigating the health effects of 100% apple juice

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bioactive compounds	Control/Placebo group	Main findings	Reference
Apple (cloudy)	RCT, blinded, parallel, 4 weeks	$n = 68$ (M, 38 intervention), OB, mean age 49 years	750 ml/d	802·5 mg total phenols	Isoenergetic control drink without (poly) phenols	↓ body fat % (in C/C variants of IL 6 174 G/C polymorphism); no changes in BMI and WC, adipokines, hs CRP, IL 6, TNF α, ICAM 1, VCAM 1, TC, LDL c, and HDL c, ↑ plasma TAG levels in both groups	Barth *et al.*, 2012[78]
Apple (cloudy (CDJ) clear (CLJ))	RT, SB, CO, 4 weeks	$n = 23$ (14 F), healthy, NW, 36 (SD 18) years	Restricted diet with 500 ml/d juice	total (poly)phenols: CDJ: 145 mg; CLJ: 108 mg	Restricted diet without supplementation	No changes in BW and WHR, BP, hs CRP, insulin, IGF1 and IGFBP3, TAG and HDL c; CDJ trend in lowering TC and LDL c; CLJ trend in increasing these parameters	Ravn Haren *et al.*, 2013[79]
Apple (vitamin C rich (VCR) or (poly)phenol rich (PR) cloudy apple juice)	RT, CO, 4 weeks	$n = 20$ (12 F), healthy, NW, 24 (SD 2) years	500 ml/d	PR: 11 mg vitamin C, 496·5 mg epicate chin eq.; VCR: 30 mg vitamin C, 255 mg epicatechin eq.	Comparison of both interventions	No changes in inflammation related parame ters; PR: ↑ insulin and HOMA, ↓ GSH levels in PBMCs; VCR: ↑ FRAP, ↓ trend in ICAM 1 and TC	Soriano Maldonado *et al.*, 2014[82]
Apple (cloudy)	RCT, DB, parallel, 4 weeks	$n = 10$ (M, 5 inter vention), patients with T2D, NW, 57 71 years	750 ml/d		Isoenergetic control drink without (poly) phenols	↓ Enterococci and Firmicutes, the overall micro biota profile did not change with respect to the control	Cho *et al.*, 2015[85]
Apple	RCT, CO, single dose	$n = 51$ (15 control, 19 apple, 17 apple juice), healthy, NW/ OW, 18 65 years	small (170 ml) and large (340 ml) servings		Positive control (fruc tose beverage), negative control (glucose beverage) and apple segments	↑ plasma uric acid after consumption of all fruc tose containing treatments	White *et al.*, 2018[83]

Juices were 100% juice unless otherwise stated. Abbreviations: BP, blood pressure; BMI, body mass index; BW, body weight; CLJ, clear apple juice; CO, crossover; DB, double blind; F, female; FRAP, ferric reducing ability of plasma; GSH, glutathione; hs CRP, high sensitivity CRP; ICAM 1, intercellular adhesion molecule 1; IGF1, insuline like growth factor; IGFBC3, Insulin like growth factor binding protein 3; IL 6, interleukin 6; HDL c, HDL cholesterol; LDL c, LDL cholesterol; M, male; NW, normal weight (BMI: 18,5 24,9 kg/m^2); OB, obesity (BMI: >30 kg/m^2); OL, open label; OW, overweight (BMI: 25 30 kg/m^2); PBMCs, peripheral blood mononuclear cell; PR, (poly)phenol rich juice; RCT, randomised controlled trial; RT, randomised trial; SB, single blind; T2D, type 2 diabetes; TAG, triglycerides; TC, total cholesterol; TNF α, tumour necrosis factor α; VCAM 1, vascular cell adhesion molecule; VCR, vitamin C rich juice; WC, waist circumference; WHR, waist to hip ratio; ↓, decreased level; ↑ increased level

inter individual variability has been reported in the metabolism of apple flavan 3 ols[86], leading to different profiles of biologically active metabolites, individual profiles of phenolic metabolites, as well as genotypic differences, should be investigated in further interventions studies with apple juice. Further efforts to assess the impact of compositional differences would favour further mechanistic research.

Grape juice

Red (or purple) and white grape juices from *Vitis vinifera* cultivars are predominant in the market, and most of the scientific literature on the health properties of grape juices is related to these two juices. Nevertheless, other purple grape juices made from Concord (*V. labrusca*) and Muscadine (*V. rotundifolia*) cultivars have received much attention in recent years. Grapes are typically good sources of (poly)phenols, being rich in flavan 3 ols (both catechins and proanthocyanidins), flavonols, phenolic acids, stilbenes and, in the case of red/purple cultivars, anthocyanins. The cultivar used for juice production substantially influences the phenolic profile and content, as well as environmental factors and cultivation methods[87]. As a general indication, white grape juice shows higher contents in phenolic acids and resveratrol and lower contents in flavan 3 ols, flavonols, and anthocyanins[88]. Although their health effects may change notably due to the grape type (Table 4), all the grape juices are discussed together to provide a global overview and since the evidence in humans is not so broad as for grape wines.

Zuanazzi *et al.* (2019)[89] investigated the health effects of 100% white grape juice from *V. labrusca*, characterised by a total phenolic content of 267·9 mg/l, where caffeic acid (13·9 mg/l) and (+) catechin (11·3 mg/l) were the most abundant compounds. Over a 30 d intervention at 7 ml/kg/d (490 ml/d for a 70 kg woman), white grape juice supplementation to twenty five non smoking women (eleven eutrophic and four teen who were overweight or obese) reduced BMI and waist and abdominal circumference. Nevertheless, the lack of a control arm precludes solid conclusions. Indeed, in contrast to this work, Dohadwala *et al.* (2010)[90] reported no change in body weight following consumption of 7 ml/kg/d of 100% Concord grape juice (total phenols: 1970 mg/l) or placebo beverage for 8 weeks in sixty four otherwise healthy patients (with prehy pertension and with stage one hypertension, but taking no anti hypertensive medications).

Considering vascular function, BP did not change after consumption of white (Zuanazzi *et al.* 2019)[89] or Concord grape juice[90]. Similarly, no effect on BP was observed after 12 week daily consumption of 355 ml Concord grape juice (total phenols: 2188 mg/l, 21% anthocyanins and 43% proanthocya nidins) in healthy middle aged working mothers compared with a placebo[91]. Nevertheless, some works have reported a positive effect of grape juice consumption on both systolic and diastolic BP in healthy individuals (Concord grape juice, 5·5 ml/kg/d, 8 weeks)[92], hypertensive men (Concord grape juice, 5·5 ml/kg/d, 8 weeks)[93] and hypercholesterolemic patients (purple grape juice, 500 ml/d, 2 weeks)[94], so that a beneficial effect of grape juice on BP cannot be ruled out. While BP effects are contradictory, the evidence on arterial function assessed using FMD seems more promising. Coimbra *et al.* (hypercholesteraemic patients)[94], Stein *et al.* (coronary patients, Concord grape juice, 8 ml/kg/d, 2 weeks)[95], Chou *et al.* (coronary patients, Concord grape juice, 4 and 8 ml/kg/d, 8 weeks)[96], and Siasos *et al.* (healthy smokers, Concord grape juice, 7 ml/kg/d, 2 weeks; juice phenolics: flavan 3 ols 434 µmol/l, anthocyanins 296 µmol/l, hydroxycinnamates 162 µmol/l, and flavonols 76 µmol/l)[97] demonstrated that short term ingestion of purple/Concord grape juice could improve FMD in different population settings.

Regarding lipid profile, white[89], purple[94], and Concord[96] grape juice did not affect blood lipids, except for a 16% increase in HDL C in women consuming white grape juice for 30 d[89]. In the case of glucose metabolism, grape juice supplementation did not modify glycaemia or insulin levels[89,90], unless for a minimal but significant reduction in glucose levels after 8 week Concord grape juice consumption[90]. Taking into account other cardio metabolic biomarkers, no major changes in blood markers of inflammation and platelet activity are reported in the literature.

Examining biomarkers of oxidative stress, Zuanazzi *et al.* (2019)[89] reported no change in nitric oxide levels or markers of oxidative damage following consumption of white grape juice in women. No change in lipid peroxidation was observed following a single dose of 10 ml/kg of 100% purple grape juice in recreational runners[98]. Differently, O'Byrne *et al.* (2002)[99] found that consumption of 10 ml/kg/d 100% Concord grape juice for 2 weeks increased serum antioxidant capacity and protected LDL against oxidation in thirty two healthy adults, to an extent similar to that obtained with 268 mg/d α tocopherol, while decreased native plasma protein oxidation significantly more than α tocopherol. A reduction in LDL susceptibility to oxidation was also reported by Stein *et al.*[95]. Last, protective effects on lymphocyte DNA damage have also been reported[92].

The association between grape juice and cognitive function has been widely studied. A recent critical review of epidemio logical and randomised controlled human subject trials regarding the role of grapes and their derivatives in modulating cognitive decline was conducted by Restani *et al.* (2021)[100]. All reviewed studies investigating the effect of grape juice con sumption reported improved cognitive function in the interven tion group versus the control group after both single dose and long term (up to 6 months) supplementation. Remarkably, the most encouraging results included reaction times, verbal skills, degree of orientation, learning, and memory. Cognitive improve ment was observed in both healthy young adults (21·05 ± 0·89 years)[101], healthy middle aged women (40 50 years)[91], and older adults with mild cognitive decline (78·2; SD 5·0 years)[102]. Restani *et al.* (2021)[100] concluded that Concord and purple grape juice consumption (200 500 ml/d) was generally associated with improved cognitive performance. Similar conclusions have been presented in a recent systematic review on the topic[103].

Grape juice is considered a potentially ergogenic food for sports performance. De Lima Tavares Toscano *et al.* (2020)[104] demonstrated that drinking a single dose of 100% purple grape juice (10 ml/kg, total phenols: 3106 mg/l) increased run time to exhaustion by almost 19% in fourteen male recreational runners. In a previous study, Toscano *et al.* (2015)[105] also found a 15% increased physical performance following 28 d supplementa tion with a similar juice (10 ml/kg/d, same grape cultivar).

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Table 4. Characteristics of some representative studies investigating the health effects of 100% grape (white, red/purple and Concord) juice

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bioactive compounds	Control/Placebo group	Main findings	Reference
Grape (Concord grape)	RT, prospective single centre, 2 weeks	*n* = 15 (3 F), CAD patients, 63 (SD 13) years	8 ml/kg/d		No control nor placebo	↓ LDL susceptibility to oxidation; improved FMD	Stein *et al.*, 1999[95]
Grape (Concord grape)	RT, prospective single centre, 4 weeks	*n* = 22 (4 F, 11 high GJ dose, 11 low GJ dose), with CAD, 64 (SD 10) years	4 ml/kg/d and 8 ml/kg/twice daily		Comparison of both interventions	↑ FMD; no changes in blood lipids, glucose, insulin levels	Chou *et al.*, 2001[96]
Grape (Concord grape or capsules of α tocopherol)	RT, blinded, 2 weeks	*n* = 32 (19 F, 15 intervention), healthy, NW/OW/OB, 28 (SD 5) years	10 ml/kg/d	560 mg phenolic equivalents per litre of flavonoid content	Comparison of both interventions	↑ serum antioxidant capacity and protected LDL against oxidation, ↓ native plasma protein oxidation	O'Byrne *et al.*, 2002[99]
Grape (Concord grape)	RCT, DB, 8 weeks	*n* = 40 (M, 21 intervention with GJ), hypertensive not treated, OW, 45 (SD 2) years (GJ)	5·5 ml/kg/d	2109 mg/l phenol content	Placebo drink without (poly) phenols	↓ SBP and DBP	Park *et al.*, 2004[93]
Grape (purple grape)	RCT, CO, 2 weeks	*n* = 16 (8 F) + 24 external controls, hypercholesterolemic individuals, NW/OW, 52 (SD 8) years	500 ml/d		Red wine 250 ml/d	↓ ICAM 1; ↑ FMD; no changes in BA diameter, NTGD, Lp(a), Apo A, Apo B, VCAM 1	Coimbra *et al.*, 2005[94]
Grape (Concord grape)	RCT, DB, 8 weeks	*n* = 40 (M, 21 intervention with GJ), not treated mild hypertensive men, OW, 45 (SD 2) years (GJ)	5·5 ml/kg/d	2108 mg/l phenol content	Placebo drink without (poly) phenols	↓ SBP and DBP, lymphocyte DNA damage; no effects on plasma lipids and TRAP	Park *et al.*, 2009[92]
Grape (Concord grape)	RCT, DB, CO, 8 weeks	*n* = 64 (20 F), with prehypertension and stage 1 hypertension taking no medication, OW, 43 (SD 12) years	7 ml/kg/d	473 mg/8 oz total (poly)phenols	Colour/flavour/energy matched beverage without (poly)phenolics	↓ glycaemia; no changes in BW, BP, blood markers of inflammation and platelet activity, HDL c, TC, LDL c, TAG, insulin	Dohadwala *et al.*, 2010[90]
Grape (Concord grape)	RT, DB, 16 weeks	*n* = 21 (10 F), with mild age related cognitive impairment, OW/OB, 77 (SD 6) years	6·3 7·8 ml/kg/d	2091 mg GAE/l total (poly)phenolics, 425 mg/l anthocyanin, 888 mg/l proanthocyanidins	Colour/flavour/energy matched beverage without (poly)phenolic compounds	Improved cognitive function	Krikorian *et al.*, 2012[102]
Grape (Concord grape)	RCT, DB, CO, 2 weeks	*n* = 26 (16 F), healthy smokers, NW/OW, 26 (SD 5) years	7 ml/kg/d	473 mg/240 ml total (poly)phenols, flavan 3 ols 434 μmol/l, anthocyanins 296 μmol/l, hydroxycinnamates 162 μmol/l, and flavonols 76 μmol/l	Grapefruit juice without (poly) phenol	Improved FMD and PWV; no changes in body weight, total cholesterol, triglycerides, LDL c, serum glucose, and SBP, DBP	Siasos *et al.*, 2014[97]
Grape (purple grape)	RT, 28 d	*n* = 28 (6 F, 15 intervention), NW/OW, 40 (SD 8) years	10 ml/kg/d		Isoenergetic, isoglycemic beverage (artificial grape flavour)	↑ run time to exhaustion (15% increase)	Toscano *et al.*, 2015[105]

Table 4. (*Continued*)

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bioactive compounds	Control/Placebo group	Main findings	Reference
Grape (Concord grape)	RCT, DB, CO, 12 weeks	*n* = 25 (F, 25 completed the first arm, 19 completed both arms, 10 completed driving performance task), healthy, NW/OW, 43 (SD 1) years	355 ml/d	777 mg GAE total (poly) phenolics	Colour/flavour/energy matched beverage, without (poly)phenolic compounds	No effect on BP; improvement in cognitive function, better immediate spatial memory and driving performance	Lamport *et al.*, 2016[91]
Grape (purple grape)	RCT, DB, counterbalanced CO, single dose	*n* = 20 (13 F), healthy, 21 (SD 1) years	230 ml (200 ml purple grape juice plus 30 ml of Schweppes™ blackcurrant flavour cordial)	1504 ug GAE/ml total phenolics, 138 mg/l anthocyanin content	Beverage with 200 ml white grape juice plus 10 ml black currant flavour cordial and 20 ml cold water, only a small concentration of phenolic compounds	Improved cognitive function	Haskell Ramsay *et al.*, 2017[101]
Grape	RCT, DB, parallel, 4 weeks	*n* = 26 (17 F, 14 intervention), hypertensive, NW/OW, 53 (SD 2) years	150 ml for men, 100 ml for women		Control drink	↓ BP at rest; improved PEH	Neto *et al.*, 2017[107]
Grape (JG, exercise group and juice + exercise group)	RT, prospective, parallel, 12 weeks	*n* = 45 (12 JG), hypertensive, NW/OW, 69 (SD 5) years	200 ml/d		Control drink	↓ SBP, DBP and HR	Leal *et al.*, 2019[106]
Grape (white grape)	30 d	*n* = 25 (F), NW/OW/OB, 50 67 years	7 ml/kg/d	267·9 mg GAE/l total phenolic, 13·9 mg/l caffeic acid, 11·3 mg/l (+) catechin	No control	↓ BMI, WC and AC; ↑ HDL c; no changes in BP, TC, LDL c, TAG, glycemia, insulin, NO, SOD	Zuanazzi *et al.*, 2019[89]
Grape (purple grape)	RCT, DB, CO, single dose	*n* = 14 (M), recreational runners, NW/OW, 39 (SD 9) years	10 ml/kg/d	3107 mg/l total phenolics, 84 mg/l phenolic acids	Colour/flavour/energy matched beverage, total (poly)phenol content: 940 mg/l	No change in lipid peroxidation; ↑ run time to exhaustion (18·7% increase)	de Lima Tavares Toscano *et al.*, 2020[98]

Juices were 100% juice unless otherwise stated. Abbreviations: AC, abdominal circumference; Apo A, apolipoprotein A; Apo B, apolipoprotein B; BA, brachial artery; BP, blood pressure; CAD, coronary artery disease; CO, crossover; DB, double blind; DBP, diastolic blood pressure; F, female; FMD, flow mediated dilation; GAE, gallic acid equivalent; GJ, grape juice; HDL c, HDL cholesterol; HR, heart rate; ICAM 1, intercellular adhesion molecule 1; JG, juice group; LDL c, LDL cholesterol; Lp(a), lipoprotein (a); M, male; NW, normal weight (BMI: 18,5 24,9 kg/m^2); OB, obesity (BMI: >30 kg/m^2); OL, open label; OW, overweight (BMI: 25 30 kg/m^2); NO, nitric oxide; NTGD, nitroglycerin mediated vasodilation; PEH, post exercise hypotension; PWV, pulse wave velocity; RCT, randomised controlled trial; RT, randomised trial; SB, single blind; SBP, systolic blood pressure; SOD, superoxide dismutase; TAG, triglycerides; TC, total cholesterol; TRAP, plasma total radical trapping antioxidant potential; VCAM 1, vascular cell adhesion molecule; WC, waist circumference; ↓, decreased level; ↑ increased level

Authors also reported some benefits in inflammatory markers in these runners. Last, contrary to the evidence on BP upon chronic consumption of grape juice by non sport individuals, grape juice supplementation may also help BP management after aerobic exercise[110, 111].

In conclusion, homogeneous results were observed for vascular and cognitive function, showing moderate improvements after red or Concord grape juice consumption. Some benefits in specific markers of oxidative stress are also well documented. The benefits on exercise conditions are of interest, but they cannot be extrapolated to all physical activity contexts. More discordant results for other outcomes were achieved. In general, the evidence to date is quite limited, considering the importance of this juice at the market level. Although some health benefits might be similar to those investigated for grape wines[108], further high quality intervention studies are needed. In addition, emphasis should also be paid to white grape juice, as the evidence is quite limited. Comparisons among different classes of grape juice (white, red or Concord) may help to better understand the potential role of grape juices in disease prevention and what are the responsible compounds backing the physiological effects observed.

Pomegranate juice

Regarding main bioactive compounds, pomegranate juice contains anthocyanins, ellagitannins and ellagic acid derivatives, among other phenolics[109]. Although the edible part of pomegranate (arils) contains almost exclusively anthocyanins, commercial pomegranate juices also present high amounts of ellagitannins and ellagic acid coming from the peel and inner parts (mesocarp) as a consequence of the juicing process[110]. In addition, besides cultivars, agronomical and harvest conditions, processing may pretty much alter the phytochemical composition of pomegranate juices[72,111,112,113]. Several works have reviewed the evidence behind the potential health benefits of pomegranate juice[112,113,114,115,116], so here only a brief overview is presented. Of note, many studies have focused on the role of pomegranate juice in patients rather than in the general population (Table 5).

Moazzen & Alizadeh (2017)[118], in a double blinded randomised crossover controlled trial, investigated the effects of 1 week supplementation with 500 ml/d of pomegranate juice on cardiovascular risk factors in thirty patients with metabolic syndrome. The juice contained 100 mg/l of anthocyanins, while the composition in ellagitannins was not reported. Results showed a reduction in systolic and diastolic BP in the intervention group compared with placebo[117]. Similarly, after 6 weeks at 200 ml/d of pomegranate juice (total polyphenols: 2125 mg/l), a significantly reduced systolic and diastolic BP was observed in sixty patients with T2D in comparison with the control group (no juice supplementation)[119]. In another double blind randomised controlled study in 101 haemodialysis patients, Shema Didi *et al.* (2014)[120] found that systolic BP decreased with respect to placebo after one year of consuming 100 ml pomegranate juice (total polyphenols: about 1190 mg/l) three times per week. However, improvements in BP or PWV were not observed in fifty one healthy subjects (middle aged normotensive adults) consuming 330 ml/d of pomegranate juice (total polyphenols: 3162 mg/l; potassium: 1711 mg/l) for 4 weeks[121]. Cumulative evidence indicates that pomegranate juice consumption may lead to consistent benefits on BP, as stated by a SRMA of eight RCT[122]. Nevertheless, these BP improvements happen mainly in hypertensive patients, regardless of the presence/absence of antihypertensive medication, that may also suffer from other cardiometabolic diseases. Further information on healthy subjects or individuals at risk of hypertension may help to draw preventive strategies taking pomegranate juice into account.

Evaluating the effect of pomegranate juice on lipid profile, 500 ml/d supplementation for 1 week increased blood TG and very low density lipoprotein cholesterol (VLDL C) levels in individuals with metabolic syndrome, as opposed to the placebo, whereas TC, HDL C, and LDL C did not change[117]. Authors hypothesised that this negative effect could disappear in a long term supplementation so, rather than as a negative outcome, this data should be regarded as part of the inconclusive evidence on the role of pomegranate juice in the lipid profile. For instance, contrary to the previous work, TC, LDL C, HDL C and TG concentrations were not different compared with the control group after 6 week pomegranate juice consumption in patients with T2D[119]. Shema Didi *et al.* (2014)[120] found that 1 year pomegranate juice consumption, compared with the placebo, improved TG and HDL C levels in haemodialysis patients, with a greater effect in subjects with hypertension, low HDL C and high blood TGs (higher cardiovascular risk)[120]. Overall, it seems that pomegranate juice is not able to modify the lipid profile consistently. Differences may be due to the heterogeneous evidence available, as well as due to the different physiological responses of individuals metabolising differently pomegranate ellagitannins[115].

