THE SCIENCE ON 100% FRUIT JUICES

AN EVIDENCE REVIEW OF HEALTH IMPACTS

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1: EXECUTIVE SUMMARY

100% FRUIT JUICE, IN MODERATE AMOUNTS, CAN BE COMPLEMENTARY WHEN IMPROVING FRUIT AND VEGETABLE CONSUMPTION IN EUROPEAN POPULATIONS.

However, assumptions are often made about the benefits and risks of consuming fruit juice, with concerns raised about the potential impact of naturally occurring fruit juice sugars on obesity, cardiovascular health and metabolic health, particularly risk of type 2 diabetes.

When examining the evidence from high quality sources – such as systematic reviews and meta-analyses or randomised controlled trials – it is clear that drinking a moderate amount of fruit juice regularly does not pose a risk to health. Studies are consistent in reporting no adverse effects of fruit juice consumption, at a broad range of intakes, in relation to body weight, body fatness, risk of type 2 diabetes, blood glucose and insulin levels, long-term blood glucose control, blood lipids or inflammation.

Turning to potential benefits, observational studies show that fruit juice consumers tend to have more nutrient-rich diets and are more likely to achieve specific recommendations for vitamins and minerals. There is no evidence that fruit juice is consumed instead of whole fruit. According to the growing number of studies on cardiovascular health, it is becoming clear that fruit juice consumption is associated with a significantly lower risk of stroke and, based on randomised controlled trials, can lower blood pressure and improve vascular function.

Researchers propose that the mechanisms for this relate to the vitamins, minerals (especially potassium) and bioactive polyphenol compounds provided by 100% fruit juice.

This evidence is compelling and should be examined further in order to benefit adult populations at risk of cardiovascular disease.

Emerging evidence on cognitive function and gut health suggests that polyphenols in fruit juices – in a similar way to the polyphenols in whole fruits – may have positive effects on markers of brain health and function, and on the composition of the gut microbiota. Further studies are needed to confirm these findings and assess the public health relevance.

In conclusion, the balance of evidence indicates a positive role for 100% fruit juice in human health which deserves to be recognised in order to provide effective, evidence-based dietary advice to consumers. A sugar-focussed approach to fruit juice is not justified by the clear, consistent findings of a lack of harm associated with regular, moderate fruit juice consumption.

2: INTRODUCTION

IN 2021 – THE FAO'S INTERNATIONAL YEAR OF FRUIT AND VEGETABLES – IT IS MORE IMPORTANT THAN EVER TO ENCOURAGE MORE PEOPLE TO EAT MORE PLANT-BASED FOODS.

Fruit and vegetables are rich in vitamins, minerals and bioactive compounds, such as polyphenols. Evidence from scientific studies and expert panels also confirms that eating fruit and vegetables is associated with better health. The prevalence of heart disease, stroke, cancer and type 2 diabetes is lower when populations eat more fruit and vegetables, while gut health and immune function benefit from the fibre, vitamin C and polyphenols found in these foods.

In the latest Global Burden of Disease report, dietary risks were the second largest contributor to preventable death in women, and the third in men. An earlier analysis from this study found that unhealthy diets were responsible for 11 million deaths worldwide during 2017, with 2 million of these directly blamed on low fruit consumption. Eating too little fruit was also linked to 65 million Disability-adjusted Life Years (DALYs), which is a marker of years lost to illness.

Despite the broad consensus that fruit and vegetables should be eaten more often – the WHO recommends at least 400g daily – surveys across Europe show that intakes are too low. Official EU figures reveal that just two thirds of Europeans report eating at least one serving of fruit per day while a similar proportion ate vegetables daily. This leaves a third of the population with wholly inadequate intakes while just 14% ate the recommended five daily servings of fruit and vegetables.

Drinking a daily glass of 100% fruit juice (FJ) complements fruit and vegetable consumption and, in some European countries such as the UK and Germany, one small glass counts as a serving of fruit. Despite the fact that FJ is classified as minimally processed, according to the FAO, and is strictly regulated for its composition in Europe, criticisms have arisen from some quarters in relation to the natural sugar content. These include assumptions that drinking FJ is linked to a greater risk of obesity and type 2 diabetes, and offers no nutritional or health value. In fact, according to the substantial evidence base that has been published over the years, these assumptions are incorrect.