In the case of glucose insulin metabolism, pomegranate juice did not change fasting blood glucose, insulin and HOMA IR in patients with metabolic syndrome on 1 week of consumption[117]. Similarly, no adverse effect on fasting blood glucose level was found after 6 weeks at 200 ml/d[123] and 12 weeks at 250 ml/d[124] in T2D patients. In the case of acute responses, Kerimi *et al.* (2017)[125] found that 200 ml pomegranate juice (71·5 mg punicalin, 12·4 mg punicalagin, 4·8 mg ellagic acid and 2·8 mg ellagic acid hexose), consumed with approximately 109 g of white bread (50 g available carbohydrate), significantly attenuated the post prandial glycaemic response in healthy subjects, compared with a control solution containing the equivalent amount of sugars. These authors proposed that the effect was primarily due to the ability of punicalagin to inhibit human subject salivary α amylase, whereas microbial metabolites of pomegranate ellagitannins (namely urolithins) may also modulate glucose metabolism after the acute post prandial period. Interestingly, a pomegranate polyphenol rich extract was ineffective on glycaemic response, and the beneficial effects were only observed after juice intake. So, while pomegranate juice does not seem able to modify glucose metabolism in chronic conditions, it may be able to reduce acute post prandial glycemic response in healthy subjects[125].

In the context of inflammation, Moazzen and Alizadeh (2017)[118] found that pomegranate juice (500 ml/d, 1 week), but not the placebo, decreased hs CRP levels in patients with

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Table 5. Characteristics of some representative studies investigating the health effects of 100% pomegranate juice

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bioactive com pounds	Control/Placebo group	Main findings	Reference
Pomegranate	RCT, OL, parallel, 4 weeks	*n* = 48 (32 F, 24 intervention group), healthy, OW, 38 (SD 1) years	330 ml/d	6·14 mmol total phenol	Commercial lemonade drink matched for energy and carbohy drate content	↓ SBP and DBP; no effect on PWV	Lynn *et al.*, 2012[121]
Pomegranate	RCT, DB, 1 year (3 times per week)	*n* = 101 (66 intervention), chronic hemodialysis patients, 66 (SD 12) years	100 ml/time	0·7 mmol (poly)phenols	Colour/flavour matched juice without (poly) phenols	↓ SBP, PP, TAG; ↑ HDL c; no changes in TC, LDL c, DBP	Shema Didi *et al.*, 2014[120]
Pomegranate	RCT, DB, 12 weeks	*n* = 44 (21 F, 22 intervention), with T2D, OW/OB, 56 (SD 7) years	250 ml/d	486 mg GAE total phenol, 86 mg total flavonoid	Colour/flavour/energy matched beverage without (poly)phenols	↑ TAC; ↓ MDA; no effect on FG, pentosidine and CML	Sohrab *et al.*, 2015[124]
Pomegranate	RCT, DB, CO, acute, six arm	*n* = 16, healthy, NW/OW, 31 (SD 5) years	200 ml	71·5 mg punicalin, 12·4 mg punicalagin, 4·8 mg ellagic acid, 2·8 mg ellagic acid hexose	Water with balancing sugars	Attenuated the post prandial glyce mic response due to the con sumption of bread	Kerimi *et al.*, 2017[125]
Pomegranate	RCT, DB, CO, 1 week	*n* = 30 patients with MetS, (60% female), 52 (SD 10) years	500 ml/d	50 mg anthocyanins, 142 mg total flavonoids	Isoenergetic control drink	↓ SBP and DBP, hs CRP; ↑ TAG and VLDL; no changes in TC, HDL c, and LDL c, FG, insulin, HOMA IR	Moazzen & Alizadeh, 2017[117]
Pomegranate	RT, SB, 6 weeks	*n* = 60 (30 F, 30 intervention), with T2D, NW/OW/OB, 55 (SD 8) years	200 ml/d	425 mg (poly)phenols and 77 mg flavonoids	No intervention	↓ ox LDL c and anti oxidised LDL antibodies; ↑ TAC and PON1; no adverse effect on FG level	Sohrab *et al.*, 2017[123]
Pomegranate	RT, SB, 6 weeks	*n* = 60 (30 F, 30 intervention), with T2D, NW/OW/OB, 55 (SD 8) years	200 ml/d	425 mg (poly)phenol	No intervention	↓ SBP and DBP; no changes in TC, TAG, LDL c and HDL c	Sohrab *et al.*, 2019[119]
Pomegranate	RCT, DB, parallel, 12 months	*n* = 200 (98 intervention group), with mild cognitive impair ment, NW/OW/OB, 61 (SD 7) years	236·5 ml/d	368 mg punicalagins, 93 mg anthocyanins, 29 mg ellagic acid, 98 mg other tannins	Colour/flavour/energy matched beverage without pomegranate (poly)phenols	No change in the ability to learn visual information	Siddarth *et al.*, 2020[128]

Juices were 100% juice unless otherwise stated. Abbreviations: CML, carboxy methyl lysine; CO, crossover; DB, double blind; DBP, diastolic blood pressure; F, female; FG, fasting blood glucose; HDL c, HDL cholesterol; HOMA IR, homeostasis model assessment insulin resistance; hs CRP, high sensitivity CRP; LDL c, LDL cholesterol; M, male; MDA, malondialdehyde; MetS, metabolic syndrome; NW, normal weight (BMI: 18,5 24,9 kg/m^2); OB, obesity (BMI: >30 kg/m^2); OL, open label; OW, overweight (BMI: 25 30 kg/m^2); ox LDL, oxidised LDL; PON1, paraoxonase 1; PP, pulse blood pressure; PWV, pulse wave velocity; RCT, randomised controlled trial; RT, randomised trial; SB, single blind; SBP, systolic blood pressure; T2D, type 2 diabetes; TAC, total antioxidant capacity; TAG, triglycerides; TC, total cholesterol; VLDL, very low density lipoproteins; ↓, decreased level; ↑ increased level

metabolic syndrome. However, when pooling evidence, a meta analysis of five RCT did not indicate a significant effect of pomegranate juice in lowering plasma CRP levels[126]. Similarly, a recent SRMA of six RCT showed no significant effect of pomegranate juice on vascular adhesion factors, intercellular adhesion molecule 1 (ICAM 1), VCAM 1 and E selectin com pared with the control group, but a significant effect in reduction of IL 6[127].

Examining biomarkers of oxidative stress, the information is not so robust, but still promising. For instance, Sohrab *et al.* (2017)[123] found that consumption of 200 ml/d of pomegranate juice for 6 weeks significantly decreased oxidised LDL (ox LDL) and anti oxidised LDL antibodies, as well as increased total serum antioxidant capacity and arylesterase activity of para oxonase 1 (PON 1) in T2D patients in comparison with the control group. An increase in total antioxidant capacity in diabetic patients had already been observed in a previous study[124]; however, reductions in any biomarkers of oxidative stress were not reported. Detailed information on the potential antioxidant effects of pomegranate juice, particularly in the context of LDL oxidation, is broadly discussed in some comprehensive reviews[112,115,116].

Taking into account health outcomes beyond cardiometa bolic diseases, some information has been published with regard to memory and exercise performance. In a recent randomised double blind placebo controlled study, Siddarth *et al.* (2020)[128] investigated the memory effects of pomegranate juice in non demented middle aged and older adults. The intervention group did not show any change in the ability to learn visual information after daily consumption of 236 ml (8 oz.) of pomegranate juice (368 mg punicalagin, 93 mg anthocyanins, 29 mg ellagic acid and 98 mg other tannins) for 12 months, whereas the placebo group showed a significant decline. Other visual and verbal memory measures were not significantly different between groups. On the other hand, pomegranate juice has also been evaluated for its effect on exercise performance and post exercise recovery. Ammar *et al.* (2018)[129], in a systematic review of eleven studies, nine on pomegranate juice and two on pomegranate extract, concluded that pomegranate could enhance exercise perfor mance and expedite recovery from intensive exercise in healthy adults. However, positive effects were more likely when pomegranate juice contained >1·4 g/l total (poly)phenols, when it was consumed at least 60 min before exercise, and when large muscle mass exercise was engaged.

In conclusion, pomegranate juice may significantly improve BP and, to a limited extent, post prandial glycaemic response, markers of oxidative stress, some cognitive markers and exercise performance. Further well designed experiments are needed to confirm these insights[115]. Attention should be paid to the accurate characterisation of the phytochemical profile (most of the studies present a scarce characterisation of the juice bioactives) and the inter individual variability in the metabolism of their bioactive compounds (the existence of diverse metabolic phenotypes in the metabolism of ellagitannins is well known). Of note, while ellagitannins, in particular punicalagins, have attracted much attention in nutrition research, the amount of anthocyanins in some pomegranate juices may also play a role in their beneficial effect, and they should be considered[112,116].

Berry juices

Berries are a broad family of species including cranberries, blueberries, strawberries, raspberries, blackberries, choke berries, blackcurrants, elderberries and bilberries, among others. They have attracted considerable attention owing to their potential benefits to human subject health[130]. Besides vitamins, minerals, and fibre, they present high amounts of different bioactives, in particular (poly)phenols. Berries are rich in flavonoids, such as coloured anthocyanins, flavonols, and flavan 3 ols (both catechins and proanthocyanidins), phenolic acids (both hydroxybenzoic and hydroxycinnamic acids) and hydrolysable tannins such as ellagitannins. Their phenolic composition depends on the botanical species, cultivar, growing location, environmental and growing conditions, ripeness stage, time of harvest, and subsequent storage conditions and processing methods[131]. To date, most of the evidence on the health effects of berries comes from dietary interventions considering whole fruits or extracts, while the insights derived from dietary interventions with berry juices are scarce. This review will focus on major berry juices such as cranberry and chokeberry, but will also consider other interesting outcomes associated with other berry juices.

Cranberry juice. Cranberries (*Vaccinium macrocarpon*) have been widely associated with the prevention of urinary tract infections and cardiometabolic diseases. Their beneficial effects have been associated with their unique phenolic profile, rich in anthocyanins, proanthocyanidins (both A and B type), flavo nols and hydroxycinnamic acids. However, evidence is incon clusive and further research is needed[132]. The following lines will provide an overview of the state of the art, taking into account, when possible, 100% cranberry juices, although most of the evidence is provided for beverages prepared with cranberry juice concentrate (Table 6). Cranberry beverages prepared with powders/extracts were not considered.

Regarding anthropometric parameters, the information available is quite limited. Javid *et al.* (2017)[133] indicated that daily supplementation of 400 ml cranberry juice (230 mg/l vitamin C, 40 mg/l anthocyanins and 535 mg/l proanthocya nidins, 13 g/l fructose, 4 g/l glucose and 2 g/l sucrose) for 8 weeks in diabetic patients with periodontal disease did not condition BMI or waist circumference. Similarly, 480 ml/d of low calorie cranberry beverage (27% cranberry juice, 250 mg/l vitamin C, 52 mg/l anthocyanins, 496 mg/l proanthocyanidins, 20 g/l fructose, 8 g/l glucose, 0·4 g/l sucrose) for 8 weeks did not significantly affect waist circumference in women with metabolic syndrome[135].

The former study also assessed the effect of juice supple mentation on BP, but no significant improvements following cranberry or placebo beverage were observed[135]. Conversely, Novotny *et al.* (2015)[136] found a reduction in diastolic BP in healthy adults (predominantly subjects who were overweight/ obese) after 8 weeks at 480 ml/d of low calorie cranberry juice (its composition was almost identical to that previously reported for Basu *et al.*, 2011, also for sugar content)[135] compared with the placebo beverage. Nevertheless, pooled evidence from a recent meta analysis indicated that cranberry juice could not

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Table 6. Characteristics of some representative studies investigating the health effects of cranberry juices

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bioactive compounds	Control/Placebo group	Main findings	Reference
Cranberry (low calorie beverage)	RCT, DB, 8 weeks	*n* = 31 (F, 15 intervention), with features of MetS, OB, 52 (SD 8) years	480 ml/d	458 mg phenolic com pounds, 238 mg proan thocyanidins, 25 mg anthocyanins	Cranberry flavoured beverage without (poly)phenol	No changes in WC, BP, hs CRP, IL 6, TAG, TC, LDL c, VLDL, HDL c, glucose; ↑ plasma antioxidant capacity; ↓ ox LDL and MDA	Basu *et al.*, 2011[135]
Cranberry (54% cran berry juice)	RCT, DB, CO, 4 weeks	*n* = 44, patients with stable coronary artery disease, OW/OB, 61 (SD 11) years	480 ml/d	835 mg total phenolics, 94 mg anthocyanins	Isoenergetic control drink without (poly) phenols	↓ PWV	Dohadwala *et al.*, 2011[142]
Cranberry (27% cran berry juice)	Multi centre, RCT, DB, three arm, median of 168 d	*n* = 176 (F, 120 intervention), with a history of ≥1 UTI in the previous year, 26 (SD 7) years	4 oz/d 8 oz/d		Isoenergetic control drink without (poly) phenols	No reduction in UTI risk	Stapleton *et al.*, 2012[148]
Cranberry (low calorie beverage)	RCT, two arm, 2 months	*n* = 56 (42 F, 20 intervention) with the MetS, OW/OB, median age 51 years	700 ml/d	104 mg total phenolics, 66 mg proanthocyanidins	No drink	↑ adiponectin and folic acid, ↓ homocysteine, lipoperoxida tion and protein oxidation levels	Simão *et al.*, 2013[145]
Cranberry (low calorie beverage)	RCT, DB, CO, single dose	*n* = 12 (6 F), NW, 28 (SD 1) years	16 oz	LCJC 338 mg total phe nolics, 17·4 mg total anthocyanins, 192 mg proanthocyanidins	Placebo (19 mg total phenolics) and cran berry leaf extract bev erage (111 mg)	↑ GSH, SOD activity; ↓ IL 4, plasma NO concentrations; no changes in CRP, creatinine excretion	Mathison *et al.*, 2014[144]
Cranberry (low calorie beverage)	RCT, DB, paral lel, 8 weeks	*n* = 56 (30 F, 29 intervention), healthy, NW/OW/OB, 51 (SD 11) years	480 ml/d	346 mg phenolic com pounds, 236 mg proan thocyanidins, 21 mg anthocyanins	Colour/flavour/energy matched beverage, 124 mg phenolic compounds	↓ DBP, hs CRP, HOMA IR, fasting serum TAG, FG; no changes in SBP, IL 6, IL 10, IL 1β, and TNF α, ICAM 1, VCAM 1, TC, LDL c, and HDL c, fasting serum insulin	Novotny *et al.*, 2015[136]
Cranberry (27% cran berry juice)	Multicentre, RCT, DB, 24 week	*n* = 322 (F, 160 intervention), with a history of ≥2 UTI in the previous year, OW, 41 (SD 1) years	240 ml/d	135 (SD 31) mg total phe nolics	Isoenergetic control drink with 17±5 mg total phenolics/240 ml	↓ number of UTI episodes	Maki *et al.*, 2016[147]
Cranberry (25, 48, 76, 94, and 117%, doses of concentrated cran berry juice)	RCT, DB, CO, 6 da	*n* = 10 (M), NW/OW, 24 (SD 2) years	450 ml/d	409, 787, 1238, 1534, and 1910 mg total (poly) phenols	Isoenergetic control drink without (poly) phenols	↑ FMD in a dose dependent way	Rodriguez Mateos *et al.*, 2016[139]
Cranberry (low calorie beverage)	RCT, parallel, 8 weeks	*n* = 41 (27 F; 9 CJ), diabetic patients with periodontal disease, NW/OW/OB, 56 (SD 7) years	400 ml/d	390 mg total phenolics, 16 mg anthocyanins, 214 mg proanthocyanidins	Control, omega 3, cran berry juice+omega 3	No changes in BMI, WC, FG, TAG, TC, LDL C, HDL C, HbA1c and PD	Javid *et al.*, 2017[133]
Cranberry (27% cran berry juice)	RCT, DB, 2 × CO, 8 weeks	*n* = 40, with elevated brachial blood pressure, OW/OB, 47 (SD 12) years	500 ml/d		Isoenergetic control drink without (poly) phenols	↓ 24 h ambulatory DBP and the lipoprotein profile; no effects for central or brachial diastolic pressure or other measures of vascular function, glucose/insulin, lipids, markers of oxidative stress	Richter *et al.*, 2021[138]
Cranberry (35% cran berry juices)	RCT, DB, 8 weeks	*n* = 470, Helicobacter pylori positive adults, 47 (SD 11) years	480 ml/d	88 mg A type proantho cyanidin/480 ml	Cranberry flavoured beverage without A type proanthocyani dins	↓ *H. pylori* infection rate (20%), as compared with other dos ages (23 and 44 mg A type proanthocyanidin/d) and pla cebo	Li *et al* , 2021[155]

Juices were 100% juice unless otherwise stated. Abbreviations: BMI, body mass index; BP, blood pressure; CO, crossover; DB, double blind; DBP, diastolic blood pressure; F, female; FG, fasting blood glucose; FMD, flow mediated dilation; GSH, glutathione; HbA1c, hemoglobin A1c; HDL c, HDL cholesterol; HOMA IR, homeostasis model assessment insulin resistance; hs CRP, high sensitivity CRP; ICAM 1, intercellular adhesion molecule 1; IL 1β, interleukin 1β; IL 6, interleukin 6; IL 10, interleukin 10; LDL c, LDL cholesterol; M, male; MDA, malondialdehyde; MetS, metabolic syndrome; NO, nitric oxide; NW, normal weight (BMI: 18,5 24,9 kg/m^2); OB, obesity (BMI: >30 kg/m^2); OL, open label; OW, overweight (BMI: 25 30 kg/m^2); ox LDL, oxidised LDL; PD, pocket depth; PWV, pulse wave velocity; RCT, randomised controlled trial; RT, randomised trial; SB, single blind; SOD, superoxide dismutase; TAG, triglycerides; TC, total cholesterol; TNF α, tumour necrosis factor α; UTI, urinary tract infection; VCAM 1, vascular cell adhesion molecule; VLDL, very low density lipoproteins; WC, waist circumference; ↓, decreased level; ↑ increased level

reduce systolic or diastolic BP, while cranberry products as a whole may favour physiologically relevant decreases in systolic BP[137]. A recent work carried out in middle aged adults with overweight/obesity and elevated brachial blood pressure also accounted for a lack of effect of cranberry juice (8 weeks, 500 ml/d, 27% cranberry juice; 27 g/l of total sugars of which 19 g/l are added sugars) on BP[138]. In the case of acute studies on vascular function, the work by Rodriguez Mateos *et al.* (2016)[139] is worth mentioning as it assessed whether cranberry juice consumption in a dose dependent manner could improve vascular function in healthy men. The different doses (450 ml) were equivalent to 25, 48, 76, 94 and 117% of concentrated cranberry juice, having a total sugar content of 78 g/l. Juice supplementation increased FMD in a dose dependent way and the effect was correlated to a series of phenolic metabolites belonging to different classes of (poly)phenols[139]. Interestingly, cranberry juice consumption also increased the production of phenyl γ valerolactones in a dose dependent way[140], which are the main gut microbial metabolites derived from flavan 3 ols that may be behind some beneficial effects attributed to flavan 3 ol rich sources such as cranberry juice[141]. Improvements in vascular function (PWV) have also been reported upon chronic consumption of cranberry juice (54% juice, 835 mg total polyphenols and 94 mg anthocyanins; 3% glucose and 1% fructose) for 4 weeks in comparison with placebo[142].

Regarding biochemical parameters associated with cardio metabolic risk, a recent SRMA concluded that neither cranberry products nor cranberry juice specifically improve TC, LDL C, HDL C, TG, fasting glucose, fasting insulin and HOMA IR[138]. Some controversy has been observed for fasting serum TG levels, as they decreased after 8 week cranberry juice consumption in the work by Novotny *et al.* (2015)[136], while they increased significantly in the study conducted by Basu *et al.* (2011)[135] in women with metabolic syndrome. The recent paper by Richter *et al.* (2021)[138] confirmed the lack of effect in blood lipids of cranberry juice after 8 weeks at 500 ml/d in subjects at risk of CVD, while it reported an interesting shift in the lipoprotein profile.

Considering inflammation biomarkers, CRP did not change after cranberry juice consumption[137], and a lack of effect on other biomarkers (IL 6, IL 10, IL 1β, tumour necrosis factor alpha or TNF α, soluble ICAM or sICAM, and soluble VCAM or sVCAM) has also been reported[136]. Cranberry juice significantly increased plasma antioxidant capacity and decreased ox LDL and MDA at 8 weeks versus placebo[135]. In agreement with these findings, other works have also reported improvements in the endogenous antioxidant status[144] and oxidative stress measurements[145].

Many studies have investigated the effect of cranberry juice on the prevention of recurrent urinary tract infections (UTI)[146]. To date, the results are contradictory. Maki *et al.* (2016)[147] reported that consumption of a cranberry juice beverage (27% juice, 240 ml/d, 5 mg/l anthocyanins, 496 mg/l proanthocyanidins, 25 g/l sugars) for 24 weeks significantly reduced the number of UTI episodes in women (40·9 SD 1·1 years) with a history of ≥2 UTI in the previous year. Conversely, Stapleton *et al.* (2012) [148] did not observe a significant reduction in UTI risk after juice consumption juice (27% juice and sucralose, 120 or 240 ml/d) compared with placebo in premenopausal women with a history of ≥1 UTI in the previous year. To comprehensively assess the effect of cranberry on the risk of UTI recurrence in otherwise healthy women, Fu *et al.* (2017)[149] conducted a SRMA of seven randomised controlled trials. The meta analysis revealed that cranberry products could effectively prevent UTI recurrence, but this protective effect was not significant when only juice related studies were taken into account. Similar insights (protective effect of cranberry products, but not cranberry juice by itself) were reported for another, more updated meta analysis for women and UTI[150]. Nevertheless, the last meta analysis published in this field, taking into account not only women with recurrent UTI but also children and patients using indwelling catheters, for a total of almost 4000 participants, concluded that cranberry juice could be considered an adjuvant therapy for preventing UTI in susceptible populations[151]. Of note, all the authors of these meta analyses emphasised the need for larger, high quality studies to confirm these results. A call for caution in the design of new studies is thus needed as one of the reasons behind this inconsistent evidence may be related to the high inter individual variability associated with the metabolism of cranberry phenolics[139,140]. Some phenolic metabolites, in particular phenyl γ valerolactones, have demonstrated to exert a high anti adhesive activity against uropathogenic *Escherichia coli* in bladder epithelial cells at concentrations achievable upon consumption of reasonable amounts of cranberry juice[152,153]. Consequently, they may be the responsible compounds behind the preventive features of cranberry juice on UTI. However, not everybody metabolises these compounds equally[139,140] and some individuals may benefit more from a dietary intervention with cranberry juice. Keeping in mind the existence of different metabolic phenotypes in the production of phenyl γ valerolactones and phenyl propanoic acids after cranberry intake[154] might be a winning strategy to demonstrate the effectiveness of this juice in UTI prevention.

The antimicrobial activity of cranberry juice components has also been investigated for *Helicobacter pylori*. *H. pylori* infection can induce peptic ulcers and increase the risk of developing gastric cancer. In a recent double blind randomised placebo controlled study, Li *et al.* (2021)[155] evaluated the effects of cranberry juice in 522 *H. pylori* infected adults. Consumption of 240 ml of a beverage containing 35% cranberry juice (4·6% cranberry concentrate, 11·8% beet sugar and 83·6% water, 183 mg/l A type proanthocyanidins) twice daily for 8 weeks (high proanthocyanidin cranberry juice) decreased infection rate by 20% as compared with other dosages (low and medium proanthocyanidin cranberry juices) and placebo. Furthermore, an increase in the percentage of *H. pylori* negative participants was observed. Contrary to juice, encapsulated cranberry powders were not significantly effective.

Overall, cranberry juice showed no effect on body weight, BP, blood lipids, glycaemic control and biomarkers of inflammation. Nevertheless, promising insights have been reported about the role of cranberry juice on vascular function (FMD), redox status, prevention of UTI recurrence in susceptible populations and suppression of *H. pylori* infection. Although most of the publications were conducted with juice made from concentrates and presenting low/medium (27 56%) amounts of juice, the evidence behind this juice is encouraging and may boost the development of 100% cranberry juices acceptable from a sensory

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point of view. Cranberry juices are preferably blended with other fruit juices or added with sweeteners to improve palatability affected by the tart taste. In any case, the amount of phenolic compounds provided by these diluted juices is high compared with other FVJ and this may, in fact, back the beneficial effects observed. To better understand cranberry juice effects, further research should consider the high inter individual variability in the metabolism of cranberry phenolics.

Black chokeberry juice. Black chokeberry or aronia (*Aronia melanocarpa*) is known for its high content in anthocyanins and intense red/black colour, but it also contains high amounts of hydroxycinnamic acids and proanthocyanidins. This significant amount of (poly)phenols has been related to the potential benefits on human subject health[156]. Nevertheless, the evidence of chokeberry juice in humans is limited as only a few studies have been conducted (Table 7). Most of the biological properties of aronia have been tested in human subject interventions with extracts or animal models, as recently reviewed[156].

In a randomised controlled double blind study, Pokimica *et al.* (2019)[157] found no significant change in BMI after a 4 week intervention with 100 ml/d of high or low dose polyphenol chokeberry juice (or a polyphenol free placebo drink) in individuals with cardiovascular risk. The high polyphenol juice consisted of a 100% chokeberry juice containing almost 12000 mg/l total phenols and 1100 mg/l anthocyanins; the low polyphenol dose was prepared by dilution (1:3) of the juice into the placebo drink. Similarly, in an 8 week intervention study in subjects with untreated mild hypertension, body weight remained unchanged after 300 ml/d of a 100% chokeberry hybrid juice mixed with chokeberry powder (3 g)[158]. Chokeberry juice mixed with the powder provided a total of 7313 mg of polyphenols per litre, anthocyanins (3413 mg/l) and proanthocyanidins (2483 mg/l) being the most abundant compounds.

Considering cardiometabolic biomarkers, Pokimica *et al.* (2019)[157] concluded that a 4 week intake of 100 ml/d of chokeberry juice could not be linked with a reduction in systolic and diastolic BP in individuals at cardiovascular risk. An acute study investigating the effect of chokeberry juice (three portions consumed at 1 h intervals, for a total of 600 ml) on BP did not yield significant improvements in young adults[159]. Differently, Loo *et al.* (2016)[160] found that 8 week consumption of 300 ml/d of chokeberry juice mixed with chokeberry powder decreased daytime ambulatory diastolic BP in patients with untreated mild hypertension. No conclusive results can be drawn from this information.

In the case of the lipid profile, chokeberry juice containing either low or high doses of polyphenols did not significantly change TC and LDL C compared with the placebo drink[157]. Similarly, Loo *et al.* (2016)[160] reported no effect of chokeberry juice on lipoproteins and TG. Indeed, although some positive effects on HDL C have been reported for aronia products, benefits occurred in works carried out with supplements[161]. No significant impacts of chokeberry consumption on serum glucose concentration have been reported[157,159,160].

A reduction in the concentration of the inflammation biomarkers IL 10 and TNF α and a downward trend for IL 4 and IL 5 have been reported[158]. However, no significant effects on the serum levels of the other cytokines (IL 6, IL 7, IL 8, IL 13) and hs CRP levels were observed in this study[158]. In general, the meta analysis by Rahmani *et al.* (2019)[161] did not show beneficial effects of aronia products on inflammatory markers.

In conclusion, chokeberry juice showed only limited benefits on HDL C and systolic BP. Further studies are fully needed to increase the limited body of evidence available to date.

Other berries juices: blueberry, bayberry, bilberry, barberry, blackcurrant, sea buckthorn, açaí, juçara and noni. Huma subject interventions have been conducted for many other berry juices, but the information available for them is scarce, and many targets have not been investigated. Here, a selection of some interesting articles for specific juices is presented to provide some insights on the overall prospects of 100% berry juice consumption on human subject health (Table 7).

Regarding wild (lowbush) blueberry (*Vaccinium angustifolium*), 240 ml/d of 100% blueberry juice (total phenols and anthocyanins: 8900 and 1300 mg/l, respectively) in adults at risk for T2D for 7 d did not change body weight, anthropometric parameters, endothelial function, glucose, insulin, insulin sensitivity (HOMA IR), TG, and inflammatory and oxidative stress markers in a single blind placebo controlled randomised crossover trial[162]. The only benefit was an increase in nitric oxide production that could be related to a non significant, marginal decrease in systolic BP[162]. A lack of effect of blueberry juice from concentrate (30 ml twice daily; 774 mg anthocyanins) on anthropometric parameters and BP has been recently reported in healthy adults after 20 d juice supplementation[163]. Of note, while a reduction of LDL C levels compared with placebo was found, fasting glucose increased slightly[163]. On the contrary, a trend for lower glucose levels was found when providing 100% blueberry juice (6 9 ml/kg body weight, 428 598 mg anthocyanins) to older adults for 12 weeks[163], emphasising the need for further studies in this topic. Improvements in memory tests were observed, although the sample size was quite limited[164].

Guo *et al.* (2014)[165], in a randomised double blind crossover study, supplemented 250 ml of 100% Chinese bayberry (*Myrica rubra*) juice, twice per day, for 4 weeks to young individuals with features of non alcoholic fatty liver disease (NAFLD). The juice contained 896 mg/l vitamin C, 2702 mg/l total phenols and 835 mg/l anthocyanins, and the placebo was matched for vitamin C content. The treatment did not affect body weight, BMI and other anthropometric parameters, blood lipids, glucose, insulin and insulin sensitivity. Bayberry juice significantly decreased plasma levels of TNF α, IL 8 and protein carbonyl groups, whereas no significant alterations in plasma levels of hs CRP or apoptotic markers were observed[165].

Bilberry (*Vaccinium myrtillus*) juice consumption has also been assessed in subjects at increased risk of CVD[166]. Consumption of 330 ml 100% bilberry juice/d (diluted to 1 litre using tap water) for 4 weeks, compared with placebo (1 litre of water per day), did not modify body weight and blood lipids. A significant decrease in plasma concentrations of CRP, IL 6, IL 15, and monokine induced by interferon γ was reported, but, surprisingly, TNF α increased in the bilberry group. No changes in antioxidant status and oxidative stress biomarkers occurred[166].

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Table 7. Characteristics of some representative studies investigating the health effects of some berries (chokeberry, blueberry, bayberry, bilberry, barberry, blackcurrant, sea buckthorn, açaí, juçara and noni) juices

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bioactive compounds	Control/Placebo group	Main findings	Reference
Chokeberry hydrid mixed with chokeberry powder (3 g/d)	RCT, SB, CO, two 8 weeks periods	$n=37$, untreated mild hypertensive, NW/OW, 40 70 years	300 ml/d	2194 mg total (poly)phenols, 1024 mg anthocyanins, 745 mg proanthocyanidins	Isoenergetic placebo juice	↓ daytime ambulatory DBP, the true awake SBP and DBP (measured on awakening), IL 10 and TNF α; no changes in BW, IL 6, IL 7, IL 8, IL 13, hs CRP, TC, HDL c, TAG, serum glucose	Loo *et al.*, 2016[158]
Chokeberry	RT, parallel, four arm, single dose	$n=88$ (49 F, 22 intervention), NW/OW, 25 (SD 6) years	3 × 200 ml/d	6393 mg GAE total (poly) phenol	Noni juice, energy drink, water	No changes in SBP, DBP, HR, BG	Nowak *et al.*, 2019[159]
Chokeberry	RCT, DB, parallel, 4 weeks	$n=84$ (52 F), at cardiovascular risk, NW/OW/OB, 41 (SD 7) years	100 ml/d	High (1177 mg GAE) or low dose (294 mg GAE) (poly)phenol, 113 mg and 28 mg total cyanidin 3 glucoside equivalents, respectively	Isoenergetic control drink without (poly) phenols	No change in BMI, SBP, DBP, TC, LDL c, blood glucose; ↑ saturated fatty acids; ↓ *n* 6 polyunsaturated fatty acids	Pokimica *et al.*, 2019[157]
Wild blueberry	RCT, SB, CO, 7 d	$n=19$ (F), at risk for T2D, 53 (SD 6) years	240 ml/d	2138 GAE mg total phenolics, 314 mg anthocyanins	Colour/flavour/energy matched juice but without (poly)phenols	No changes in BW, anthropometric parameters, SBP, DBP, endothelial function, IL 6, IL 10, hs CRP, TNF α, serum amyloid A, ICAM 1, VCAM 1, TAG, glucose, insulin, HOMA IR, oxidative stress; downward trend for SBP	Stote *et al.*, 2017[162]
Blueberry	RCT, SB, parallel, three arm, 20 d	$n=44$ (20 F), healthy, NW/OW, 34 (SD 13) years	60 ml/d (diluted in 200 ml of water)	774 mg anthocyanins	Isoenergetic placebo juice	No changes in anthropometric parameters and SBP; ↓ TC, LDL c; ↑ glucose; improved psychological wellbeing indices	Sinclair *et al.*, 2022[163]
Bayberry	RCT, DB, 2 × 2 CO, 4 weeks	$n=44$ (32 F), OW, 21 (SD 1) years	500 ml/d	1351 mg total (poly)phenol, 417 mg anthocyanin	Isoenergetic control drink without (poly) phenols	↓ TNF α, IL 8, PCG; no changes in BW, hs CRP, TAG, TC, LDL c, glucose, insulin and HOMA IR	Guo *et al.*, 2014[165]
Bilberry	RCT, parallel, 4 weeks	$n=62$ (17 F, 31 intervention), at risk of CVD, OW, mean age 53 years	330 ml/d (diluted to 1 litre using tap water)		Water	↓ hs CRP, IL 6, IL 15, and MIG; ↑ TNF α; no changes in oxidative stress, blood lipids, and BW	Karlsen *et al.*, 2010[166]
Barberry	RCT, parallel, 8 weeks	$n=42$ (27 F, 21 intervention), patients with T2D, OW/OB, 57 (SD 8) years	200 ml/d	481 mg GAE total (poly) phenols	No intervention	↓ SBP and DBP, fasting glucose, TC and TG, ↑ PON 1	Lazavi *et al.*, 2018[167]
Blackcurrant 20%	RCT, DB, CO, single dose	$n=20$ (11 F), NW/OW, 45 (SD 13) years	250 ml/d		Isoenergetic control drink without (poly) phenols	↑ plasma vitamin C, insulin and urinary anthocyanins; trend for an increase in plasma phenolic acids; no effect on vascular reactivity or biomarkers of endothelial function	Jin *et al.*, 2011[170]

Table 7. (*Continued*)

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bioactive compounds	Control/Placebo group	Main findings	Reference
Blackcurrant 20%	RCT, DB, three arm, parallel, 6 weeks	*n* = 64 (21 F, 22 low BJ, 21 high BJ), healthy subjects with habitually low intake of fruit and vegetables, OW, mean age 53 years	1 litre/d	High BJ (20% juice; 815 mg total (poly)phenols, 143 mg anthocyanins)	Low BJ (6·4% juice; final diluted concen tration: 273 mg total (poly)phenols, 40 mg anthocyanins); flavoured water	↑ FMD and plasma vitamin C; ↓ F2 isoprostanes marker of oxidative stress	Khan *et al.*, 2014[169]
Blackcurrant	RCT, DB, CO, pilot, single dose	*n* = 9 (6 F), healthy, NW, mean age 23 years	100 ml/d	516 mg total (poly)phenols, 119 anthocyanins	Isoenergetic control drink without (poly) phenols	↑ mood and attention; no changes for any outcome	Watson *et al.*, 2019[168]
Sea buckthorn fruit puree (95·7%)	RCT, DB, CO, two stage, 35 d	*n* = 38 (30 F), subjects with impaired glucose regulation, 59·1 (SD 4·8) years	90 ml/d	84 mg total flavonoids	Colour/flavour matched juice without (poly) phenols	Trend in ↓ FG; no effect on 2h post prandial plasma glucose or glycated serum protein; no change in BP or BMI	Ren *et al.*, 2021[171]
Açaí (AJ) and Juçara (JJ)	RT, SB, CO, 4 weeks	*n* = 30 (22 F), healthy, NW, 28 (SD 7) years	200 ml/d	cyanidin derivatives: Açaí: 222 mg GAE; Juçara: 330 mg GAE	Comparison of both interventions	AJ and JJ ↑ HDL c; no changes in TC, LDL c, TAG; AJ ↑ FG, TAC and activities of catalase and glutathione peroxidase, ↓ OSI; JJ ↑catalase	de Liz *et al.*, 2020[172]
Noni	RT, parallel, four arm, single dose	*n* = 88 (49 F, 22 interven tion), NW/OW, 25 (SD 6) years	90 ml/d	318 mg GAE total (poly) phenol	Chokeberry juice, energy drink, water	↓ SBP, DBP, HR, BG	Nowak *et al.*, 2019[159]

Juices were 100% juice unless otherwise stated. Abbreviations: AJ, Açaí juice; BG, blood glucose; BJ, blackcurrant juice drink; BMI, body mass index; BW, body weight; CO, crossover; CVD, cardiovascular disease; DB, double blind; DBP, diastolic blood pressure; F, female; GAE, gallic acid equivalent; HDL c, HDL cholesterol; HR, heart rate; hs CRP, high sensitivity CRP; ICAM 1, intercellular adhesion molecule 1; IL 6, interleukin 6; IL 7, interleukin 7; IL 8, interleukin 8; IL 10, interleukin 10; IL 13, interleukin 13; IL 15, interleukin 15; JJ, Juçara juice; LDL c, LDL cholesterol; M, male; MIG, monokine induce by INF γ; NW, normal weight (BMI: 18,5 24,9 kg/m^2); OB, obesity (BMI: >30 kg/m^2); OL, open label; OSI, oxidative stress index; OW, overweight (BMI: 25 30 kg/m^2); PCG, protein carbonyl groups; RCT, randomised controlled trial; RT, randomised trial; SB, single blind; SBP, systolic blood pressure; T2D, type 2 diabetes; TAC, total antioxidant capacity; TAG, triglycerides; TC, total cholesterol; TNF α, tumour necrosis factor α; VCAM 1, vascular cell adhesion molecule; ↓, decreased level; ↑ increased level

Barberry (*Berberis vulgaris*) juice consumption (100% from concentrate, 200 ml/d, 8 weeks, 2403 mg/l total phenols) by patients with T2D led to significant decreases in systolic and diastolic BP, fasting glucose and TC and an increase in PON 1[167]. The amount of the alkaloid berberine, which may have some protective cardiometabolic effects, was not indicated.

Blackcurrant (*Ribes nigrum*) juice has been tested in different contexts and promising effects have been reported. Briefly, 100% anthocyanin rich blackcurrant juice (about 100 ml, 500 mg polyphenols per serving) improved mood and attention in young health volunteers[168], while 20% blackcurrant juice has demonstrated improvements in FMD in healthy subjects with habitually low intake of fruit and vegetables[169] and vascular reactivity in acute conditions[170].

Sea buckthorn (*Hippophae rhamnoides*) berries contain flavonols such as quercetin, isorhamnetin, kaempferol and myricetin[171]. Sea buckthorn fruit puree(95·7% fruit, 90 ml/d) consumption for 35 d led to a slight downward trend in fasting plasma glucose in subjects with impaired glucose regulation, but it did not affect the 2 h post prandial plasma glucose or glycated serum protein, compared with a placebo[171]. Juice supplementation did not change BP or BMI. The juice contained 930 mg/l of total flavonoids, with isorhamnetin glycosides being the main flavonols[171].

Açaí (*Euterpe oleracea*) and juçara (*E. edulis*) berries are characterised by a high anthocyanin content[172]. In a randomised crossover study, de Liz *et al.* (2020)[172] found that consumption of 200 ml/d of açaí or juçara juice (1105 and 1645 mg/l cyanidin derivatives, respectively) for 4 weeks promoted a significant increase in HDL C compared with the respective baseline values in thirty healthy adults, with greater increase observed after juçara juice consumption. Conversely, TC, LDL C and TG were not affected by the interventions. A significant increase was also observed for fasting glucose levels only after açaí juice consumption; nonetheless, the results were within the reference range. Concerning biomarkers of oxidative stress, açaí juice was more effective, leading to increases in the activity of antioxidant enzymes (catalase and glutathione peroxidase) and total antioxidant capacity, also decreasing an oxidative stress index (the ratio of total oxidant status to total antioxidant capacity); juçara juice increased only catalase[172]. The lack of a control juice hindered the understanding of the true relevance of these insights but did not preclude the collection of encouraging results with regard to the preventive features of these anthocyanin rich berry juices.

Noni (*Morinda citrifolia*) fruits show a particular phytochemical profile, including flavonols such as quercetin and rutin, hydroxycoumarin such as scopoletin, and anthraquinone 5,15 dimethylmorindol[173]. Despite some controversial hepatotoxic events related to products labelled as noni products, but lacking noni, noni has been recognised as safe[174]. West *et al.* (2018)[174] conducted a review of human subject intervention studies to evaluate the potential health benefits of noni juice. Potential health benefits included protection against tobacco smoke toxicity, joint pain and mobility improvement, bone health, control of BP and antioxidant activity, among others. Nevertheless, all the studies reviewed regarded mixed noni juice beverages, so the evidence on pure noni juice is limited. A recent study conducted with pure noni juice evaluated the acute effects on BP and glucose of noni juice, chokeberry juice and an energy drink and water (placebo) in eighty eight young adults[159]. Acute intake of three portions of noni juice at 1 h intervals (30 ml/portion) led to a significant reduction in BP and a mild, borderline reduction in blood glucose[159].

In conclusion, the evidence for minor berry juices showed some beneficial effects of 100% juice consumption on subjects at risk for disease or with pre existing diseases. However, the number of studies for each berry juice is quite limited, so no major conclusions should be drawn from them. Further studies are fully needed, and they should take into account also other population settings to really address the preventive effects of these berry juices for the general population. Of note, some important studies on the health properties of commercially relevant berry juices, such as blueberry[175] or strawberry[176], were performed with reconstituted freeze dried powders. Although they provided significant outcomes on the bioactivity of these fruits, similar works should be carried out with 100% juices to endow them with robust insights and increase the body of evidence for berry juices.

Cherry juice

Cherries can be classified into sweet cherries (*Prunus avium* L.) and tart cherries (*Prunus cerasus* L.). They are rich in vitamin C, potassium and phenolic compounds, and especially rich in anthocyanins such as cyanidin and peonidin derivatives, with notable amounts of hydroxycinnamic acids and flavan 3 ols. Generally, tart cherries show higher concentrations of phenolics than sweet cherries[177] and evidence of the health effects of cherry juices comes predominantly from tart cherries. Many studies used tart cherry juice from the 'Montmorency' cultivar, which shows high amounts of anthocyanins[178]. Melatonin is also present in cherries, and some sleep regulation related biological activities have been attributed to this compound[177]. Here, the available literature on cherry juice is discussed even when no 100% chery juices, but only diluted ones, were provided to volunteers, as the number of intervention studies providing pure cherry juice is quite scarce, and the amounts of (poly)phenols provided by these diluted ones are quite high and might lead to potential beneficial effects (Table 8).