The purpose of this report is to review several areas of health where high quality evidence exists for FJ in order to guide public health stakeholders, policy makers and the media on the role this category has in the European diet. Where available, systematic reviews/meta-analyses and randomised controlled trials will be selected over observational studies, such as cross-sectional, case control or prospective cohort studies. This is because the accepted hierarchy of evidence, used by bodies such as the European Food Safety Authority, gives a low-quality rating to observational evidence. In addition, observational studies are vulnerable to bias and confounding from other dietary and lifestyle factors, and cannot be used to determine cause and effect.

JUST 14% OF EUROPEANS ARE EATING THE RECOMMENDED FIVE DAILY SERVINGS OF FRUIT AND VEGETABLES

3: WHAT IS IN FRUIT JUICE?

AS PER THE 2001 EU FRUIT JUICE DIRECTIVE7, FJ IS DEFINED AS: "THE FERMENTABLE BUT UNFERMENTED PRODUCT OBTAINED FROM THE EDIBLE PART OF FRUIT WHICH IS SOUND AND RIPE, FRESH OR PRESERVED BY CHILLING OR FREEZING OF ONE OR MORE KINDS MIXED TOGETHER HAVING THE CHARACTERISTIC COLOUR, FLAVOUR AND TASTE TYPICAL OF THE JUICE OF THE FRUIT FROM WHICH IT COMES".

It is not permitted to add sugar to FJ and the Brix level (concentration): "shall be the one of the juice as extracted from the fruit and shall not be modified, except by blending with the juice of the same species of fruit". This means that the sugar content of fruit juice cannot be modified – either to make it higher or lower.

FJ has been dismissed as 'sugary water' by some commentators, but this couldn't be further from the truth. As per standard food tables and a recent analysis by SGF International, 100% orange juice and a standard sugar-containing beverage contain the following nutrients and plant bioactives:

BY LAW, 100% FRUIT JUICE CONTAINS NO ADDED SUGARS AND MUST REFLECT THE NATURAL COMPOSITION OF THE FRUIT WITH WHICH IT IS MADE.

Per 100 grams	Orange juice	Typical sugar-sweetened beverage
Energy kcal	41	40.6
Total sugars g	9.1	10.8
Calcium mg	11	5.9
Iron mg	0.2	0
Magnesium mg	9.5	1
Phosphorus mg	15.3	29.7
Potassium mg	152	1
Zinc mg	0.1	0
Vitamin C mg	45	0
Thiamin mg	0.1	0
Riboflavin mg	0	0
Niacin mg	0.3	0
Folate mcg	21.5	0
Vitamin B6 mg	0.1	0
Vitamin A mcg	4.1	0
Vitamin E mcg	0.2	0
Total carotenoids mg	0.7	0
Hesperidin & narirutin mg	63	0
Pectin (fibre) mg	33.4	0

In the EU, most FJ can make a 'rich in' claim for vitamin C and a 'source of' claim for folate and potassium, therefore enabling associated health claims, such as maintenance of normal blood pressure, or maintenance of normal immune function.

3.1 BIOACCESSIBILITY

Nutrients in a food mean little unless they can be absorbed and utilised by the body – called bioaccessibility. Consistent evidence from blood biomarker studies confirms that the vitamins, minerals and plant bioactives (e.g. polyphenols such as hesperidin) in fruit juices are taken up by the body.