Chai *et al.* (2019)[180], in a randomised controlled trial, showed no change in body weight or BMI after 12 week supplementation of either 480 ml/d of Montmorency tart cherry juice (68 ml juice concentrate diluted in water, total phenols: 937 mg/l, potassium: 740 mg/l) or control drink in 34 older adults who were overweight. In this line, Johnson *et al.*[181] claimed that 480 ml/d of tart cherry juice for 12 weeks in metabolic syndrome patients did not affect body weight or composition. A lack of effect of Montmorency tart cherry juice from concentrate on anthropometric parameters has also been reported recently by two studies in healthy adults[175,197]. No effect on BP was also noted in these studies[175,197], contrary to previous evidence in at risk/diseased subjects. Indeed, in a randomised single blind crossover trial, Desai *et al.* (2021)[183] investigated the effects of 130 ml/d consumption of Montmorency tart cherry juice (30 ml juice concentrate diluted in water, 2076 mg/l anthocyanins) on

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Table 8. Characteristics of some representative studies investigating the health effects of cherry (sweet and tart) juices

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bioac tive compounds	Control/Placebo group	Main findings	Reference
Montmorency tart cherry	RCT, OL, paral lel, 6 weeks	*n* = 46 (29 F), healthy, NW/ OW, 38 (SD 6) years	250 ml/d (30 ml juice concentrate diluted)	273 mg total anthocyanin	Commercial lemonade	↑ FRAP; no changes in PWV, SBP, DBP, TC, HDL c, CRP, arterial stiffness	Lynn *et al.*, 2014[188]
Montmorency tart cherry	RCT, blinded, LS, CO, single dose	*n* = 15 (M), nonsmoking, hypertensive, OW, 31 (SD 9) years	160 ml (60 ml juice concentrate diluted)		Isoenergetic control drink without (poly) phenols	↓ SBP; no changes in PWV, microvascular vasodilation	Keane *et al.*, 2016[186]
Bing sweet cherry	RCT, parallel, 12 weeks	*n* = 42 (21 intervention), with mild to moderate Alzheimer's type demen tia, NW/OW, 81 (SD 7) years	200 ml/d	138 mg anthocyanin	Commercially apple juice with negligible anthocyanin content	↓ SBP, trend in reducing DBP; ↑ verbal flu ency, short and long term memory	Kent *et al.*, 2017[185]
Montmorency tart cherry	RCT, parallel, 12 weeks	*n* = 34 (17 intervention), consuming ≤5 servings of fruits and vegetables per day, OW, 70 (SD 4) years	480 ml/d (68 ml juice concentrate diluted in water)	451 mg total phe nolics, 96 mg tannins	Isoenergetic control drink without (poly) phenols	↓ SBP, LDL c; ↑ glucose levels; no change in BW, DBP, HDL c, insulin and HOMA IR	Chai *et al.*, 2018[184]
Tart Cherry	RCT, 2 × 2 CO, pilot, 4 weeks	*n* = 10 (8 F), OW/OB, 38 (SD 12) years	240 ml/d	438 GAE total (poly) phenol	Isoenergetic control drink without (poly) phenols	No change in hs CRP levels, IL 6 or IL 10 levels; ↓ proinflammatory MCP 1; trend for reducing TNF α levels	Martin *et al.*, 2018[191]
Tart Cherry	RCT, parallel, 12 weeks	*n* = 34 (20 intervention), NW/OW/OB, 70 (SD 4) years	480 ml/d (68 ml juice concentrate diluted)	451 GAE total phenolics, 95·9 mg tannins	Isoenergetic con trol drink with out (poly) phenols	↑ cognitive abilities, subjective memory in the domain of contentment with memory by 5% and reduced movement time by 4%; ↓ errors in episodic visual memory by 23%	Chai *et al.*, 2019[180]
Tart Cherry	RCT, parallel, 12 week	*n* = 34 (20 intervention), NW/OW/OB, 70 (SD 4) years	480 ml/d (68 ml juice concentrate diluted)	451 GAE total phenolics, 95·9 mg tannins	Isoenergetic control drink without (poly) phenols	↓ CRP, MDA, and ox LDL; ↑ DNA repair activity of 8 oxoguanine glycosylase; TNF α, 4HNE, 8 OHdG	Chai *et al.*, 2019b[179]
Montmorency tart cherry	RCT, SB, CO, pilot, 6 h	*n* = 11 (5 F), with MetS, OB, 49 (SD 12) years	130 ml (30 ml juice concentrate diluted)	270 mg anthocyanin	Commercially available fruit flavoured cordial mixed with water	↓ SBP, insulin; no changes TAG and HDL c	Desai *et al.*, 2019[190]
Tart Cherry	RCT, DB, paral lel, 9 d	*n* = 36 (M) non resistance trained men) NW/OW, 24 years	500 ml/d (30 ml concentrate juice diluted twice daily)	600 mg total phenolics	Energy matched blackcurrant flavoured mal todextrin sports drink	TCJ did not enhance recovery from high force eccentric exercise of the elbow flexors	Lamb *et al.*, 2019[196]
Tart Cherry	RCT, DB, CO, 3 d	*n* = 10 (M), soccer players, 19 (SD 1) years	250 ml/d (30 ml juice concentrate diluted)		Isoenergetic cherry flav oured control drink (CON)	No differences in CMJ, RSI and MS between groups	Abbott *et al.*, 2020[198]
Montmorency tart cherry	RCT, SB, paral lel, pilot, 12 weeks	*n* = 19 (9 F, 9 intervention), MetS patients, mean age 37 years	480 ml/d	2140 mg total phe nolics, 176 mg total anthocyanins	Isoenergetic control drink without (poly) phenols	↓ ox LDL, VCAM 1, TC; ↑ HOMA B%, WHR; no changes in BW or composition, PWV	Johnson *et al.*, 2020[181]

Table 8. (*Continued*)

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bioactive compounds	Control/Placebo group	Main findings	Reference
Montmorency tart cherry	RCT, SB, CO, 2 weeks	*n* = 11 (M, 6 intervention), rugby players, 18 (SD 1) years	260 ml/d (60 ml juice concentrate diluted)	anthocyanins 640 mg/60 ml	Isoenergetic control drink without (poly) phenols	No effects on markers of muscle soreness, function and inflammation	Morehen *et al.*, 2020[197]
Tart Cherry	RCT, 4 week	*n* = 50 (5 F), with gout and SU >0·36 mmol/l, OW/OB, mean age 59 years	four different CJ groups: 7·5, 15, 22·5, 30 ml (all consumed twice daily in 250 ml water)		Two drops of tart cherry juice	No effect in reducing serum urate levels and gout flares	Stamp *et al.*, 2020[193]
Montmorency tart cherry	RCT, SB, CO, 7 d	*n* = 12 (6 F), with MetS, OW/OB, 50 (SD 10) years	130 ml (30 ml juice concentrate diluted)	270 mg anthocyanins/130 ml	Isoenergetic control drink without (poly) phenols	↓ 24 h ambulatory SBP, DBP, mean arterial pressure, TC, LDL c, TC:HDL c ratio, FG; no changes in TAG	Desai *et al.*, 2021[183]
Montmorency tart cherry	RT, 90 da	*n* = 27 (F), healthy, largely osteopenic (82%), NW/OW, 71 (SD 4) years	240 ml once (TC1X) or twice (TC2X) daily (30 ml juice concentrate diluted)	225 mg GAE/30 ml total phenolics	Comparison of both interventions	No alterations in biomarkers of bone formation, bone turnover or bone resorption in response to TC1X; TC2X ↓ TRAcP 5b	Dodier *et al.*, 2021[195]
Montmorency tart cherry	RCT, DB, parallel, 30 d	*n* = 44, healthy, NW/OW, 28 (SD 7) years	480 ml/d	1586 mg total phenolics, 454 mg total anthocyanins	Placebo	No changes in anthropometric parameters, BP, sleep time and quality	Hillman *et al.*, 2022[182]
Montmorency tart cherry	RCT, SB, parallel, three arm, 20 d	*n* = 44 (20 F), healthy, NW/OW, 34 (SD 13) years	60 ml/d (diluted in 200 ml of water)	640 mg anthocyanins	Isoenergetic placebo juice	No changes in anthropometric parameters and SBP; ↓ glucose	Sinclair *et al.*, 2022[163]

Juices were 100% juice unless otherwise stated. Abbreviations: 4HNE, 4 hydroxynonenal; 8 OHdG, 8 hydroxydeoxyguanosine; BP, blood pressure; BW, body weight; CMJ, countermovement jump height; CO, crossover; CRP, C reactive protein; DB, double blind; DBP, diastolic blood pressure; F, female; FG, fasting blood glucose; FRAP, ferric reducing ability of plasma; HDL c, HDL cholesterol; HOMA B%, homeostasis model assessment beta cell function; HOMA IR, homeostasis model assessment insulin resistance; hs CRP, high sensitivity CRP; IL 6, interleukin 6; IL 10, interleukin 10; LDL c, LDL cholesterol; M, male; MCP 1, monocyte chemoattractant protein 1; MDA, malondialdehyde; MetS, metabolic syndrome; MS, muscle soreness; NW, normal weight (BMI: 18,5 24,9 kg/m^2); OB, obesity (BMI: >30 kg/m^2); OL, open label; OW, overweight (BMI: 25 30 kg/m^2); ox LDL, oxidised LDL; PWV, pulse wave velocity; RCT, randomised controlled trial; RSI, reactive strength index; RT, randomised trial; SB, single blind; SBP, systolic blood pressure; TAG, triglycerides; TC, total cholesterol; TCJ, tart cherry juice; TNF α, tumour necrosis factor α; TRAcP 5b, tartrate resistant acid phosphatase type 5b; VCAM 1, vascular cell adhesion molecule; WHR, waist to hip ratio; ↓, decreased level; ↑ increased level

BP in twelve metabolic syndrome patients, showing that 24 h ambulatory systolic, diastolic BP and mean arterial pressure were significantly lower than placebo after 7 d cherry juice consumption. Chai *et al.* (2018)[184] reported a reduction in systolic BP (by 4·1 mmHg), but not in diastolic BP, after 12 week consumption of 480 ml/d of Montmorency tart cherry juice in older adults who were overweight. A significant reduction in systolic BP and only a trend (not significant) for diastolic BP reduction was also observed in older adults with dementia, following 12 weeks at 200 ml/d of anthocyanin rich Bing sweet cherry juice (690 mg/l anthocyanins)[185]. Variations in BP upon acute conditions have also been assessed: a single dose of 160 ml of Montmorency tart cherry juice (60 ml juice concentrate diluted in water) significantly lowered systolic BP over a period of 3 h compared with a placebo drink in fifteen men with early hypertension[186]. Similar results were found when 300 ml of the aforementioned anthocyanin rich cherry juice was supplied to healthy volunteers[187]. Functional improvements in both studies were related to the increase in circulating phenolic metabolites. Conversely, no significant differences in PWV, measured as a predictor of arterial stiffness, were observed in three different interventions[186,188,189].

Considering other cardiometabolic markers, TC, LDL C and TC:HDL C ratio were significantly lower following 7 d consumption of 130 ml/d of Montmorency tart cherry juice compared with the placebo in twelve participants with metabolic syndrome, without changes in TG concentration[188]. Nevertheless, an acute study by the same authors in the same population setting did not account for changes in blood lipids[190], in line with two studies, one conducted in forty seven healthy adults (30 50 years) with tart cherry juice for 6 weeks[188] and another in metabolic syndrome patients for 12 weeks[181]. On the contrary, Chai *et al.* (2018)[184] reported that, after the 12 week intervention at 480 ml/d, older adults in the tart cherry juice group had lower LDL C than the control group. Neither tart cherry juice nor control altered HDL C concentrations. Data available to date in the case of glucose metabolism is also contradictory. Some authors observed that tart cherry juice did not affect insulin and HOMA IR levels, while significantly increasing glucose levels in older adults (65 80 years) who were overweight[184]. Conversely, after 7 d consumption of Montmorency tart cherry juice (130 ml/d) by metabolic syndrome patients, fasting glucose concentrations decreased significantly without major changes in insulin levels[183], while only insulin changed when supplementing the same juice in acute conditions to these patients[190].

Regarding inflammation, after 12 weeks at 480 ml/d, tart cherry juice significantly lowered CRP levels but not TNF α levels compared with the control drink in older adults[179]. Conversely, Martin *et al.* (2018)[191], in a randomised crossover study, showed no change in hs CRP, IL 6, IL 10 and TNF α levels after 4 week consumption of either 240 ml/d 100% tart cherry juice (total polyphenols: 1827 mg/l) or placebo in ten adults who were overweight/obese. Nevertheless, there was a significant decrease in pro inflammatory monocyte chemoattractant protein 1 (MCP 1) compared with the placebo group[191]. Examining biomarkers of oxidative stress, Chai *et al.* (2019)[180] showed that tart cherry juice significantly increased the DNA repair activity of 8 oxoguanine glycosylase compared with the control drink. In addition, plasma levels of MDA slightly decreased after 12 weeks of tart cherry juice consumption compared with the control drink. Other biomarkers such as 4 hydroxynonenal and 8 hydroxydeoxyguanosine were not affected by either tart cherry or control juice[179]. Tart cherry juice supplementation twice daily for 12 weeks reduced ox LDL and VCAM 1, but not ICAM 1, in adults with metabolic syndrome[181]. Interestingly, serum uric acid, a marker not so commonly assessed in studies evaluating the health properties of fruit juices, has been broadly studied in interventions with cherry juices. Evidence indicates that serum urate decreases consuming tart cherry juice, which may be beneficial for gout patients[192], but further studies are needed as recent data from a dose dependent study in people with gout has pointed to a lack of effect of tart cherry juice in reducing serum urate levels and gout flares[193].

The potential beneficial effect of cherry juice on cognitive function has also been evaluated. In a randomised controlled trial, Kent *et al.* (2017)[194] investigated the effect of 200 ml/d of anthocyanin rich Bing sweet cherry juice in older adults with dementia. After 12 weeks of intervention, improvements in verbal fluency, and short and long term memory were found only in the cherry juice group. Improvements in cognitive abilities have also been shown upon consumption of tart cherry juice by older adults (65 80 years)[180]. Overall, cherry juice supplementation might improve psychomotor speed, as assessed in a recent meta analysis[103]. Interestingly, the elderly population has also been addressed with regard to testing the effect of Montmorency tart cherry juice on bone metabolism, but no major benefits were observed in post menopausal women, who were largely osteopenic at baseline (82%), after 90 d juice consumption[195].

In the case of exercise performance/recovery, most studies have not found ergogenic effects. Lamb *et al.* (2019)[196] showed that 500 ml/d of tart cherry juice for 9 d did not enhance recovery in non resistance trained men after high force eccentric exercise of the elbow flexors. A lack of effect of cherry juice has also been described for rugby and soccer players[197,198]. Cherry juice had no effect on the sleep quality of rugby players[197,198] or healthy adults[182] despite the presence of melatonin in cherry juice.

In conclusion, tart cherry juice has attracted much more attention than sweet cherry juice. Cherry juice, in particular tart cherry juice, seems to improve BP and cognitive function, while it may also lead to some benefits at inflammation and oxidative stress level. Some studies have investigated the role of these juices in bone metabolism, exercise performance and gout, with no significant beneficial effects seen. In addition, most of the studies available were carried out using reconstituted concentrate juices, so human subject interventions with 100% juices would be helpful to increase the evidence behind cherry juice.

Plum juice

The term plum refers to a series of *Prunus* species, namely *P. domestica* (European plum), *P. cerasifera* (myrobalan or cherry plum) and *P. salicina* (Japanese plum). Plums provide phenolic compounds such as chlorogenic acids and other hydroxycinnamates, benzoates, anthocyanins, flavan 3 ol monomers and proanthocyanidins, flavonols, and coumarins.

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Among thirty three plum varieties analysed, chlorogenic acids and proanthocyanidins were the major phenolics present in plums, but the qualitative and quantitative phenolic profiles showed high diversity even among closely related cultivars[199]. Regarding the health effects of plums (reviewed by Igwe and Charlton, 2016; including fresh, dried plums and juice)[200], most studies used Queen Garnet (QG) plum, an anthocyanin rich Japanese plum cultivar developed in Australia[201] (Table 9). Evidence on plum juice is provided below.

In a randomised double blinded placebo controlled trial, Bhaswant *et al.* (2019)[202] found that 250 ml/d of QG plum juice for 12 weeks (1020 mg/l anthocyanins mainly cyanidin 3 glucoside; 360 mg/l quercetin derivatives) did not change body weight, waist to hip ratio and body composition measurements in twenty nine mildly hypertensive subjects who were over weight or obese. A lack of effect on BMI has also been reported for two QG plum juices containing different anthocyanins levels (48 and 201 mg daily) after supplementation of 250 ml for 8 weeks in older adults with mild cognitive impairment[203]. Considering BP, QG plum juice 12 week treatment decreased systolic and diastolic BP compared to baseline values and placebo drink (without flavonoids)[202], while do Rosario *et al.* (2021)[203] did not find any effect on BP for any QG plum juice regardless of the anthocyanin amount in older adults after 8 weeks. Under acute conditions, a BP reduction effect was reported for an anthocyanin rich QG plum juice in both young and older adults[204], while 250 ml of QG plum juice, providing 200 mg anthocyanins and consumed in con junction with a high fat high energy meal, did not change the increased post prandial BP compared with an apricot juice (control juice, no anthocyanins) in sixteen older adults who were overweight[205]. However, the authors observed that 2 h post prandial FMD and some parameters of microvascular function were better in the QG plum juice than the apricot juice group.

Modifications of lipid profile and glucose metabolism by plum juice consumption have been scarcely investigated. QG plum juice for 12 weeks decreased fasting plasma LDL C, but not HDL C, TC and TG concentration, in mildly hypertensive subjects who were overweight or obese[202]. A three arm randomised double blind crossover trial conducted with 200 ml anthocyanin rich QG plum juice (1010 mg/l anthocyanins: 760 mg/l cyanidin 3 glucoside, 250 mg/l cyanidin 3 rutinoside; 437 mg/l quercetin derivatives), prune juice (no anthocyanins neither quercetin derivatives) and a control drink (matched for energy and macronutrients) for 4 weeks in twenty one healthy adults did not lead to changes in blood lipids after consumption of any of the juices, which may be related to the adequate physiological conditions of the study population[201]. Similarly, the post prandial increases in TC and TGs due to a high fat high energy meal were not altered by either QG plum juice or control juice[205]. Interestingly, Bhaswant *et al.* (2019)[202] reported that QG plum juice decreased fasting plasma glucose and insulin compared with baseline and placebo. This effect was not observed when plum juice was tested in healthy adults[201]. Platelet aggregation has also been considered in plum juice research: Santhakumar *et al.* (2015)[206] indicated that QG plum juice but not prune juice had a significant effect on different markers of thrombosis, reducing platelet activation and hyper coagulability.

In relation to inflammatory markers, Bhaswant *et al.* (2019)[202] found a reduction in TNF α and plasma interleukins such as IL 6 and IL 13 after QG plum juice in mildly hypertensive subjects who were overweight or obesity. Decreased concen trations of TNF α were also observed in older adults after 8 week QG consumption[203]. Conversely, in healthy adults, Santhakumar *et al.* (2015)[206] reported that there were no significant changes in inflammatory markers regardless of the treatment (QG plum juice, prune juice or control). Under acute post prandial conditions, anthocyanin rich QG plum juice decreased hs CRP levels compared with the apricot juice[205]. Do Rosario *et al.* (2021)[205] also observed a downtrend for IL 6 while no treatment altered TNF α and IL 1β. Examining biomarkers of oxidative stress, 200 ml/d QG plum juice for 4 weeks decreased plasma MDA levels, while prune juice did not[201]. A lack of effect of QG plum juice on oxidative stress status under acute conditions has also been reported[205]. A single dose of QG plum juice did not improve cognitive function in younger or older adults[204].

Few studies have assessed the health effects of plum juice, in particular in the case of common European plum juices. Anthocyanin rich QG plum juice has attracted almost all the attention in terms of plum juice research, and it might be able to have positive moderate effects on vascular function, LDL C and inflammatory status. Its ability to attenuate some biomarkers related to cardiovascular risk was seen mainly in subjects at risk of disease, but not in healthy ones. On the other hand, the choice of apricot or prune juices as control drinks[201,205] could bias the results as both drupe juices share some bioactive compounds with plum juice. Although these juices can be good choices to exclude the role of anthocyanins, they did not allow a complete assessment of the effect of plum juice on health outcomes. Further research on these drupe juices may also be needed.

Tomato juice

Tomato is one of the most popular vegetables worldwide, and its juice is likely the predominant vegetable juice on the market. Lycopene is the main carotenoid in tomatoes and tomato based products and, among phenolic compounds, quercetin, kaemp ferol, naringenin, luteolin and caffeic acid derivatives are the most common[207]. Tomato has been typically investigated for its lycopene content and has been related epidemiologically to cancer prevention, specifically for prostate cancer[208]. However, the only meta analysis that considered tomato juice for sub group analysis did not find any significant association between juice consumption and the risk of prostate cancer, so further studies would be needed to clarify the potential chemo preventive effects of tomato juice[209]. Epidemiological studies have also emphasised the potential cardiometabolic benefits associated with tomato consumption, while the contribution of tomato juice is unknown[210]. The results from key intervention studies with 100% tomato juice are discussed below and are focused mainly on blood lipids, inflammatory markers and oxidative stress status (Table 10).

Michaličková *et al.* (2019)[211] assessed the effects of daily ingestion of tomato juice enriched in polyphenols using a tomato extract against a standard tomato juice on BP in subjects with

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Table 9. Characteristics of some representative studies investigating the health effects of plum juices

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bioactive compounds	Control/Placebo group	Main findings	Reference
Queen Garnet plum	RCT, DB, CO, three arm, 4 weeks	*n* = 20 (10 F), healthy, NW, 33 (SD 12) years	200 ml/d	202 mg anthocyanins; 87 mg quercetin derivatives	Prune juice without antho cyanins or quercetins; placebo drink: diluted raspberry cordial	Inhibited platelet aggregation; ↓ plasma fibrinogen, MDA; no changes in blood lipids	Santhakumar *et al.*, 2015[201]
Queen Garnet plum	Pilot, CO, acute	*n* = 12 (9 F), OW, 77 (SD 6) years; *n* = 12 (8 F), NW, 31 (SD 8) years	300 ml single dose or 3 × 100 ml over 3 h	369 mg total antho cyanins	No control	↓ BP (anthocyanin rich QG plum juice group)	Igwe *et al.*, 2017[204]
Queen Garnet plum	RCT, DB, 12 weeks	*n* = 29 (14 F, 15 interven tion), mild hypertensive with no medication, OW/ OB, 43 (SD 13) years	250 ml/d	255 mg cyanidin 3 glucoside eq. antho cyanins, 90 mg quercetin glyco sides	Commercial raspberry cordial flavoured with out flavonoids	↓ SBP, DBP, IL 6, IL 13, TNF α, FG, insulin, LDL c; no changes in BW, WHR, body composition measure ments, HDL c, TC, TAG	Bhaswant *et al.*, 2019[202]
Queen Garnet plum	RCT, DB, CO, single dose	*n* = 16 (13 F), OW/OB, 66 (SD 6) years	250 ml/d (220 g plum puree added with 30 ml water) + HFHE meal	200 mg anthocyanins	Apricot juice with no anthocyanins	no changes in post prandial BP, TNF α, IL 1β, TC, TAG, DROM; ↑ post prandial FMD; ↓ post prandial hs CRP	do Rosario *et al.*, 2021a[205]
Queen Garnet plum	RCT, DB, three arm, 8 weeks	*n* = 31 (19 F), with MCI, OW, 75 (SD 7) years	250 ml/d	48 mg anthocyanins (low dose), 201 mg anthocyanins (high dose)	Apricot juice	no changes in BP, IL 6, IL 1 β, CRP, and parameters of microvascular function; ↓ TNF a (high dose antho cyanins group)	do Rosario *et al.*, 2021b[203]

Juices were 100% juice unless otherwise stated. Abbreviations: BP, blood pressure; BW, body weight; CO, crossover; CRP, C reactive protein; DB, double blind; DBP, diastolic blood pressure; DROM, derivatives of reactive oxidative metabolites; F, female; FG, fasting blood glucose; FMD, flow mediated dilation; HDL c, HDL cholesterol; HFHE, high fat high energy; hs CRP, high sensitivity CRP; IL 1β, interleukin 1β; IL 6, interleukin 6; IL 13, interleukin 13; LDL c, LDL cholesterol; M, male; MCI, mild cognitive impairment; MDA, malondialdehyde; NW, normal weight (BMI: 18,5 24,9 kg/m^2); OB, obesity (BMI: >30 kg/m^2); OL, open label; OW, overweight (BMI: 25 30 kg/m^2); QG, Queen Garnet; RCT, randomised controlled trial; RT, randomised trial; SB, single blind; SBP, systolic blood pressure; TAG, triglycerides; TC, total cholesterol; TNF α, tumour necrosis factor α; WHR, waist to hip ratio; ↓, decreased level; ↑ increased level

Table 10. Characteristics of some representative studies investigating the health effects of tomato juice

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bioactive compounds	Control/Placebo group	Main findings	Reference
Tomato	RCT, parallel, four arm, 4 weeks	$n = 52$ (20 F, 15 intervention), with T2D, 59 (SD 9) years	500 ml/d		Placebo gelatin capsule containing pharmaceutical starch	No changes in CRP, ICAM 1 and VCAM 1; ↑ resistance of LDL to oxidation induced by copper ions	Upritchard *et al.*, 2000[221]
Tomato	RT, 8 week	$n = 50$ (32 F, 29 intervention), healthy, OW/OB, 70 (SD 6) years	330 ml/d	47·1 mg lycopene, 1·7 mg β carotene	Mineral water	↓ LDL oxidation in R allele carriers (QR/RR) but not in the QQ wild type (PON1 192 polymorphism)	Bub *et al.*, 2002[224]
Tomato	RT, CO, 2 weeks	$n = 22$ (M), healthy, non smoking, in a low carotenoid diet	330 ml/d	37 mg lycopene, 1·6 mg β carotene	Carrot juice (27 mg β carotene, 13 mg α carotene)	No changes in MDA in plasma and faeces; ↑ lag time during *ex vivo* LDL oxidisation	Briviba *et al.*, 2004[223]
Tomato	RT, 3 weeks	$n = 21$ (16 F), healthy, NW/OW, mean 30 years	400 ml/d tomato juice and 30 g/d ketchup	27 mg lycopene/d (23·6 mg from juice and 3·7 mg from ketchup)	Low tomato diet (no tomato products, or fruit and vegetables containing lycopene).	↓ TC and LDL c compared to the LTD; HTD ↑ LDL c resistance to copper ion induced oxidation	Silaste *et al.*, 2007[214]
Tomato	RCT, 20 d	$n = 104$ (F, 53 intervention), OW/OB, 23 (SD 1) years	330 ml/d	37 mg lycopene	Water	↓ IL 8 and TNF α in OW subjects, IL 6 in OB subjects	Ghavipour *et al.*, 2013[220]
Tomato	RCT, 20 d	$n = 60$ (F, 32 intervention), OW, 25 (SD 1) years	330 ml/d	37 mg lycopene	Water	↑ plasma TAC and erythrocyte antioxidant enzymes; ↓ MDA	Ghavipour *et al.*, 2015[222]
Tomato	RCT, CO, 4 weeks	$n = 28$, with high risk of developing CVD, OW/OB, 70 (SD 3) years	200 ml/d or 400 ml/d (both with 5% olive oil)	80 mg, trans lycopene (48·1%) and β carotene (47·4%)	Water	↓ ICAM 1 and VCAM 1; downward trend in IL 8; no changes in CRP, eotaxin, IFN γ, CXCL10	Colmán Martínez *et al.*, 2017[219]
Tomato (juice enriched in (poly)phenols)	RCT, SB, parallel, 4 weeks	$n = 26$ (19 F, 13 intervention), subjects with stage one hypertension, NW/OW, 46 (SD 6) years	200 g + 1g of ethanolic extract of whole tomato fruit	144 mg GAE/200 g phenolic content, 3 mg/200 g lycopene	Standard tomato juice (97 mg GAE/200 g phenolic content)	No changes in BP, FG, PT; TC and LDL c ↓ in the control group	Michaličková *et al.* (2019)[211]
Tomato	RCT, CO, 3 d	$n = 25$ (F), healthy, NW, 22 (SD 4) years	200 g		Tomato fruits, water	Improved post prandial glucose response	Saito *et al.*, 2020[216]

Juices were 100% juice unless otherwise stated. Abbreviations: BP, blood pressure; CO, crossover; CRP, C reactive protein; CVD, cardiovascular disease; CXCL10, CXC motif chemokine 10; DB, double blind; F, female; FG, fasting blood glucose; GAE, gallic acid equivalent; HTD, high tomato diet; ICAM 1, intercellular adhesion molecule 1; IFN γ, interferon gamma; IL 6, interleukin 6; IL 8, interleukin 8; LDL c, LDL cholesterol; LTD, low tomato diet; M, male; MDA, malondialdehyde; NW, normal weight (BMI: 18,5 24,9 kg/m^2); OB, obesity (BMI: >30 kg/m^2); OL, open label; OW, overweight (BMI: 25 30 kg/m^2); PON1, paraoxonase 1; PT, prothrombin time; RCT, randomised controlled trial; RT, randomised trial; SB, single blind; T2D, type 2 diabetes; TAC, total antioxidant capacity; TC, total cholesterol; VCAM 1, vascular cell adhesion molecule; ↓, decreased level; ↑ increased level

stage one hypertension. Juice composition was similar in both products (16 mg/l lycopene) except for the phenolic content (486 versus 721 mg/l for the control juice and the enriched one, respectively). BP did not change significantly for any treatment after 4 weeks, although 5 10 mmHg reductions were reported as a consequence of both treatments. Although pooled data from a meta analysis have demonstrated similar outcomes for tomato products[212], the limited evidence of tomato juice effects on BP precludes from drawing robust conclusions. Nevertheless, a 5 mmHg lowering in BP could represent a reduction in the risk of cardiovascular events by about 10%, so this topic should be better explored[213].

Considering the lipid profile, Silaste *et al.* (2007)[214] observed a reduction in TC and LDL C concentrations in healthy, normocholesterolaemic adults after a 3 week high tomato diet (400 of ml/d tomato juice and 30 mg/d of tomato ketchup) compared with the 3 week low tomato diet (no tomato products, or fruit and vegetables containing lycopene). The high tomato diet provided approximately 27 mg lycopene/d, of which 23·6 mg lycopene per 400 ml was from juice and 3·7 mg lycopene per 30 mg was from ketchup, and blood lipid improvements were correlated to changes in serum concentrations of lycopene, β carotene and γ carotene. TC and LDL C also decreased in the work by Michaličková *et al.* (2019)[211], but only in the control group (tomato juice with no added polyphenols). In the case of glucose metabolism, this last work did not record differences between groups for fasting glucose after 3 weeks[211], in line with pooled data for tomato products[215]. However, under acute conditions, consuming 200 g of tomato juice 30 min before a carbohydrate rich challenge ameliorated the post prandial glucose response[216].

Platelet hyperaggregability is among the factors associated with CVD risk. A recent review of human subject intervention studies by Cámara *et al.* (2020)[217] concluded that consuming tomatoes and tomato products is a promising nutritional strategy for the prevention of platelet aggregation. Indeed, the European Food Safety Authority (EFSA) has assessed positively the beneficial effects of a water soluble tomato concentrate in platelet aggregation[218]. Nevertheless, the information related to tomato juice is scarce and, for instance, Michaličková *et al.* (2019)[211] did not observe differences in prothrombin time between treatments.

In a randomised controlled crossover trial, Colmán Martínez *et al.* (2017)[219] found that, in subjects at high cardiovascular risk after 4 week consumption of tomato juice at 200 ml/d or 400 ml/d (401 μmol/l of carotenoids, *trans* lycopene and β carotene accounting for about 48% and 47% of the total carotenoids, respectively; both juices contained 5% olive oil), the concentration of adhesion molecules ICAM 1 and VCAM 1 was significantly lower compared with the control group (water). Other inflammatory biomarkers (IL 8, CRP, eotaxin, interferon γ, and CXC motif chemokine 10 CXCL10) were not significantly different in the intervention group compared with the control group. The lowering effect in inflammatory biomarkers was correlated with the *trans* lycopene in circulation, while the other carotenoids in tomato juice showed a minor or no association[219]. In another study, using IL 6, IL 8, hs CRP and TNF α as biomarkers of inflammation, Ghavipour *et al.* (2013)[220] found that 330 ml/d of tomato juice (112 mg lycopene/l) for 20 d significantly decreased serum concentrations of IL 8 and TNF α in subjects who were overweight, while, among subjects with obesity, only serum IL 6 concentration decreased in the intervention group. Conversely, after 4 week consumption of 500 ml/d of tomato juice, no changes in inflammatory biomarkers (CRP, ICAM 1, and VCAM 1) in patients with T2D were observed[221].

Many studies have investigated the effect of tomato juice on biomarkers of oxidative stress. Ghavipour *et al.* (2015)[222], in a randomised controlled trial in females who were overweight, found that 330 ml/d of tomato juice for 20 d increased plasma total antioxidant capacity and erythrocyte antioxidant enzymes and decreased serum MDA levels compared with both baseline and the control group. No improvement was observed in subjects with obesity and, as hypothesised by the authors, this may be due to the need for a greater amount of lycopene or a longer duration of lycopene supplementation[222]. Upritchard *et al.* (2000)[221] reported that consumption of 500 ml/d of tomato juice for 4 weeks by T2D patients increased both plasma lycopene levels and the resistance of LDL to oxidation, almost as effectively as supplementation with a high dose of vitamin E (537 mg/d). Increased LDL resistance to oxidation was also observed by Silaste *et al.*[214] after 3 weeks of a high tomato diet in healthy adults (27 mg lycopene/d). Conversely, in the study by Briviba *et al.* (2004)[223], MDA levels in plasma and faeces and *ex vivo* LDL oxidation were not affected in healthy men by supplementation for 2 weeks of 330 ml/d of tomato juice (112 and 5 mg/l of lycopene and β carotene, respectively) in comparison to carrot juice[223]. Nonetheless, most studies have found improvements in biomarkers of oxidative stress. In addition, Bub *et al.* (2002)[224] found that the changes in antioxidant status after tomato juice consumption could be genotype dependent, precisely related to the PON 1 192 polymorphism. Indeed, their results showed that consumption of 330 ml/d of tomato juice for 8 weeks reduced LDL oxidation in healthy elderly who were R allele carriers (QR/RR) but not in the QQ wildtype[224].

In conclusion, tomato juice may have favourable effects on lipid metabolism and glucose post prandial response and could improve biomarkers of inflammation and oxidative stress. However, further studies are needed to demonstrate the effect of tomato juice on CVD risk factors and establish dose response effects taking into account the responsible bioactive compounds. Although most of the evidence points to lycopene, the role of phenolic compounds on the health benefits of 100% tomato juice should not be neglected. Genotypic differences should also be considered.

Carrot juice

Carrot (*Daucus carota*) is a popular root vegetable and an important source of dietary carotenoids. Besides vitamins and minerals, carrot juice is rich in α and β carotene[225]. Both carotenes are vitamin A precursors (the pro vitamin A activity of α and β carotene is 50% and 100%, respectively), and β carotene has attracted much attention during the last decades due to its preventive features in different pathophysiological scenarios.

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Moreover, carrot juice is rich in caffeic acid, among other (poly) phenols, while black carrot juice may also present a high amount of anthocyanins[225]. Carrot juice and blends are important vegetable juices from a market point of view, while the level of evidence on their health properties is low due to the limited number of works published (Table 11).

Potter *et al.* (2011)[226] evaluated the effect of carrot juice on different cardiometabolic risk markers in seventeen individuals with elevated plasma cholesterol and TG levels. Treatment consisted of 470 ml (16 oz) of freshly squeezed carrot juice for 3 months without a control group. Carrot juice did not alter anthropometric parameters, body fat percentage, BP, lipid profile, glucose metabolism markers, and inflammatory markers, while it led to an increase in plasma antioxidant status and a decrease in MDA[226]. Contrary to these benefits in the oxidative stress balance, Briviba *et al.* (2004)[223] studied lipid peroxidation in plasma and faeces of healthy men consuming a diet low in carotenoids supplemented with 330 ml/d of tomato juice, as previously reported, or carrot juice (82 and 39 mg/l of β carotene and α carotene, respectively) for 2 weeks. Carrot juice consumption raised the plasma levels of α and β carotene, but this did not lead to improvements in biomarkers of lipid peroxidation[223]. In addition, carrot juice did not modulate immune functions in comparison to tomato juice[227].

Ramezani *et al.* (2010) conducted a randomised controlled double blind study with 200 ml/d β carotene enriched carrot juice (active group) and carrot juice (placebo) for 8 weeks in forty four patients with T2D[228]. Although serum levels of β carotene increased, both treatments had no effect on markers of glycaemic homeostasis (glucose and insulin)[228] or inflammation (CRP and IL 6)[229].

Overall, despite the content of β carotene and other bioactives, carrot juice does not seem to exert any significant effects on human subject health.

Beetroot juice

Beetroot (*Beta vulgaris*) juice has been primarily investigated for its high concentration of dietary nitrate (NO_3^-), which is partially converted to NO after consumption and may exert vasodilation related benefits associated with vascular function, cardiorespiratory endurance and exercise performance. Zamani *et al.* (2021)[230] recently conducted a systematic review of the benefits and risks of beetroot juice consumption in healthy subjects, and it can be useful to deepen the knowledge on beetroot juice (Table 12).

Beetroot juice could help lower systolic and diastolic BP in healthy young adults, likely due to the vasodilatory effects of NO, whereas results in the elderly were inconclusive[230]. Several studies have reported a reduction in BP within 3 h after a single dose of beetroot juice, the effect lasting for several hours. For instance, Vanhatalo *et al.* (2010)[231] observed that 500 ml/d of beetroot juice for 15 d (10·4 mmol nitrate per litre) reduced both systolic and diastolic BP at different time points between 2·5 h and 15 d, suggesting that the effect of dietary nitrate may be maintained over time if supplementation continues. However, further studies investigating the beneficial effect of long term beetroot juice in healthy people are needed. Regarding otherwise healthy populations, Kapil *et al.* (2015)[232] demonstrated that consumption of dietary nitrate from 250 ml/d of beetroot juice (~25·6 mmol nitrate per litre) for 4 weeks significantly reduced BP in hypertensive patients with hypertension at trial inception, with no evidence of tachyphylaxis over the 4 weeks, in comparison to a nitrate free beetroot juice (control). BP was measured as clinic BP, 24 h ambulatory BP and home BP and significant reductions in both systolic and diastolic BP were shown[232]. Conversely, despite increased plasma, salivary, and urinary nitrite and nitrate, Bondonno *et al.* (2015)[233] observed no differences in home BP or 24 h ambulatory BP after 1 week of 70 ml of concentrated beetroot juice twice daily (~50 mmol nitrate per litre) compared with the placebo (nitrate depleted beetroot juice) in treated hypertensive individuals. Similarly, 250 ml/d of beetroot juice (30 mmol nitrate per litre) for 2 weeks led to an increase in plasma nitrite and nitrate concentration but did not reduce 24 h mean ambulatory BP in T2D patients with antihypertensive therapy, compared with placebo (nitrate depleted beetroot juice)[234]. It has been hypothesised that antihypertensive medication may limit the potential benefits of the dietary nitrates present in beetroot[235], explaining the absence of significant results in the two previous studies. Nevertheless, pooled evidence accounts for the beneficial effect of beetroot juice on BP reduction, and a greater reduction in both systolic and diastolic BP has been reported after beetroot juice supplementation in at risk subjects compared with healthy participants[251,252].

In a randomised double blind placebo controlled 6 week study, Velmurugan *et al.* (2016)[238] reported that consumption of 250 ml/d of beetroot juice (~24 mmol nitrate per litre) significantly increased the FMD response in untreated hypercholesterolemic individuals, with a worsening in the placebo group (nitrate depleted beetroot juice). Dietary nitrates were thus associated with an improvement in vascular function. Nitrate rich beetroot juice also led to a small but significant reduction in platelet monocyte aggregates (a marker of platelet activation) as well as a reduction in P selectin expression[238]. The authors also observed a modest improvement in measures of arterial stiffness (aortic PWV and augmentation index) compared with the control group. In line with these results, Kapil *et al.* (2015)[232] reported an improvement in endothelial function and a reduction in arterial stiffness in hypertensive patients who consumed beetroot juice, with no change after control treatment. However, dietary nitrate from beetroot juice did not improve endothelial function in patients with T2D[234].

Many studies have evaluated the effects of beetroot juice on exercise and sport performance in healthy subjects[230]. Beetroot juice could improve sport performance through several mechanisms, such as reducing oxygen consumption in skeletal muscle and accelerating the transition between anaerobic and aerobic metabolism in muscle cells. In the latter case, the reduced accumulation of metabolites produced during anaerobic respiration (such as lactate) can delay the onset of fatigue and increase power output and force. In addition, due to the vasodilatory effect of NO, beetroot juice could increase muscle and cerebral blood flow[230]. Consumption of a single dose of beetroot juice has led to inconclusive results on training performance, although most of the studies in recreationally active or well trained women suggested positive effects. Short

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Table 11. Characteristics of some representative studies investigating the health effects of 100% carrot juice

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bioactive compounds	Control/Placebo group	Main findings	Reference
Carrot	RT, CO, 2 weeks	*n* = 22 (M), healthy, non smoking, in a low carotenoid diet	330 ml/d	27 mg β carotene, 13 mg α carotene	Tomato juice (37 mg lycopene, 1·6 mg β carotene)	No modulation of immune functions in comparison to tomato juice No changes in MDA in plasma and faeces; ↑ lag time during *ex vivo* LDL oxidisation	Watzl *et al.*, 2003[227] Briviba *et al.*, 2004[223]
Carrot	RCT, DB, two arm, parallel, 8 weeks	*n* = 44 (22 F, 22 β carotene enriched carrot juice (active group), 22 carrot juice), patients with T2D, NW/OW/OB, 55 (SD 6) years	200 ml/d		Comparison of both interventions	no changes in glucose and insulin	Ramezani *et al.*, 2010[228]
Carrot	RT, 3 month	*n* = 17 (9 F), with high levels of plasma cholesterol and triglycerols, OW/OB	470 ml/d (16 fl oz)		No control	↑ plasma antioxidant status; ↓ MDA and SBP; no changes in anthropometry, DBP, TC, LDL, HDL, TAG, Apo A, Apo B, body fat %, insulin, leptin, IL 1α, CRP	Potter *et al.* (2011)[226]
Carrot	RCT, DB, two arm, parallel, 8 weeks	*n* = 44 (22 F, 22 β carotene enriched carrot juice (active group), 22 carrot juice), patients with T2D, NW/OW/OB, 55 (SD 6) years	200 ml/d		Comparison of both interventions	↑ β carotene levels in active group; no changes in CRP and IL 6	Ramezani *et al.*, 2014[229]

Juices were 100% juice unless otherwise stated. Abbreviations: Apo A, apolipoprotein A; Apo B, apolipoprotein B; CO, crossover; CRP, C reactive protein; DB, double blind; DBP, diastolic blood pressure; F, female; HDL c, HDL cholesterol; IL 1α, interleukin 1α; IL 6, interleukin 6; LDL c, LDL cholesterol; M, male; MDA, malondialdehyde; NW, normal weight (BMI: 18,5 24,9 kg/m^2); OB, obesity (BMI: >30 kg/m^2); OL, open label; OW, overweight (BMI: 25 30 kg/m^2); RCT, randomised controlled trial; RT, randomised trial; SBP, systolic blood pressure; T2D, type 2 diabetes; TAG, triglycerides; TC, total cholesterol; ↓, decreased level; ↑ increased level

Table 12. Characteristics of some representative studies investigating the health effects of 100% beetroot juice

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bio active compounds	Control/Placebo group	Main findings	Reference
Beetroot	RT, CO, 15 d	$n = 8$ (3 F), healthy, 29 (SD 6) years	500 ml/d	10·4 mmol nitrate per litre	Low calorie blackcurrant juice cordial (no nitrate)	↓ SBP and DBP	Vanhatalo *et al.*, 2010[231]
Beetroot	RCT, DB, CO, 2 weeks	$n = 27$ (9 F), patients with >5 year T2D, hypertensive, OB, 67 (SD 5) years	250 ml/d	30 mmol nitrate per litre	Nitrate depleted beet root juice	No changes in 24 h mean ambulatory BP and endothelial function	Gilchrist *et al.*, 2013[234]
Beetroot	RCT, DB, CO, 1 week	$n = 27$ (17 F), hypertensive medicated subjects, NW/OW, 63 (SD 4) years	140 ml/d	~50 mmol nitrate per litre	Nitrate depleted beet root juice	No changes in home BP and 24 h ambulatory BP	Bondonno *et al.*, 2015[233]
Beetroot	RCT, DB, 4 weeks	$n = 64$ (38 F, 32 intervention group), hypertensive patients, OW/OB, 56 (SD 16) years	250 ml/d	~25·6 mmol nitrate per litre	Nitrate depleted beet root juice	↓ SBP, DBP and arterial stiffness; improvement in endothelial function	Kapil *et al.*, 2015[232]
Beetroot	RCT, DB, CO, 4 d	$n = 48$ (13 F), patients with >5 years T2D, OW/OB, 63 (SD 7) years	70 ml/d	92 mmol nitrate per litre	Nitrate depleted beet root juice	No change in the O_2 cost of walking test and distance covered in the 6 min walk test	Shepherd, Gilchrist *et al.*, 2015[239]
Beetroot	RCT, DB, CO, 2·5 d with the final supplement ~3 h before testing	$n = 13$, with mild moderate COPD, OW, 65 (SD 8) years	140 ml/d	97 mmol nitrate per litre (6·77 mmol/d)	Nitrate depleted beet root juice	↑ plasma nitrite and nitrate concentration; no reduction in the O_2 cost of cycling test nor in SBP and DBP	Shepherd, Wilkerson *et al.*, 2015[240]
Beetroot	RCT, DB, parallel, 6 weeks	$n = 65$ (33 intervention), healthy hypercholesterolemic, NW/OW/OB, 53 (SD 12) years	250 ml/d	~24 mmol nitrate per litre	Nitrate depleted beetroot juice	↑ FMD, aortic PWV and augmentation index; ↓ platelet monocyte aggregates, P selectin expression; no differences in ox LDL; ↑ microbial species capable of nitrate reduction in salivary microbiome	Velmurugan *et al.*, 2016[238]

Juices were 100% juice unless otherwise stated. Abbreviations: BP, blood pressure; CO, crossover; COPD, chronic obstructive pulmonary disease; DB, double blind; DBP, diastolic blood pressure; F, female; FMD, flow mediated dilation; M, male; NW, normal weight (BMI: 18,5 24,9 kg/m^2); OB, obesity (BMI: >30 kg/m^2); OL, open label; OW, overweight (BMI: 25 30 kg/m^2); ox LDL, oxidised LDL; PWV, pulse wave velocity; RCT, randomised controlled trial; RT, randomised trial; SBP, systolic blood pressure; T2D, type 2 diabetes; ↓, decreased level; ↑ increased level

term beetroot juice consumption (more than one dose daily or multiple days) showed positive effects in recreationally active men (for example, by improving time to exhaustion or recovery), whereas results for well trained men were inconclusive[230]. When taking into consideration subjects with underlying health conditions, Shepherd *et al.* (2015)[239] found that 4 d 70 ml/d beetroot juice (92 mmol nitrate per litre) did not reduce the O_2 cost of walking in individuals with T2D nor increase the distance covered in the 6 min walk test compared with the control juice (nitrate depleted), despite plasma nitrate and nitrite concentration increased. The same results were obtained in individuals with chronic obstructive pulmonary disease consuming the same juice (70 ml/d, 97 mmol nitrateper litre) twice a day for 2·5 d, with the final serving 3 h before the activity; in this case, the O_2 cost was measured by a moderate intensity cycling[240]. Nevertheless, the research on this topic is continuously evolving, and a more in depth analysis would be needed to better understand the role of beetroot juice on exercise and sport performance.