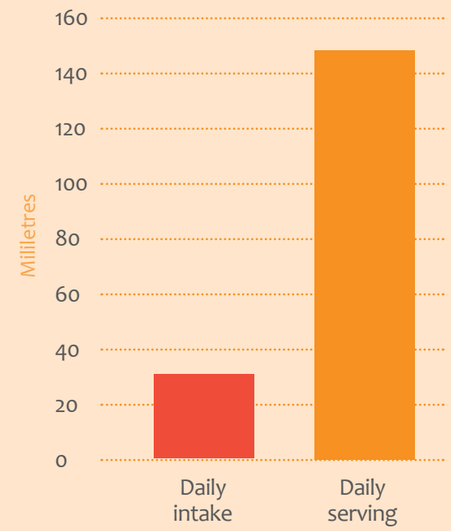
A long-term study examined the bioaccessibility of nutrients and plant bioactives in orange juice. For three weeks, 13 healthy, normal weight adults drank 236 ml juice three times daily. Compared with baseline levels, blood sampling revealed a significant increase in nutrient levels. Vitamin C and folate levels increased by around 50%, while polyphenol levels rose by eight times and carotenoids increased by 22%.

Although whole oranges contain double the hesperidin of orange juice, people absorb a similar amount from both foods9. This indicates their nutritional equivalence. The poorer uptake of hesperidin from whole fruit is most likely due to its greater pectin content which inhibits polyphenol absorption. When comparing packaged versus freshly squeezed orange juice, around three times more hesperetin (a marker of hesperidin) appears in blood after people drink packaged orange juice. This is because the more efficient commercial juicing process creates a richer hesperidin content.

3.2 INTAKES OF FRUIT JUICES

According to recent market data, the average EU citizen drank 11.5 litres of FJ during 2018, equating to 32 ml per day. This is a very modest intake compared with other beverages consumed and recommended serving sizes (100-200 ml in Germany, for example), and does not justify worries about 'overconsumption'.

There is considerable variation across European countries, for example, 37% of UK adults report some fruit juice consumption, compared with 84% of Dutch and 49% of French. Intakes in adult consumers also vary, with 40 ml consumed daily in Netherlands compared with 55 ml in France and 130 ml in the UK14,15,16. The figure below shows the average consumption of fruit juice in the EU region (2017-2018; per person per day) compared with a typical serving (150 ml).



4: ASSOCIATION WITH NUTRIENT ADEQUACY

AS FRUIT JUICES PROVIDE A SOURCE OF SPECIFIC NUTRIENTS, IT IS USEFUL TO ASK WHETHER CONSUMPTION IS A MARKER OF BETTER NUTRIENT ADEQUACY – DEFINED AS THE SUFFICIENT INTAKE OF ESSENTIAL NUTRIENTS NEEDED TO FULFIL NUTRITIONAL REQUIREMENTS FOR OPTIMAL HEALTH.

No systematic reviews/meta-analyses were located on PubMed so large observational studies were used. As summarised in the table below, these show that FJ consumption is typically associated with higher nutrient density, or better-quality diets, when compared with diets where FJ is not consumed, or is consumed at low levels. In the French studies, FJ consumers tended to eat more whole fruits and vegetables than non-consumers of FJ, suggesting that FJ is not being used to replace whole fruits in the diet.

Bearing in mind the limitations of observational studies, particularly that FJ consumption may simply be a marker of healthier habits, it cannot be assumed that drinking FJ improves nutrient adequacy, only that it is associated with higher quality diets. However, it is clear that FJ consumption is not associated with nutrient-poor or less adequate diets.

Additional evidence comes from two clinical trials where daily FJ formed part of the intervention. The first, in 45 healthy adults with a habitually low fruit/vegetable intake, examined the nutritional and metabolic impact of consuming 8 daily servings of fruit and vegetables, including 150-300 ml of FJ. After 12 weeks, significant rises were seen in blood levels of vitamin C (35%), folate (15%) and carotenoids (50-70%) compared with participants following their habitual diets. Average daily total sugars increased by 37g in the intervention group, 20g of which were non-milk extrinsic sugars and likely to have come from the FJ. Despite the sugar increase, overall energy (calories) remained constant across the intervention, as did body weight.

A second trial evaluated the impact of an energy-reduced diet in 78 obese women, with half consuming 500 ml of orange juice daily between meals while the remaining participants ate an energy-matched snack. Following the 12-week intervention, blood levels of vitamin C rose by 62% while blood folate rose by 39% (both statistically significant).