Examining biomarkers of oxidative stress, Velmurugan *et al.* (2016)[238] did not find differences in ox LDL in untreated hypercholesterolemic subjects who consumed 250 ml/d of nitrate rich beetroot or a control nitrate depleted beetroot juice. These authors also indicated that beetroot juice could influence microbiota composition. The salivary microbiome was altered after beetroot juice but not after the control, and the shift in the oral microbiome was in favour of organisms capable of nitrate reduction[238]. In fact, the effect of beetroot juice on exercise performance may be mediated by oral microbiota[241], a topic that deserves further research.

Besides beneficial effects, Zamani *et al.* (2021)[230] also considered the potential risks of consuming beetroot juice. As a source of nitrate, beetroot juice could lead to the formation of potentially carcinogenic *N* nitroso compounds. For example, Berends *et al.* (2019)[242] found a significant increase in urinary apparent total *N* nitroso compounds after a 70 ml dose of beetroot juice (~92 mmol nitrate per litre) and a further increase after seven consecutive doses. Thus, although beetroot juice has shown several beneficial effects, further studies should also investigate the link between its intake and the formation of *N* nitroso compounds.

In conclusion, dietary nitrate from beetroot juice has been shown to improve BP in healthy individuals or untreated hypertensive subjects, but not in treated hypertensive patients or T2D patients. Improvements in vascular function have also been reported for untreated hypercholesterolemic and hypertensive patients, but not for patients with T2D. In general, pooled results from meta analyses point to the beneficial effects of beetroot juice on BP and vascular function, whereas the baseline characteristics of the populations seem to be critical to benefit from juice consumption[236]. The benefits of beetroot juice on exercise performance were seen in some populations, but they depended very much on the dose and type of exercise, among other factors. The effect of beetroot juice on other common cardiometabolic risk factors beyond cardiovascular function has been scarcely investigated and deserves further research. Last, attention has been paid to nitrate, but other beetroot bioactives such as betalains may also play a role and, once again, additional research is needed.

Other juices

Watermelon juice. Watermelon (*Citrullus lanatus*) is a rich source of the non essential amino acid L citrulline, a precursor of L arginine, which is a substrate for nitric oxide (NO) synthase. Additionally, it is a source of lycopene and other carotenoids[243]. As previously stated, NO is a vasodilator molecule, and it is key to vascular endothelial function. In exercise/sport physiology, NO has received much interest because of its ergogenic effect and, indeed, watermelon juice has been studied primarily related to sport activity.

Shanely *et al.* (2020)[243] observed that 6 week supplemen tation of 710 ml/d of 100% watermelon puree (1·87 g L citrulline per litre, 0·39 g L arginine per litre, 45 mg lycopene per litre) improved sVCAM 1 levels, a marker connected to atherogenesis, in post menopausal women who were overweight/obese, whereas fasting blood glucose, insulin and HOMA IR did not change (Table 13). In another study conducted on post menopausal women, two daily 360 ml servings of 100% watermelon juice for 4 weeks did not affect BP or arterial stiffness despite an increase in circulating lycopene being recorded[244]. No effect on inflammation and oxidative stress markers was observed[245], while fasting blood glucose slightly increased although changes in glucose homeostasis lacked clinical relevance[244]. Some post prandial beneficial effects of watermelon juice have recently been observed in healthy adults[246].

Regarding the role of watermelon juice on exercise, Blohm *et al.* (2020)[247] found that a single dose pre exercise of 355 ml of watermelon juice (2·2 g L citrullineper litre; 3·1 g potassium per litre) prevented increased post exercise systolic and diastolic BP in fourteen healthy non athletic females, but not in thirteen males. It was thus suggested to examine the effect of sex when assessing the efficacy of watermelon juice on BP. Authors found no effect on post exercise muscle soreness, blood lactate levels or exercise performance[247]. A lack of effect of watermelon juice on exercise performance in comparison with a placebo carbohydrate beverage was reported when twenty trained cyclists consumed 980 ml/d of watermelon puree for 2 weeks and during 75 km cycling time trials, despite watermelon increased plasma L citrulline and L arginine concentrations and total nitrates[248]. In another rando mised crossover study, Martínez Sánchez *et al.* (2017)[249] reported a lower muscle soreness perception from 24 to 72 h after a half marathon race and lower plasma lactate concentrations in amateur runners who consumed 500 ml L citrulline enriched watermelon juice (6·91 g L citrulline per litre; 13·98 mg lycopene per litre) 2 h before the marathon race compared to runners in the placebo group (no L citrulline and lycopene).

Few studies were available on watermelon juice to draw major conclusions. The effect of 100% watermelon juice consumption at cardiometabolic level has been studied mainly in post menopausal women, and no relevant benefits were reported. Although it has been hypothesised that watermelon juice may have a significant effect on exercise performance, no

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Table 13. Characteristics of some representative studies investigating the health effects of other 100% juices like watermelon, wild passionfruit and cashew apple

Intervention juice	Study design	Study participants	Juice amount	Daily dose of bioactive compounds	Control/Placebo group	Main findings	Reference
Watermelon	RCT, DB, CO, single dose 2h pre marathon	*n* = 21 (M), healthy, amateur runners male, 35 (SD 11) years	500 ml	6·91 g L citrulline per litre; 13·98 mg lycopene per litre	Beverage without L citrulline	↓ plasma lactate and muscle soreness perception from 24 to 72 h after the half marathon race	Martínez Sánchez *et al.*, 2017[249]
Watermelon	RCT, CO, single dose pre exercise	*n* = 27 (14 F), healthy, NW, 25 (SD 1) years	355 ml	2·2 g L citrulline per litre; 3·1 g potassium per litre	Bottled water, sugar water, Gatorade	No increased post exercise SBP and DBP in females, not in males; no effect on post exercise muscle soreness, blood lactate levels or exercise performance	Blohm *et al.*, 2020[247]
Watermelon puree	RCT, 2 arm, 6 weeks	*n* = 45 (F, 26 inter vention), OW/OB post menopausal, 60 (SD 1) years	710 ml/d	1·87 g L citrulline per litre, 0·39 g L argi nine per litre, 45 mg lycopene per litre	No intervention	↓ VCAM 1 levels; no change in FG, insulin, and HOMA IR	Shanely *et al.*, 2020[243]
Watermelon	RCT, DB, CO, 4 weeks	*n* = 21 (F), post menopausal, 60 (SD 4) years	360 ml twice/d	2·26 g citrulline/l, 1·60 g arginine/l, 20 mg lycopene/l	Isoenergetic placebo matched for sugar content	No effect on inflammatory markers, oxidative stress and cognitive tests ↑ FG, no change in insulin, HOMA IR, BP, PWV, FMD, BMI, fat %	Crowe White *et al.* 2021[245] Ellis *et al.* 2021[244]
Wild passionfruit juice (*Passiflora setacea*)	RCT, DB, two phase, single dose	*n* = 12 (M), OW/OB, 49 (SD 7) years	250 ml		Isoenergetic placebo drink: 100 ml of a passionfruit flavoured isotonic drink with 150 ml of water	↑ HDL c; ↓ insulin and HOMA IR; no changes in TC, LDL c, TAG, circulating cytokines	Duarte *et al.*, 2020[250]
Cashew apple	RCT, CO, 4 weeks	*n* = 20 (M, trained/ untrained), NW, 2 (SD 3) years	3·5 ml/kg/d		Isoenergetic control drink without (poly)phenols	↑ fat oxidation during high intensity exercise in trained and untrained subjects	Prasertsri *et al.*, 2013[251]
Cashew apple	RCT, DB, CO, 4 weeks	*n* = 20 (M, trained/ untrained), NW, 20 (SD 3) years	3·5 ml/kg/d		Isoenergetic control drink without (poly)phenols	↑ exercise induced leucocyte and resting neutrophil counts in trained men	Prasertsri *et al.*, 2019[252]

Juices were 100% juice unless otherwise stated. Abbreviations: BMI, body mass index; BP, blood pressure; CO, crossover; DB, double blind; DBP, diastolic blood pressure; F, female; FG, fasting blood glucose; FMD, flow mediated dilation; HDL c, HDL cholesterol; HOMA IR, homeostasis model assessment insulin resistance; LDL c, LDL cholesterol; M, male; NW, normal weight (BMI: 18,5 24,9 kg/m^2); OB, obesity (BMI: >30 kg/m^2); OL, open label; OW, overweight (BMI: 25 30 kg/m^2); PWV, pulse wave velocity; RCT, randomised controlled trial; RT, randomised trial; SBP, systolic blood pressure; TAG, triglycerides; TC, total cholesterol; VCAM 1, vascular cell adhesion molecule; ↓, decreased level; ↑ increased level

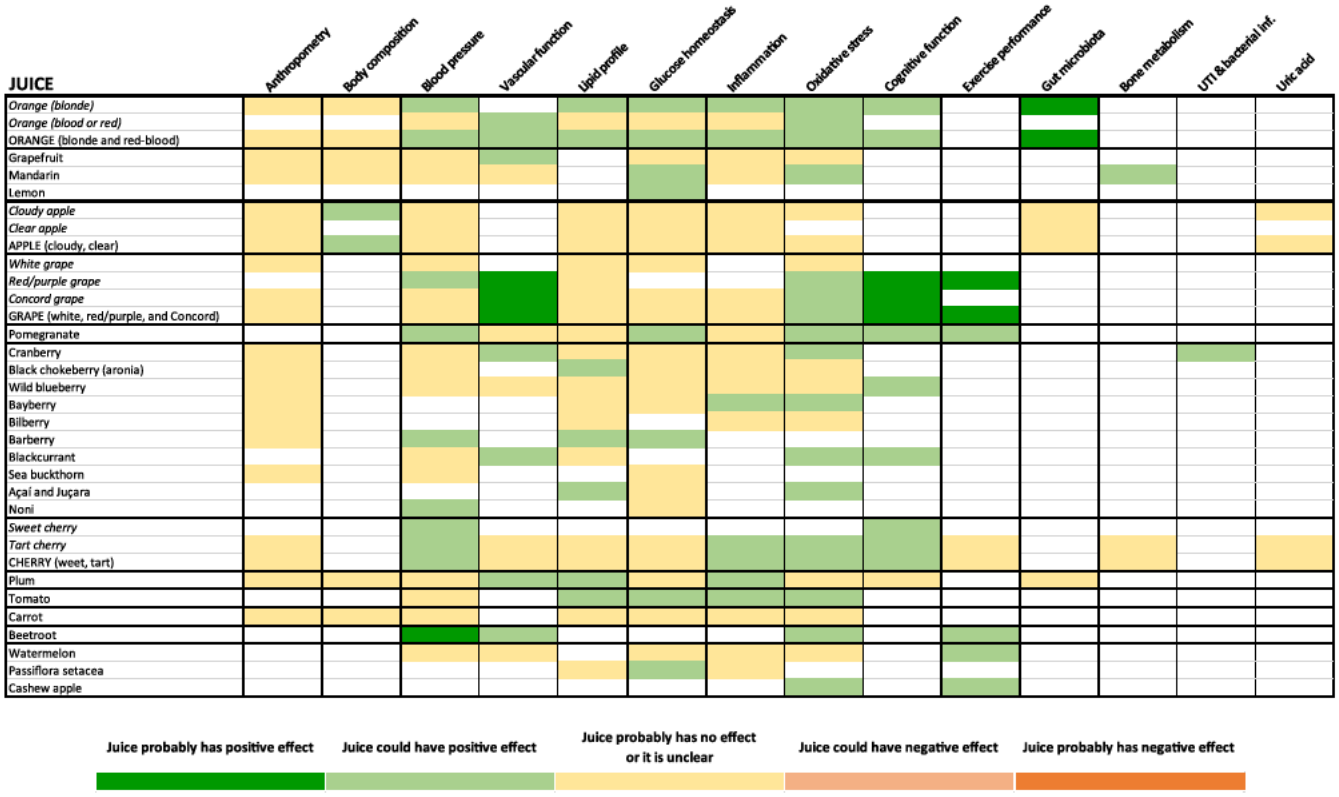

Fig. 2. Potential impact of specific 100% FVJ on human subject health for the main outcomes addressed in the literature. Categories have been attributed considering the evidence presented for each juice and adopting a conservative approach, indicated in 'summary of the evidence'

consistent effects have been seen in studies, perhaps due to heterogeneity in populations and exercise protocols.

Wild passionfruit juice. *Passiflora setacea* or sleep passionfruit is a wild passionfruit species particularly rich in *C* glycoside flavones, such as orientin, homoorientin, vitexin and isovitexin[250]. Duarte *et al.* (2020)[250] observed that 3 h after 250 ml *P. setacea* juice consumption, HDL C levels slightly increased significantly in twelve overweight males, while they did not change after placebo intake (Table 13). Furthermore, insulin levels and HOMA IR decreased significantly 3 h after *P. setacea* juice, whereas no changes were observed after placebo. TC, LDL C, TG, glucose and inflammatory cytokines were not affected by the treatment. The nutrigenomic study revealed genes differentially expressed after *P. setacea* juice consumption, some involved in processes such as inflammation, cytokine cytokine receptor or cell adhesion[250].

Cashew apple juice. The cashew apple is a product of cashew nut (*Anacardium occidentale*) manufacturing. The effect of cashew apple juice was investigated on high intensity exercise, and the potential beneficial effect was related to its content of vitamin C, anacardic acids (phenolic lipids) and branch chain amino acids (Table 13). Prasertsri *et al.* (2013)[251] suggested that 4 week consumption of 3·5 ml/kg/d of cashew apple juice (245 ml/d for a 70 kg subject) enhanced fat oxidation during high intensity exercise in trained and untrained subjects; thus, it could be beneficial for endurance performance. In another study with the same design (4 week, 3·5 ml/kg/d), Prasertsri *et al.* (2019)[252] found that cashew apple juice enhanced exercise induced leucocyte and resting neutrophil counts in trained men, highlighting that the possible mechanism for this effect was a reduction in oxidative stress.

Summary of the evidence

Epidemiological evidence, although heterogeneous, has demonstrated that moderate consumption of FVJ may have a positive or neutral association with human subject health. The results of this review on intervention studies for specific 100% FVJ also accounted for a beneficial or neutral impact of juice consumption on many health outcomes. Most of the studies in the literature have been focused on anthropometry and cardiometabolic markers (BP, vascular function, lipid profile, glucose metabolism, inflammatory markers and oxidative stress status), with some research also addressing cognitive and exercise performance, bone metabolism, gut microbiota composition and bacterial infections. A summary of the potential impact of each 100% FVJ on human subject health for the outcomes assessed is provided in Fig. 2. This review spotted that no significant harmful effects were observed for any juice, while moderate or major benefits were seen on particular outcomes for many juices. A total of 100% FVJ did not significantly impact anthropometric parameters or body composition. Major beneficial effects on BP were related to beetroot juice consumption, as well as orange, pomegranate, and cherry juices. FMD improved significantly after red and Concord grape juices, while juices made from

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cranberry, plum and beetroot may also positively influence endothelial function. Other cardiometabolic markers related to the lipid profile and glucose homeostasis showed improvements after consumption of some juices like orange or tomato juices. Inflammatory and oxidative stress markers also improved after orange, tart cherry and tomato juice consumption, but the literature on these outcomes is generally difficult to assess as many markers with different biological significance are usually considered and may yield contrasting results. Benefits at the cognitive level were found after red and Concord grape and sweet and tart cherry juices, while only red grape juice and beetroot showed clear improvements in exercise performance. Other less explored outcomes indicated that orange juice could positively modulate gut microbiota composition, whereas cranberry juice might have a moderate influence on bacterial infections.

The results summarised in Fig. 2 should be considered carefully. They are just a simplification of the evidence to date, and several factors should be taken into account before promoting specific FVJ for some physiological targets. First, the population setting is key as different (patho)physiological conditions may lead to different effects depending on individ ual's health status. Individuals who are overweight or obese, with hyperlipidemia, T2D or other cardiometabolic issues cannot be addressed in the same way as healthy individuals. Medication or genetic polymorphisms may also limit the benefits of an intervention with a particular 100% fruit or vegetable juice. Age and sex are other aspects to keep in mind, as the response to the intervention may also change. Second, in line with the previous point, not all the dietary interventions with 100% FVJ may benefit the whole population as a high inter individual response to these juices or their potential bioactive compounds have been reported. This does not obviously preclude juice consumption, but it should further encourage the juice community to deepen this pivotal point and strengthen the evidence behind the beneficial effects of FVJ on specific individuals. Although a 'one size fits all' approach may be appealing from a commercial point of view, it does not necessarily reflect the current scientific evidence and may lead to controversial matters in the long term. Third, the size and number of daily/weekly servings determine the efficacy of any intervention with 100% FVJ, as evaluated from the available literature. Servings should also be considered within the diet of each individual, being aware of the fact that 'the more, the better' is something that usually never works in the nutrition of man. Indeed, several studies were conducted with serving sizes not consistent with dietary advice in most countries (for instance, with 400 800 ml/d); so, although these doses can be useful when assessing juice effects on human subject health, research conducted with lower doses (125 250 ml/d) may be a better help to rethink the role of 100% FVJ consumption on dietary guidelines. Last, most beneficial effects were linked to (poly) phenols or, in some cases, to other dietary components. Even though approaches focused on individual compounds or families of bioactives are scientifically supported, juices should be regarded as a whole, including not only other families of bioactives but also nutrient composition.

The evidence summarised in Fig. 2 is subject to some bias. The information on some juices and outcomes was relatively scarce, often limited to one or just a few articles. A cautious approach was followed, and major positive effects were only indicated when several works pointed out the same results and data were backed by meta analyses. Moderate positive effects were shown even when only one or two works yielded a significant improvement in a particular outcome. Consequently, moderate benefits should be regarded as preliminary in some cases, although they may be helpful to drive further research efforts to confirm these promising results. On the other hand, beyond differences in population settings, there is a high heterogeneity among the existing studies on the health effects of 100% FVJ: doses, daily servings, periods of consumption, and juice compositions often varied among interventions. This diversity may limit the impact of the available research; so, when possible and compatible with the research hypothesis, further efforts should be directed to the use of more reproducible protocols. Good examples of similar research protocols were seen, for instance, for Concord grape, cranberry, tart cherry, QG plum and beetroot juice studies. On the other hand, juice composition is sometimes missing or is not correctly reported, the profile of macro , micro nutrients and bioactive compounds being quite incomplete. In addition, the use of non selective spectrometric tools for the characterisation of juice bioactives, in particular in the case of phenolic compounds, does not allow for the identification of specific compounds in the juice but just the class. In this sense, juice composition is vital to evaluate the juice impact on health and better understand how to boost its potential beneficial effects through new agronomical/processing techniques. Last, not all the juices were 100% single strength juices: some used concentrated juices that were reconstituted to the original juice or that were further diluted. Nevertheless, some juices are not commonly sold as 100% juice due to their organoleptic characteristics (for example, high acidity, bitterness, astringency, etc.), so the evidence presented is the closest to what a consumer may purchase and drink. On the other hand, some juices also included extracts rich in the bioactive compounds that are naturally presented in the juice: they were just considered to collect further evidence and serve for the design of new juice products with superior bioactive characteristics, as well as to make more sustainable juice productions by including by products usually containing plenty of bioactive compounds, such as juice pomace.

Conclusions

100% FVJ appear to have a beneficial or neutral effect on the health of man in human subject intervention studies. Some juices have demonstrated the ability to exert potential preventive effects on some outcomes with others exerting effects on other health outcomes, which may be related to their differential composition in bioactive compounds. Further efforts should be devoted to this topic as robust, evidence based conclusions are needed to demonstrate the beneficial impacts of 100% FVJ on human subject health and to support the development of dietary guidelines that inform population dietary choices. Lack of

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evidence may also jeopardise industry competitiveness through the use of unsupported statements.

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Authorship

P.M. conceptualised and designed the study; I.R. contributed to literature search and conducted data analysis and interpretation; P.M. visualised the data; I.R. and P.M. wrote the manuscript; C.M. and D.D.R critically reviewed the manuscript. All authors read and approved the final version.

Nomenclature

BMI body mass index;
BP blood pressure;
CRP C reactive protein;
CVD cardiovascular disease;
FJ fruit juice;
FMD flow mediated dilation;
FVJ fruit and vegetable juice;
HDL C HDL cholesterol;
HOMA IR homeostasis model assessment insulin resistance;
hs CRP high sensitivity CRP;
ICAM 1 intercellular adhesion molecule 1;
IL n interleukin n;
LDL C LDL cholesterol;
MDA malondialdehyde;
ox LD Loxidised LDL;
PON 1 paraoxonase 1;
PWV pulse wave velocity;
QG Queen Garnet;
sICAM soluble ICAM;
SSB sugar sweetened beverages;
sVCAM soluble VCAM;
T2D type 2 diabetes;
TC total cholesterol;
TG triglycerols;
TNF α tumour necrosis factor alpha;
UTI urinary tract infections;
VCAM 1 vascular cell adhesion molecule 1.