Reference	Population	Results and quotes
Murphy et al. (2020)	Individuals ≥1 year (n = 34,351) participating in the Canadian Community Health Survey 2004	"More frequent consumption of fruit juice was associated with higher intakes of fruits and vegetables, energy, total sugars, vitamin C and potassium. More frequent consumption of fruit juice was associated with improved intake adequacy of vitamin C for adults".
Mitchell et al. (2020)14	National dietary intake surveys of the U.S. (n = 8661), UK (n = 2546) and Brazil (n = 34,003)	"100% FJ contributed to more than 5% of the RDAs for vitamin C and folate. In the U.S. and Brazil, 100% FJ contributed to more than 5% of the RDA for magnesium and more than 5% of the AI for potassium".
Bellisle et al. (2018)	Representative survey of 1607 French adults	"In consumers, FJ brought 2% daily energy and contributed larger proportions of vitamins (B1 7%, B2 3%, B5 5%, B6 6%, B9 10%, C 32%, beta-carotene 5%), minerals (magnesium 4%, potassium 7%), and free sugars (19%).
Crowe-White et al. (2016)	Systematic review of studies relating to children aged 1 to 18 years	"Limited evidence from eight studies suggests that children consuming 100% fruit juice have higher intake and adequacy of dietary fiber, vitamin C, magnesium, and potassium".
Francou et al. (2015)16	Nationally representative CCAF survey of 1930 respondents	Fruit and vegetable juice (FVJ) "consumers had higher quality diets than did non-consumers, after adjusting for covariates."
O'Neil et al. (2012)	Adults 19+ years of age (n = 8,861) participating in the US NHANES 2003-2006	Consumers of 100% orange juice had: "a higher percentage of the population meeting the [recommendations] for vitamin A, vitamin C, folate, and magnesium. Consumers were also more likely to be above the [recommendation] for potassium".
O'Neil et al. (2012)	Children and adolescents 2-18 years (n 7250) participating in the US NHANES 2003-2006	"Compared with 100 % FJ consumers, a significantly higher percentage of non-consumers had intakes below the Estimated Average Requirement for vitamin A, vitamin C, folate... A greater percentage of 100 % FJ consumers exceeded the Adequate Intake for potassium compared with non-consumers".

5: CARDIOVASCULAR HEALTH

WHOLE FRUIT CONSUMPTION IS ASSOCIATED WITH BETTER CARDIOVASCULAR HEALTH, AND REDUCED RISK OF HEART DISEASE AND STROKE. CONSIDERING THAT FJ CONTAIN SIMILAR NUTRIENTS AND PLANT BIOACTIVES, WHAT DOES THE EVIDENCE SAY ABOUT THEIR POTENTIAL IMPACT ON CARDIOVASCULAR HEALTH?

5.1 OBSERVATIONAL EVIDENCE

In a prospective cohort study of more than 34,000 adults from the Netherlands, drinking up to one glass per day of FJ was significantly associated with a 12-17% reduced risk of cardiovascular disease and coronary heart disease, and a 20-24% reduced risk of stroke. This is supported by a major systematic review and meta-analysis of more than 80 cohort studies which, overall, followed up 4,031,896 individuals for an average of 11 years. During that time, more than 125,000 strokes and heart attacks were recorded. The study found that fruit, vegetables and fruit juices were similarly associated with a relative risk reduction of 13-14 per cent in heart disease mortality. Also, regular FJ consumption was statistically linked with a 33% reduced risk of stroke mortality; greater than the risk reduction seen for whole fruit (13%) and vegetables (6%). The study concluded that the most important individual fruits and vegetables for lowering the risk of cardiovascular disease were citrus fruits, FJ, apples, allium vegetables, carrots, cruciferous vegetables and green leafy vegetables.

5.2 SYSTEMATIC REVIEWS & META-ANALYSES

The association between FJ consumption and lower risk of stroke is plausible as several trials have found that FJ contributes to blood pressure reduction. A meta-analysis of 19 randomised controlled trials (RCT) comprising 618 participants reported that FJ consumption reduced diastolic blood pressure by 2.07 mmHg on average compared with a placebo. The authors estimated that such a reduction could lower the incidence of hypertension by 17% and coronary heart disease by 6%.