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Fruit Juice Consumption, Body Mass Index, and Adolescent Diet Quality in a Biracial Cohort

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Abstract: Fruit juice consumption during childhood remains controversial. Here, we evaluated the association between preadolescent 100% fruit juice intake and later adolescent diet quality and body mass index (BMI). We used prospective data over 10 years from the National Growth and Health Study for 1921 black and white girls, ages 9–10 years at baseline, for analyses of diet quality, and 2165 girls for BMI analyses. Statistical analyses included repeated measures analysis of variance and logistic regression models. Girls who drank ≥1.0 cup/day of fruit juice in preadolescence consumed 0.44 cup/day more total fruit in later adolescence than non-juice-drinking girls ($p < 0.0001$). White and black girls who drank ≥1.25 cups/day in preadolescence were 2.62 (95% CI: 1.35–5.08) and 2.54 (1.27–5.07) times more likely, respectively, to meet the Dietary Guidelines for whole fruit by later adolescence than those with the lowest juice intakes. Further, fruit juice consumption was positively associated with diet quality scores. Overall, girls consuming ≥1.25 cups/day of juice had a BMI in late adolescence that was 1.7 kg/m^2 lower than that of non-juice-drinking girls. In conclusion, early adolescent fruit juice intake was positively associated with subsequent whole fruit consumption, better diet quality, and lower BMI in later adolescence.

Keywords: fruit juice; fruit intake; diet quality; pediatric obesity; BMI; adolescence; Healthy Eating Index

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1. Introduction

Fruit is an important source of beneficial nutrients and has anti-inflammatory and antioxidant properties [1]. Fruit consumption has also been linked with positive health outcomes, including reduction in risk of hypertension and cardiovascular diseases [2,3]. Current Dietary Guidelines for Americans (DGA) recommend that at least half of the recommended total daily fruit intake for both children and adults should be derived from whole fruit [4]. While the nutrient composition of whole fruit and fruit juice is very similar, whole fruit is considered by some to be superior to 100% fruit juice due to its higher fiber content and slower absorption in the gut [5]. Data from the National Health and Nutrition Examination Survey (NHANES) suggest that children and adolescents generally fail to meet the DGA recommendations for total fruit consumption [6,7]. Although one analysis suggests that whole fruit intake has improved over time [8], the declining intakes of fruit juice over the last few decades may be responsible for the failure of most children to meet the current recommendations for total fruit consumption [9]. It is possible that fruit juice consumption may encourage the later consumption of whole fruit, although data on its contribution to whole fruit intake are limited. Recent data from NHANES found that children who consumed both more milk and more 100% fruit juice had higher scores on the Healthy Eating Index (HEI) [10].

Fruit juice consumption among children is controversial primarily due to concerns about its energy content and the resulting potential for excess weight gain and metabolic

disturbances [11]. At least one recent study found fruit juice consumption to be associated with higher levels of abdominal adiposity [12]. However, a 2016 review of 22 studies found no independent association between 100% fruit juice and risk of childhood obesity [13], and another more recent review also concluded that 100% fruit juice was not generally associated with excess weight gain or other metabolic problems during childhood [14]. Recent data from the Growing Up Today Study (GUTS) found an inverse association between orange juice consumption and body mass index (BMI) in girls and a null association in boys [15]. Another analysis in that same study also found orange juice consumption to be positively associated with height gain but not with weight gain [16].

A 2019 study of 100% fruit juice intake and diet quality among adults in the NHANES cohort concluded that fruit juice consumption was positively associated with diet quality [17]. A 2017 review of this topic by an expert panel concluded that children consuming higher amounts of 100% fruit juice had better diet quality, with higher intakes of folate, vitamin C, and potassium [18]. In another such study, children who consumed more 100% fruit juice were more likely to have adequate intakes of dietary fiber, potassium, magnesium, and vitamin C [14].

In this study, data from the prospective National Heart, Lung, and Blood Institute's National Growth and Health Study (NGHS) were used to evaluate the association between 100% fruit juice consumption in preadolescence and subsequent intakes of whole and total fruit in white and black girls throughout adolescence. We hypothesized that girls who consumed more fruit juice at baseline would have higher scores on the Healthy Eating Index (HEI) [19] and a higher likelihood of meeting the DGA for fruit consumption. In addition, we theorized that girls consuming more fruit juice would have no greater gains in BMI during adolescence than those who consumed less.

2. Materials and Methods

2.1. Subjects

The NGHS is a prospective study that began in 1987 with the recruitment and enrollment of 2379 9–10 year old (preadolescent) girls. There were approximately equal numbers of black and white girls, and they were followed annually for 10 years. In an attempt to provide a representative sample of urban residential and suburban families, participants were recruited from three clinical centers: the University of California at Berkeley, Berkeley, CA, USA; the University of Cincinnati–Cincinnati Children's Hospital Medical Center, Cincinnati, OH, USA; and Westat, Inc., Rockville, MD, USA (which was associated with a Washington, DC metropolitan-area health maintenance organization). Girls who self-declared as black or white and whose parents were similarly self-identified were eligible to participate if they were 9–10 years of age at the time of the first clinic visit and their parents or guardians signed an informed consent. Details of the original study design and methods have been previously published [20]. Of the 2379 girls enrolled at baseline, 36 failed to provide dietary data at the first visit and an additional 422 girls were missing dietary data through the end of follow-up (at age 17 or older), leaving 1921 girls for the analysis of fruit juice consumption and diet quality. For the analyses of juice intake and BMI, we excluded 36 girls missing dietary data at baseline and 178 girls with missing BMI at age 17 or older. This left 2165 girls for the BMI analyses.

The original NGHS protocol was approved by the Institutional Review Board (IRB) of each participating clinical center. These secondary analyses were deemed exempt by the Boston University Medical Campus IRB. The original data used in this study are publicly available through the NHLBI's BioLINCC repository (Biologic Specimen and Data Repository Information Coordinating Center (BioLINCC, Bethesda, MD, USA), RRID:SCR_013142).

2.2. Dietary Intake

Each child's diet was evaluated using 3-day diet records during 8 of the 10 years of follow-up (years 1–5, 7, 8, and 10). Participants received instructions for completing the

diet records from a trained study nutritionist using age-appropriate language. Girls were taught to record all food and drink consumed on three consecutive days, including two weekdays and one weekend day. The girls used standard measuring cups, spoons, and geometric shapes to estimate portion sizes and, whenever necessary, received information from a parent on recipes, brands, and other details of the foods consumed. A standardized debriefing was carried out for each set of dietary records. Data were entered into the Nutrition Data System (NDS) of the University of Minnesota, Minneapolis, MN (Food Table Version 19 was used at baseline, with updated versions of the database being used as the study progressed) [21]. During the first two years, data were entered at the Nutrition Coordinating Center (NCC, Minneapolis, MN, USA) of the University of Minnesota while in subsequent years, data were entered onsite by a NCC-trained nutritionist. Data on food servings including cup-equivalents of whole (raw) fruit (e.g., apples, pears, citrus fruits, melons, and berries), 100% fruit juice (consumed as a beverage), and total fruit (from all sources) were derived by the authors (M.R.S. and L.L.M.) by linking NDS food codes with USDA food codes [22]. Sweetened juices, such as cranberry juice and part-juice drinks, were excluded from the category of 100% fruit juice in these analyses, but the fruit portion of a part-juice drink (e.g., the fruit in a fruit smoothie) was counted in the total fruit category. Intakes of total fruit, whole fruit, and 100% fruit juice were estimated as the mean intake across all available days of dietary data within each of the following age groups: 9–10, 11–12, 13–14, 15–16, and 17–20 years. There were 186 girls who provided the first set of dietary records after they had turned 11 years old because the dietary records were completed between the baseline visit (when the girls were 9–10 years of age) and the second visit (when they were 11–12 years of age). Data for these girls were included in the calculation of baseline fruit juice intake.

2.3. Diet Quality

The HEI is a measure of diet quality that was designed through the collaborative efforts of the USDA (Washington, DC, USA) and the National Cancer Institute (Bethesda, MD, USA) to evaluate the extent to which an individual's dietary intake met the recommendations of the DGA. The HEI is comprised of 13 component scores with a maximum total score of 100. Fruit is included in two components: total fruit and whole fruit, with total fruit including both whole fruit and 100% fruit juice. HEI scores were calculated using the HEI Scoring Algorithm available at https://epi.grants.cancer.gov/hei/sas-code.html. (accessed on 4 May 2023)

2.4. Body Mass Index (BMI)

Height was measured annually in duplicate using a portable stadiometer, and weight was measured on a digital scale. BMI was estimated as mean weight (in kilograms) at each exam divided by mean height (in squared meters).

2.5. Statistical Analysis

Each child's mean baseline intake of 100% fruit juice was calculated using all available days of diet records during the first examination visit year. Intake was classified into one of four categories of intake for most analyses: 0 cups, >0–<0.5 cup/day, 0.5–<1.0 cup/day, and ≥1.0 cup/day. Because the recommended juice intake for girls of this age is up to 0.75 cup/day, we first chose our categories to bracket this level of intake and to compare it with higher and lower intakes. The primary contrast to be examined was the highest (≥1.0 cup/day) vs. the lowest (0 cups/day) juice intake. Sensitivity analyses were used to explore the sensitivity of the results to changes in juice intake categories. A second set of cutoff values (0 cups, >0–<0.75 cup/day, 0.75–<1.25 cup/day, and ≥1.25 cups/day) was designed to determine whether even higher intakes of juice (≥1.25 cups/day) had any adverse effects, particularly on BMI.

To address the first analytic question of the impact of fruit juice intake in preadolescence on the consumption of total fruit and whole fruit throughout adolescence, we used

mixed models for repeated measures due to the unbalanced nature of the groups. Mixed models allow for inclusion of both fixed and random effects and incorporate an interaction term for age (group) by juice intake (group). In these analyses, data were missing at random over the course of follow-up. Further, we chose to use an unstructured covariance assumption. Similar models were used to evaluate the association between early juice consumption and total HEI scores as well as mean BMI throughout adolescence. Logistic regression models were used to estimate the likelihood of meeting the current DGA for whole and total fruit intakes in later adolescence in each of the fruit juice intake categories, with a primary focus on comparing the highest vs. the lowest intakes. Because several of these outcomes, including intakes of whole fruit and fruit juice as well as BMI, have been shown to differ by race, we also carried out these analyses separately for black and white girls [23].

We explored potential confounding by several factors including baseline age, race (for combined models), socioeconomic status (SES) based on parental education level, physical activity, baseline BMI, total energy intake, and percent of calories from carbohydrates, protein, and fats. We examined each factor alone as a potential confounder and then in combination with other factors. We were careful not to include factors that were likely to be collinear in the same model (e.g., including carbohydrates, protein, and dietary fats in the same model). We found no confounding by any of these factors, alone or in combination, as indicated by an observed change of generally less than approximately 1% in the effect estimates. Nonetheless, we included race in the combined models but focused the primary results on the race-specific models.

3. Results

In Table 1, participant characteristics are given in four categories of intake of 100% fruit juice at baseline. There was no statistically significant difference in percent body fat or BMI at baseline by category of 100% fruit juice intake. Girls consuming more fruit juice tended to have lower energy-adjusted intakes of protein and fat and higher intakes of carbohydrates. Those girls who drank more fruit juice in preadolescence also tended to consume more whole fruit at that age than those drinking less.

Table 1. Baseline descriptive characteristics of girls according to 100% fruit juice intake at baseline.

	Intake of 100% Fruit Juice at Baseline				
	0 Cups ***n* = 535**	**>0–<0.5 Cup** ***n* = 745**	**0.5–<1.0 Cup** ***n* = 431**	**≥1.0 Cup** ***n* = 210**	
	Mean ± s.d.				*p*-trend
Age (years)	10.5 ± 0.57	10.3 ± 0.47	10.3 ± 0.48	10.3 ± 0.50	<0.0001
Height (meters)	1.43 ± 0.07	1.42 ± 0.07	1.43 ± 0.07	1.44 ± 0.07	0.0275
BMI (kg/m^2)	19.0 ± 4.0	18.9 ± 3.7	18.4 ± 3.7	18.7 ± 3.7	0.1396
Body fat (%)	24.9 ± 7.2	24.6 ± 7.3	23.9 ± 6.7	23.9 ± 7.0	0.1163
Energy (kcals/day)	1791 ± 463	1809 ± 454	1903 ± 444	2033 ± 459	<0.0001
Protein (% of energy)	14.6 ± 2.8	14.3 ± 2.5	13.9 ± 2.5	13.8 ± 2.3	<0.0001
Total fat (% of energy)	36.5 ± 5.3	36.3 ± 4.8	35.0 ± 4.9	33.5 ± 4.5	<0.0001
Carbohydrates (% of energy)	50.0 ± 6.7	50.5 ± 5.9	52.2 ± 6.1	54.0 ± 5.4	<0.0001
Calcium (mg/day)	806 ± 297	798 ± 284	799 ± 281	844 ± 310	0.2547
Potassium (mg/day)	1942 ± 592	1964 ± 553	2146 ± 537	2513 ± 590	<0.0001
Whole fruit (cup-equivalents/day)	0.45 ± 0.60	0.49 ± 0.55	0.53 ± 0.56	0.65 ± 0.74	0.0009
100% fruit juice (cup-equivalents/day)	0.0 ± 0.0	0.26 ± 0.11	0.67 ± 0.14	1.37 ± 0.48	<0.0001
Race (*n*, % white)	263 (49%)	363 (49%)	215 (50%)	95 (45%)	0.9214
Socioeconomic status (*n*, % low)	116 (22%)	187 (25%)	93 (22%)	34 (16%)	0.2357

Figure 1 provides descriptive information on the median intakes of total fruit as well as whole fruit and 100% fruit juice for white and black girls throughout adolescence. The highest median intake of fruit, whether juice or whole fruit, was found at 9–10 years of age. Black girls consumed less total fruit than white girls at all ages, and this finding was attributable to lower intakes of whole fruit. Supplementary Table S1 also shows the median intake values and interquartile ranges for the intakes at each age in Figure 1.

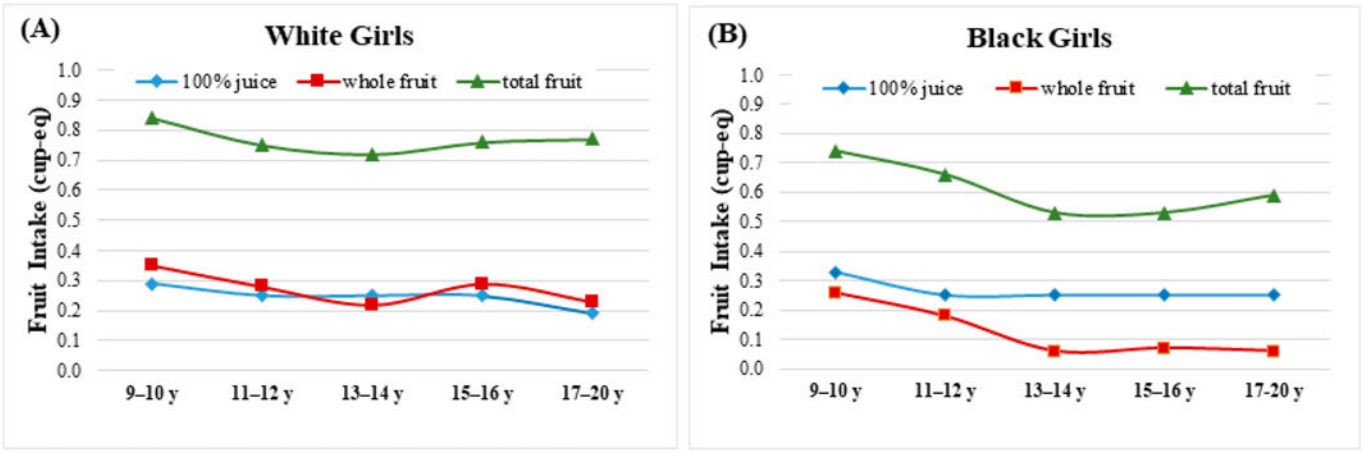


Figure 1. Median intakes of total fruit (green lines with triangles), whole fruit (red lines with squares), and 100% fruit juice (blue lines with diamonds) consumption throughout adolescence, in white (Panel (**A**)) and Black (Panel (**B**)) girls.

Figure 2 shows the association between the categories of 100% fruit juice consumption at baseline and intakes of total fruit (Panel A), whole fruit (Panel B), and 100% fruit juice (Panel C) from preadolescence to the end of adolescence. The mean intakes of total fruit throughout adolescence (Panel A) were highest among those girls with higher levels of juice consumption at baseline. Specifically, preadolescent girls who drank $\geq$ 1.0 cup/day of 100% fruit juice consumed 0.44 more cup/day of total fruit at 17–20 years of age than those who did not drink fruit juice at baseline (mean total fruit intakes at ages 17–20: 1.19 vs. 0.75 cup/day in the highest vs. lowest juice-drinking categories, respectively), as shown in Supplementary Table S2. In addition, girls who consumed the most fruit juice at baseline had the highest intakes of whole fruit at the end of adolescence (Panel B). Supplementary Table S2 also shows that overall, girls who drank more fruit juice at baseline had statistically significantly higher intakes of total fruit at every follow-up age period.

We also examined the association between 100% fruit juice consumption at baseline and subsequent overall diet quality scores as measured by the HEI in Figure 3. The sample sizes in each juice-drinking category at each age are shown below the x-axis labels. The figure shows that among white girls, the total HEI scores at each age were positively associated with fruit juice intake categories ($p < 0.0001$ at all ages). These associations among black girls were similar although somewhat less consistent during mid-adolescence. For white girls, the HEI scores at the end of follow-up (ages 17–20 years) increased as the amount of fruit juice consumed at baseline also increased. For black girls, the HEI scores at the end of follow-up were higher among girls who drank at least 0.5 cup/day at baseline, with those who drank >1.0 cup/day having the highest HEI scores ($p = 0.054$, comparing girls drinking >1.0 cup/day with those who did not drink juice at baseline).

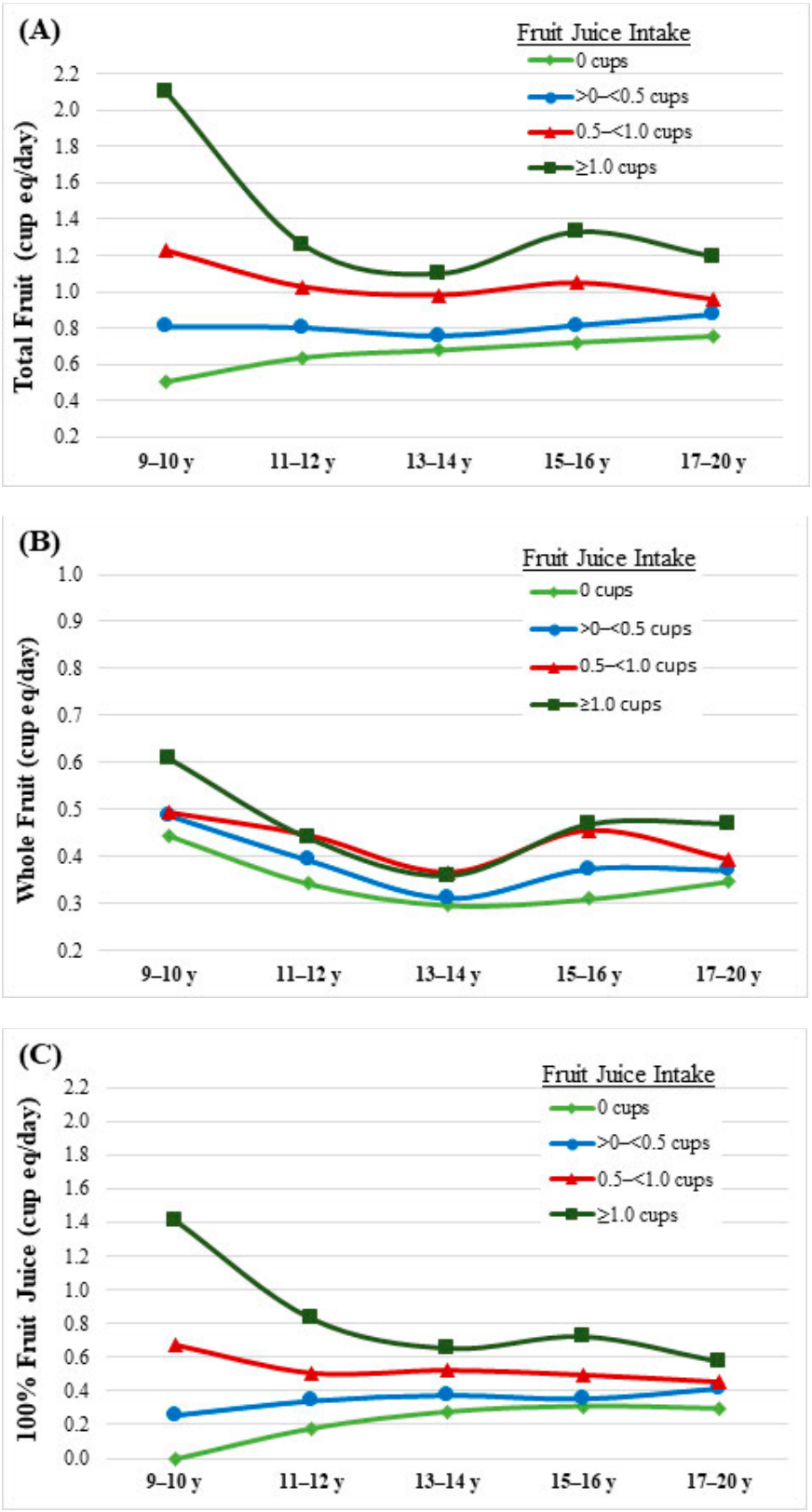
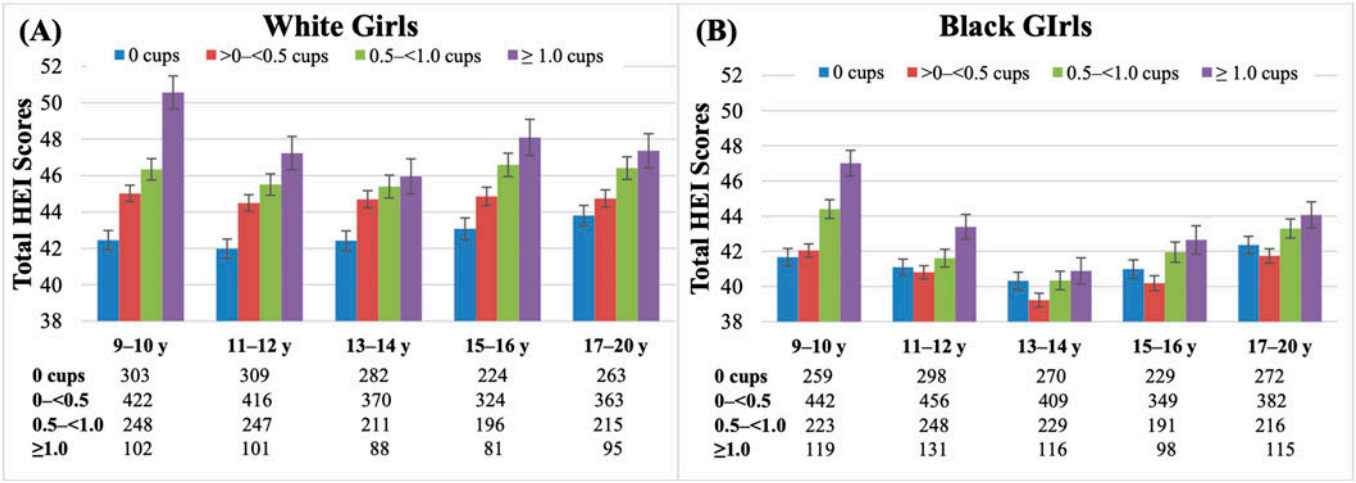


Figure 2. Mean intakes, adjusted for race, for total fruit (Panel (**A**)), whole fruit (Panel (**B**)), and 100% fruit juice (Panel (**C**)) at each age during adolescence in four categories of 100% fruit juice intake at preadolescence.