A second meta-analysis – published in 2020 – evaluated the evidence from 21 observational studies and 35 RCT. Regular consumption of FJ was associated with a statistically significant lower risk of stroke (up to 22% depending upon intake) and a significant reduction in cardiovascular events (e.g., heart attack). Beneficial associations were seen at daily intakes of 100-200 ml, which is consistent with health guidance in several European countries. Looking specifically at RCT, drinking FJ daily significantly lowered blood pressure, with average reductions of 3.14 mmHg for systolic blood pressure and 1.68 mmHg for diastolic blood pressure. In addition, FJ significantly improved vascular function, which would be expected to impact favourably on stroke risk. There was no impact of FJ consumption on blood lipids or inflammation.

A third meta-analysis of 22 RCT comprising 1248 participants reported that beetroot juice reduced systolic blood pressure on average by 3.55 mmHg and diastolic blood pressure by 1.32 mmHg compared with placebo. A fourth meta-analysis of 8 RCT reported that pomegranate juice reduced systolic blood pressure on average by 4.96 mmHg and diastolic blood pressure by 2.01 mmHg compared with placebo. A fifth meta-analysis of 10 RCTs evaluating orange juice consumption and cardiovascular and metabolic risk factors found a significantly beneficial effect of drinking orange juice (around 500ml daily) on glucose, insulin, total cholesterol, low-density lipoprotein cholesterol, and inflammation. A sixth meta-analysis of 16 RCT comprising 572 subjects reported that pomegranate juice significantly reduced markers of inflammation compared with placebo. Chronic inflammation is a marker of enhanced cardiovascular risk.

BOTH OBSERVATIONAL AND CLINICAL STUDIES SHOW A CONSISTENT BENEFICIAL EFFECT OF FRUIT JUICE ON VASCULAR FUNCTION, AND EVIDENCE FOR RISK REDUCTION FOR STROKE.

5.3 RANDOMISED CONTROLLED TRIALS

Turning to specific RCT on citrus, a 4-week crossover RCT found that daily 100% orange juice intake significantly lowered diastolic blood pressure and improved microvascular (small blood vessel) function. The authors demonstrated that the effects were related to hesperidin, a citrus polyphenol. A more recent 2-week crossover RCT reported improved blood vessel function in healthy adults following daily blood orange juice consumption with meals. Flow-mediated dilation improved by 2% which is clinically as well as statistically significant. Improvements in flow-mediated dilation of 2.9% on average were seen following daily red orange juice consumption in a 7-day crossover RCT in adults at enhanced cardiovascular risk. Importantly, there were no changes in body weight during these three interventions despite a daily orange juice intake of 400-500 ml. An acute crossover RCT found that mashed oranges, regular orange juice and flavonoid-rich orange juice similarly improved flow-mediated dilation when healthy, middle-aged men consumed two high fat test meals, designed to stress the cardiovascular system.

It has been proposed that the consistent positive vascular effects seen for FJ consumption could be due to potassium – which has a claim in the EU for supporting normal blood pressure – as well as vitamin C, nitrates, folate and polyphenols. Further work on vascular health is planned with the announcement in 2020 that the Fruit Juice Science Centre is funding a major RCT, called HESPER-HEALTH. During the 2.5-year crossover study, participants at risk of cardiovascular disease will consume daily orange juice and undergo a series of short- and long-term evaluations of vascular function, blood pressure, gene interactions, polyphenol absorption and gut microbiota. The work will take place at the University of Clermont-Ferrand and INRAE in France, and the University of Geisenheim in Germany.

6: TYPE 2 DIABETES AND GLYCAEMIC CONTROL

OBSERVATIONAL TRIALS REPORT THAT 'SUGARY DRINKS' OR SUGAR-SWEETENED BEVERAGES ARE ASSOCIATED WITH INCREASED RISK OF TYPE 2 DIABETES AND POOR GLYCAEMIC (BLOOD SUGAR) CONTROL.

This has led to speculation that FJ – which contain similar levels of naturally occurring sugars – represent a similar risk for type 2 diabetes. However, the evidence does not support this view.

6.1 TYPE 2 DIABETES RISK

In 2015, the UK's Scientific Advisory Committee on Nutrition examined the evidence for carbohydrates and health, which included commentary on FJ. In the report, while consumption of sugar-sweetened beverages was associated with increased body mass index and risk of type 2 diabetes, similar links were not seen for FJ. Supporting this view, a meta-analysis of four large prospective cohort studies concluded that FJ consumption was not statistically correlated with risk of developing type 2 diabetes. A recent meta-analysis from 2020, described previously27, concluded that FJ consumption had no significant impact on type 2 diabetes risk based on prospective observational studies.

6.2 DOES FRUIT JUICE ADVERSELY AFFECT GLYCAEMIC CONTROL?

A meta-analysis combining 18 RCT in 960 participants reported that FJ consumption had no significant impact on fasting blood glucose, insulin resistance, insulin or glycated haemoglobin (a long-term marker of glucose control). Many of the participants in this analysis were overweight or had existing metabolic risk factors, such as raised cholesterol or type 2 diabetes. A second meta-analysis combined 12 RCT in 412 participants, including those who were obese or had underlying risk factors for type 2 diabetes or cardiovascular disease. In half of the studies, daily FJ intakes were in excess of 400 ml but, despite this, FJ consumption overall was not found to significantly change fasting blood glucose or insulin levels.

A third meta-analysis of 155 study comparisons (totalling 5086 participants) concluded that certain food groups, including sugar-sweetened beverages and sweetened milks, had 'harmful effects' on glycaemic control, when tested in in substitution studies. In contrast, both fruits and FJ juices appeared to have 'beneficial effects'. A fourth meta-analysis, mentioned already (D'Elia), found no impact of regular FJ consumption on blood glucose or insulin levels, HOMA index (a marker of insulin resistance), or glycated haemoglobin based on data from RCT.

A crossover RCT in healthy adults directly compared the metabolic impact of identical amounts of 100% orange juice versus a sugar-sweetened beverage consumed daily for two weeks. For experimental purposes, a large beverage dose – representing 20% of daily energy requirements – was provided to participants. The results revealed statistically significant differences in glucose variability, 24-hour insulin secretion, serum potassium levels and serum uric acid between the two types of beverage, with a more favourable profile seen when orange juice was consumed. Thus, despite a similar total sugar content, the orange juice led to a healthier metabolic profile compared with the sugar-sweetened beverage. Metabolic benefits, such as reductions in fasting insulin, insulin resistance, cholesterol and inflammation, were seen in the intervention trial by Ribeiro et al. mentioned previously23, which included 500 ml of orange juice daily in an energy-reduced diet.

6.3 REASONS PROPOSED FOR NULL FINDINGS

Why have studies not found a negative impact on glycaemic control considering that fruit juices are a source of free sugars? Two explanations have been proposed. First, that FJ are classified as low glycaemic index (GI) meaning they have a smaller impact on blood glucose levels post-prandially than a reference food. For example, 100% apple juice has a GI of 41 (whole apples = 36) while 100% orange juice has a GI of 50 (whole orange = 43). This compares favourably with an average sugar-sweetened beverage which has a GI of 63-68. A second reason is linked to the rich polyphenol content of FJ. Studies have found that hesperidin in citrus juice, or punicalagin and punicalin in pomegranate juice, slow glucose absorption from the gut resulting in a flatter post-consumption blood glucose peak.

THERE IS CLEAR EVIDENCE FROM SEVERAL META-ANALYSES THAT DRINKING FRUIT JUICE DOES NOT CAUSE TYPE 2 DIABETES, AND IS CONSISTENT WITH NORMAL CONTROL OF BLOOD GLUCOSE (SUGARS).

7: OBESITY RISK AND WEIGHT MANAGEMENT

GIVEN THAT A 150 ML GLASS OF FJ CONTAINS AROUND 60 KCAL AND WOULD THUS CONTRIBUTE 3% TO A TYPICAL ADULT'S DAILY ENERGY RECOMMENDATION, THE IMPACT OF MODERATE FJ CONSUMPTION ON OBESITY RISK IS LIKELY TO BE NEGLIGIBLE.