Fruit Juice Intake (Baseline)	White girls		Black girls	
	Overall Differences (p-values)	End of Follow-up (p-values)	Overall differences (p-values)	End of Follow-up (p-values)
0 versus <0.5 cups	<0.0001	0.202	0.179	0.322
0 versus 0.5–<1.0 cups	<0.0001	0.002	0.014	0.199
0 versus ≥1 cup	<0.0001	0.001	<0.0001	0.054

Figure 3. Healthy Eating Index scores throughout adolescence according to 100% fruit juice intake categories in preadolescence among white (Panel (**A**)) and black (Panel (**B**)) girls. Sample sizes for each age period are shown below the x-axis age groups and show the number of girls providing dietary data for the calculation of HEI scores in each age and juice-drinking category. Note that some girls completed their first food diaries at age 11, leading to slightly larger sample sizes in the 11–12-year-old age group.

Table 2 evaluates the likelihood of meeting the DGA [24] at the end of adolescence for total fruit (≥1.5 cups/day) and whole fruit (≥0.75 cup/day) intakes according to 100% fruit juice consumption at baseline. We show two different exposure categories for the highest juice intake in this table: ≥1.0 cup/day and ≥1.25 cups/day. Since only 10 white girls and 13 black girls drank more than 2.0 cups/day of 100% fruit juice, we were unable to evaluate intakes at that level as a separate category. We found that girls who drank ≥1.0 cup/day of fruit juice (vs. non-juice consumers) in preadolescence were 2.48 times as likely (95% CI: 1.70–3.61) to meet dietary recommendations for total fruit and 2.12 times as likely (95% CI: 1.44–3.12) to meet dietary recommendations for whole fruit at 17–20 years of age. Girls who drank ≥1.25 cups/day of juice were even more likely to meet the DGA for whole fruit at older ages. There were few race-specific differences in these results.

Figure 4 and Table 3 examine the relation between fruit juice consumption and adolescent BMI. Trends in BMI according to fruit juice intake in preadolescence are shown first in Figure 4. Here, we see that girls with the highest baseline juice intake had a lower BMI throughout adolescence than girls with the lowest baseline juice intake (p = 0.0063 and p = 0.0143 comparing highest vs. lowest for white and black girls, respectively). At the end of adolescence (Table 3), girls who consumed ≥1.25 cups/day of juice had lower BMI levels (2.2 kg/m^2 lower for white girls and 1.5 kg/m^2 lower in black girls) than non-juice drinkers. In fact, the highest BMIs at the end of adolescence in both white and black girls were found among nonfruit juice consumers, and the lowest BMIs were found in the highest juice consumers. In Supplementary Table S3, we further examined whole fruit intake as well as total fruit intake at baseline in association with BMI at the end of follow-up. In these analyses, we found that the association between whole fruit and BMI was slightly weaker than that observed in Table 3 for 100% fruit juice and subsequent BMI.

Table 2. Race-specific likelihood of meeting dietary guidelines for total fruit and whole fruit in late adolescence according to categories of fruit juice intake at baseline.

			All Subjects		White		Black	
Fruit Juice Intake	**N**	**Number (%) Meeting Guidelines**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Intake Categories					**Meeting the DGA for Total Fruit**			
0 cups	535	82 (15.3%)	1.00	(Ref)	1.00	(Ref)	1.00	(Ref)
<0.5 cup	745	137 (18.4%)	1.25	0.92–1.68	1.58	1.06–2.35	0.9	0.56–1.43
0.5–<1.0 cup	431	94 (21.8%)	1.54	1.11–2.14	1.91	1.24–2.95	1.14	0.68–1.91
≥1.0 cups	210	65 (31.0%)	2.48	1.70–3.61	2.88	1.71–4.85	2.21	1.28–3.82
Intake Categories								
0 cups	535	82 (15.3%)	1.00	(Ref)	1.00	(Ref)	1.00	(Ref)
>0–<0.75 cup	1048	199 (19.0%)	1.30	0.98–1.72	1.61	3.37–2.34	0.97	0.63–1.49
0.75–<1.25 cups	229	59 (25.8%)	1.92	1.31–2.80	2.45	1.49–4.05	1.38	0.76–2.51
≥1.25 cups	109	38 (34.9%)	2.96	1.87–4.68	3.37	1.75–6.49	2.74	1.43–5.27
Intake Categories					**Meeting the DGA for Whole Fruit**			
0 cups	535	80 (15.0%)	1.00	(Ref)	1.00	(Ref)	1.00	(Ref)
<0.5 cup	745	120 (16.1%)	1.09	0.80–1.49	1.27	0.86–1.89	0.86	0.52–1.42
0.5–<1.0 cup	431	82 (19.0%)	1.34	0.95–1.87	1.47	0.95–2.27	1.16	0.67–2.00
≥1.0 cup	210	57 (27.1%)	2.12	1.44–3.12	2.55	1.52–4.28	1.84	1.01–3.34
Intake Categories								
0 cups	535	80 (15.0%)	1.00	(Ref)	1.00	(Ref)	1.00	(Ref)
>0–<0.75 cup	1048	171 (16.3%)	1.11	0.83–1.48	1.23	0.84–1.78	0.96	0.61–1.52
0.75–<1.25 cups	229	55 (24.0%)	1.80	1.22–2.64	2.45	1.50–4.01	1.08	0.55–2.11
≥1.25 cups	109	33 (30.3%)	2.47	1.54–3.96	2.62	1.35–5.08	2.54	1.27–5.07

DGA: Dietary Guidelines for Americans; OR: Odds Ratio; CI: Confidence Interval; Ref: Reference group; DGA: Dietary Guidelines for Americans.

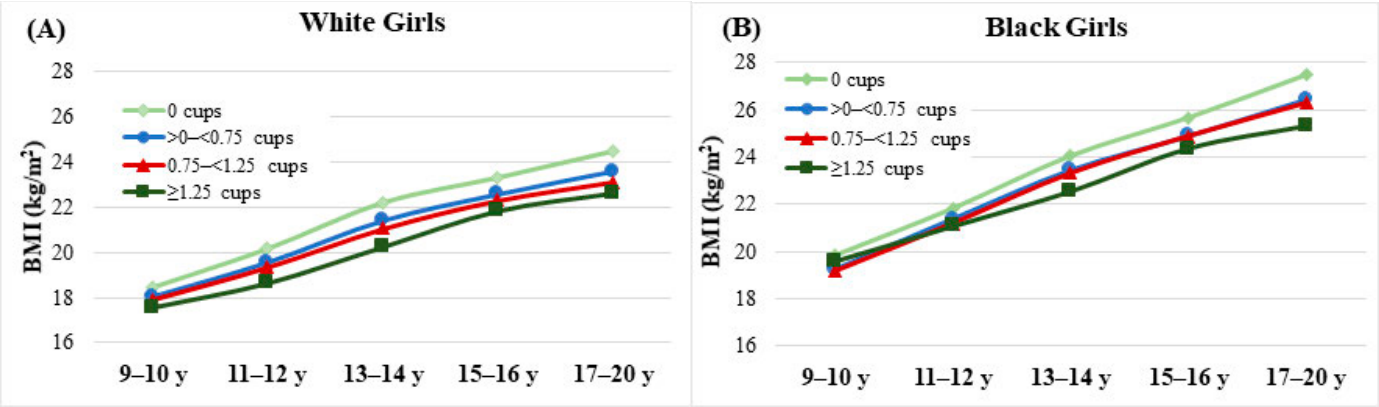


Figure 4. Trends in BMI throughout adolescence according to fruit juice intake at baseline for white (Panel (**A**)) and black (Panel (**B**)) girls. *p*-values comparing the change in BMI associated with the lowest vs. highest juice intakes were 0.0063 and 0.0143 for white and black girls, respectively.

Table 3. Mean BMI at 17–20 years of age according to intake of 100% fruit juice at baseline.

Baseline Juice Intake	*n*		All Girls * *n* = 2165	White Girls *n* = 1052	Black Girls *n* = 1113
		Median		Mean ± s.e.	
0 cups	601	0 cups	25.8 ± 0.26	24.4 ± 0.29	27.2 ± 0.42
>0–<.75 cup	1187	0.33 cup	25.1 ± 0.19	23.6 ± 0.21	26.4 ± 0.29
0.75–<1.25 cups	257	0.94 cup	24.7 ± 0.40	23.3 ± 0.45	26.0 ± 0.63
≥1.25 cups	120	1.5 cups	24.1 ± 0.58	22.2 ± 0.70	25.7 ± 0.87
p-trend			0.0022	0.001	0.058

* All girls model is adjusted for race. BMI: body mass index; s.e.: standard error.

4. Discussion

The results of these analyses suggest that higher intakes of 100% fruit juice during preadolescence were associated with higher intakes of both whole fruit and total fruit as well as better overall diet quality throughout adolescence as measured by total scores on the HEI. Black girls consumed less total fruit at all ages than white girls, and this difference was due to lower intakes of whole fruit. The positive association between fruit juice intake and later diet quality was evident in all girls, regardless of race. Both white and black girls who consumed more 100% fruit juice during preadolescence were also more likely to meet the DGA recommendations for whole fruit intake throughout adolescence. Finally, girls with higher intakes of preadolescent fruit juice had lower BMIs during adolescence and at the end of adolescence than girls who did not drink fruit juice in the preadolescent years. The beneficial effects of whole fruit consumption on BMI were similar.

The intake of total fruit, and particularly whole fruit, has increased in recent years among younger children [8]. However, this is not the case in older children. Previous studies have shown that 14–18-year-olds generally consume only half of the recommended amount of whole fruit per day [4,25]. According to the DGA, the proportion of total fruit consumed that is derived from fruit juice declines with age throughout the life span, with nearly half of total fruit coming from fruit juice among preschoolers, while only one third of total fruit is derived from fruit juice among adults. By late adolescence, total fruit intake is only about half of what is recommended [4], suggesting that the identification of strategies for promoting total fruit consumption is an important priority during the childhood years.

Whole fruit contains many essential vitamins and minerals and is an important source of dietary fiber. Thus, it is an important part of a healthy diet [26]. These analyses support those of other studies showing that fruit juice consumption is associated with a higher diet quality among children and adolescents [10]. While fruit juices provide limited amounts of dietary fiber, they do contain important quantities of magnesium and potassium [13]. Some juices, such as orange juice, have been shown to have much higher levels of bioavailability for both carotenoids and flavonoids than whole fruit [27]. Thus, the beneficial properties of whole fruit and fruit juice, including their antioxidant and anti-inflammatory properties, may differ [28,29]. Data from the DGA show that the most commonly consumed whole fruits are apples, bananas, watermelon, grapes, and strawberries, while the most commonly consumed fruit juice, by far, is orange juice [19]. Thus, whole fruit and fruit juice may have different roles in the prevention of cardiovascular disease, diabetes, and obesity, suggesting perhaps that a balanced intake of whole fruit and fruit juice may provide an optimal nutrient profile [30].

Fruit juice consumption has been at the center of controversy regarding the promotion of excess weight gain in children. In our own previous analyses using data from the Framingham Children's Study, we found no association between the consumption of 100% fruit juice starting in preschool and the change in BMI throughout childhood [31]. A 2017 meta-analysis found that one 6–8-ounce serving per day of 100% fruit juice in children ages 1–6 years led to a 0.087 unit increase in BMI z-scores [32]. However, this same amount of

fruit juice had no impact on BMI in children ages 7–18 years. The results of the current study support those of earlier studies among adolescents, including an analysis from the Growing Up Today Study II, which found that fruit juice consumption among 9–16-year-old girls was inversely associated with a change in BMI [15,16]. In the Women's Health Study, middle-aged and older women who had higher total fruit intakes had a lower risk of overweight and obesity [33]. In these analyses, we also found an inverse association between total fruit intake and BMI at the end of adolescence. This association was very similar to that for 100% fruit juice. Because fruit juice and total fruit intake are highly correlated (Pearson $r = 0.64$ at baseline and 0.72 in late adolescence), it is difficult to separate out the effect of fruit juice from total fruit. However, the weaker correlation between fruit juice and whole fruit intake at baseline ($r = 0.07$) and 0.12 in later adolescence) suggests that whole fruit itself may not be responsible for the observed beneficial association between fruit juice and BMI.

The current study has several important strengths in terms of its design. It is a relatively large prospective study with dietary data derived from multiple sets of three-day diet records, which should yield more precise estimates of dietary intake than most other methods used in large-scale epidemiologic studies. Additionally, the sample size allowed for a comparison of black and white adolescent girls. On the other hand, at the outset of the study, the girls were 9–10 years of age when accurate quantification of the amounts consumed is challenging. While the children were encouraged to obtain details of recipes and food preparation from a parent, there is no guarantee that this was consistently done. All self-reported dietary assessment methods are prone to error. However, given that these data were collected at a time when there was little concern about potential adverse effects of fruit juice consumption, the reported intakes of fruit and fruit juice are unlikely to be biased.

A 2017 commentary concluded that further evidence is needed to refine the recommendations for fruit juice consumption during childhood [34]. In the interim, they concluded that there is no justification for banning fruit juice other than during the first year of life. The current study adds evidence that may provide support for a role of fruit juice in the evolution of healthy eating behaviors without adversely impacting weight gain. These data suggest that fruit juice consumption could promote later intake of whole fruit through its impact on taste preferences because taste perception develops throughout childhood and seems to stabilize in midadolescence [35]. The taste of a variety of fruit juices tends to be acceptable to young children and may, through early exposure, facilitate the development of preferences for a variety of whole fruits. Since fruit juice is more available (regardless of climate and season), has a longer shelf life, and is often more affordable than many whole fruits, it may play a particularly important role in meeting DGA recommendations for families of a lower socioeconomic status who typically have lower intakes of total fruit and whole fruit [7].

The current data provide evidence supporting a beneficial association between early juice-drinking behaviors and the development of healthy dietary behaviors while having no apparent adverse impact on adolescent BMI.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/beverages9020042/s1, Table S1: Median intakes and interquartile ranges for white and black girls for fruit juice, whole fruit, and total fruit throughout adolescence; Table S2: Mean (±s.e.) intakes of total fruit, whole fruit, and 100% fruit juice at each age according to category of 100% fruit juice intake at 9–10 years of age; Table S3: Mean BMI at 17–20 years of age according to intake of whole fruit and total fruit at 9–10 years of age.

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Manuscript

Health effects of drinking 100% fruit and/or vegetable juice: An umbrella review of systematic reviews and meta-analyses

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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. FFM, TC, JW and CS conceived and designed the study; EB and MB executed the methods and analysed the data; EB, MB, PP, FFM, TC, JW and CS guided the methodological approach; EB and MB led the drafting of the manuscript. All authors have edited, read and agreed to the published version of the manuscript. All authors contributed to the revision of the manuscript and study concept.

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Abstract

Low fruit and vegetable intakes are major modifiable determinants of disease. 100% juice may facilitate intake, and deliver essential nutrients and bioactive compounds. However, the position of 100% juice in healthy eating guidelines remains controversial due to their lower dietary fibre and high free sugars content. We conducted an umbrella review of systematic literature reviews (SLRs) with meta-analyses (MAs) to summarise the health benefits of drinking 100% fruit and/or vegetable juice. Four databases were systematically searched for MAs of 100% juice and any health outcomes. Screening, quality, risk of bias and content overlap tools were applied, and extracted data narratively synthesized. Fifteen SLRs (51 primary MA, 6 dose-response and 87 sub-analyses; 50-1200mL/day; hours to years duration) were included, representing almost 2 million subjects. Ten MAs (19.6%) reported health benefits (blood pressure, vascular function, inflammation, stroke mortality), three MAs (5.9%) reported adverse risks (CVD mortality, prostate cancer, type 2 diabetes risk), while majority (74.5%) reported no effect (blood lipids, body composition, liver function, metabolic health, cancers, and inflammation). Findings confirm there are health benefits associated with 100% juice consumption, with limited harms. The balance of evidence continues to support the inclusion of 100% juice as a core food in dietary guidelines.

The impact of a label change on beverages: A survey of ABCL members

Introduction

The ABCL has considered the current and potential label changes impacting the non-alcoholic beverages industry, including mandatory and voluntary label changes related to nutrition, allergens, claims, recycling and sustainability guidance (Appendix). Most of these changes are at federal level, but there are competing requests also appearing at state level. For industry, a label change involves a complex, labour-intensive and lengthy process. A process that varies within individual companies, as do the resources (labour and non-labour costs) required, depending on the size of the business.

The ABCL represents approximately 95 per cent of the non-alcoholic beverages industry's production volume and our member companies include many micro, small, medium-sized and large drink manufacturers. To inform stakeholders of the impact of increasing labelling changes, the ABCL conducted a survey on the label change process across our membership. A summary of the findings is provided below.

Stages involved in applying a label change to beverage products

As the process varies in each company, we identified four principal stages attributed to the implementation of a label change (Figure 1). Each stage involves steps/gates that must be complete before moving to the next stage. Some stages require two cycles while others require multiple approval checks across company regional or global offices. Multiple teams are involved in the process, including but not limited to technical, regulatory, sustainability, marketing, design, operations, packaging, production, supply chain, finance and legal. Often, external consultants are hired where there is no in-house resource.

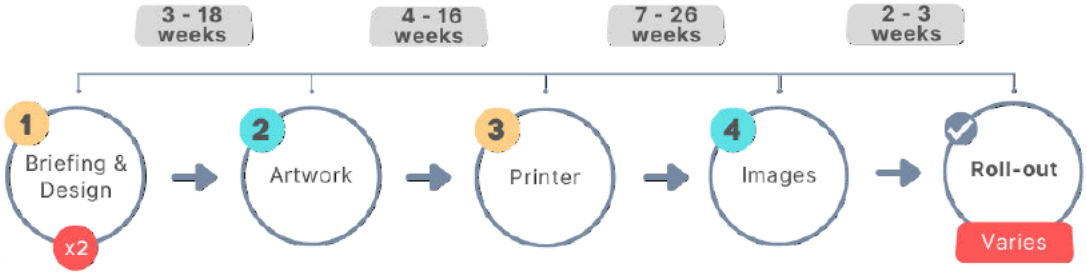

Figure 1.

The timeframes above vary and depend on: 1) the business' internal processes, 2) the degree of the label change, and 3) the number of SKUs impacted. Our SMEs indicated that a minor label change may take ~16 weeks to apply to one SKU. Larger companies advised that a major label change impacting 25 – 50 SKUs could take ~63 weeks to implement.

Cost to implement a label change

Our survey findings explained the variability of costs associated with a label change, exacerbated with the challenge of quantifying all labour costs of a typically multilateral process. Costs are provided below:

Minor label change	Change to text or 1 plate	**$2,000 - $4,000 per SKU**
Major label change	Change to >1 plate & design	**$6,000 - $7,000 per SKU**

To put the above into context, an SME with an average of 14 SKUs will incur a cost between **$28,000 to $98,000** for a single label change. For larger manufacturers with 100+ SKUs, a single label change would cost between **$300,000 - $1.5mn**. Other costs not captured and should be considered include waste of labels not used during phasing out period and costs to destroy this stock on hand.

Key takeaways

- There is a need for government to streamline the various label changes, to minimize the costs as much as possible and provide practical implementation schemes for industry.
- Cost-benefit analyses of proposed regulatory changes must include costs of destroying labels.

Appendix

Current and upcoming label changes for ABCL members

	Label Change	Implementation Date	Transition Period
Mandatory	Plain English Allergen Labelling	25 February 2021	3 years + 2 years stock-in-trade.
	Composition and Labelling of Electrolyte Drinks(Proposal P1030)	August 2022	2 years
	Nutrition labelling about added sugars	TBC	TBC
	Caffeine Review (Proposal P1056)	TBD	TBD
	Review of Formulated Supplementary Sports Foods (Proposal P1010)	TBD	TBD
	Review of Regulatory Nutrient Reference Values (Proposal P1047)	TBC	TBC
	Container Deposit Scheme (NSW, SA, QLD, WA)	Mandated already	
	Container Deposit Scheme (Tas, VIC)	Pending legislation	12 months
	Australasian Recycling Label	End of year 2023	End of Year 2023 for businesses >500M revenue
Voluntary	Health Star Rating – changes post Recommendationsfrom Five-Year Review	15 November 2020	2 years + 12 months stock-in-trade.
	Australasian Recycling Label		Expected after 2023 for businesses <500M revenue
	Recycled Content Logo	Currently being formulated	
Other changes impacted ABCL members	Pregnancy Warning Labels on Alcoholic Beverages	31 July 2020	3 years + 2 years stock-in-trade.