This is best assessed using RCT since observational studies rely heavily on self-reports of beverage consumption – open to error and bias – and often combine analyses of FJ with sugar-sweetened fruit drinks. In addition, it is typically assumed that linear dose-response relationships exist between FJ consumption and specific health outcomes – when U-shaped curves are more plausible.

7.1 EVIDENCE IN ADULTS

Two meta-analyses published in 2020 – described previously – examined the impact of FJ on obesity risk and body composition in adults. The paper by D'Elia et al.27, found no statistical associations between regular FJ consumption and body mass index or weight gain using data from observational studies and RCT. The second meta-analysis by Alhabeeb et al. 30 concluded that consumption of FJ had no significant impact on body weight, body mass index, waist circumference, fat mass or lean body mass based on RCT data. It is noteworthy that, out of 17 human intervention trials where 100% orange juice was consumed at intakes of 250-750 ml daily for 4 to 12 weeks, none reported a statistically significant change to body weight.

The previously described RCT by Duthie et al. (2018)22, found that daily consumption of FJ (150-300 ml) as part of a 12-week intervention to boost fruit and vegetable consumption to 8 daily servings, had no statistically significant impact on body weight. However, two trials have highlighted cautions about excess consumption of FJ. The first, a secondary analysis of the trial by Büsing F et al. 42 described above, found that consuming 20% of daily energy requirements as FJ between meals resulted in a statistically significant 1 kg increase in fat mass over two weeks, while the same amount of FJ consumed with meals significantly reduced fat mass by 0.3 kg. A second trial required healthy lean and overweight adults to consume either whole fruit/vegetables or FJ, equating to 20% of daily energy requirements.

On average, participants gained weight and fat mass over the 8-week intervention, with no statistically significant difference between the fruit/vegetable and FJ groups but considerable individual variation in body fat change in overweight and obese participants. In assessing these two trials, it is evident that the 980-1300 ml daily consumption of FJ was not compensated with a reduction in other foods, resulting in an overall energy (calorie) gain which led to additional fat mass.

Therefore, it is clear that drinking moderate amounts of FJ on a regular basis, even daily, is not a cause of weight gain, nor is FJ consumption associated with increased risk of obesity in adult populations.

7.2 EVIDENCE IN CHILDREN

Only one relevant RCT in children was located on PubMed, which is an important evidence gap. This was designed to test the nutritional impact of three fortified orange juices in 180 children aged 8 years on average over a 12-week period. The authors noted that "body weight remained as expected for growth" during the study, indicating that the twice-daily glass of 240 ml did not have any adverse effects on body weight.

A meta-analysis of 8 prospective cohort studies involving more than 34,000 children found different associations between FJ consumption and body mass index z scores depending on age. The authors concluded: "Consumption of 100% fruit juice is associated with a small amount of weight gain in children ages 1 to 6 years that is not clinically significant, and is not associated with weight gain in children ages 7 to 18 years". A systematic review19 of 22 studies in children and adolescents found no significant association between consumption of FJ and weight or body fatness after controlling for energy intake.

IT IS CLEAR THAT DRINKING MODERATE AMOUNTS OF FJ ON A REGULAR BASIS, EVEN DAILY, IS NOT A CAUSE OF WEIGHT GAIN

In a prospective study of more than 500 UK children, no association was found between FJ consumption and body fatness at age 5 or 7 years. Another prospective study followed up 100 US children from the age of 3–6 years, finding that regular FJ consumption was not associated with changes in body mass index. An analysis of three cross-sectional datasets from nationally representative US surveys found no statistical association between FJ consumption and body mass index in 9,069 children aged 2-19 years. Therefore, apart from the non-clinically significant weight gain seen in 1- to 6-year-olds from the meta-analysis, drinking FJ does not appear to promote obesity in children. Additional RCT are warranted and would provide additional reassurance.

HIGH QUALITY STUDIES AND META-ANALYSES CONFIRM THAT FRUIT JUICE IS NOT A CAUSE OF EXCESS WEIGHT GAIN IN CHILDREN, AND DOES NOT INCREASE OBESITY RISK IN ADULTS

8: EMERGING EVIDENCE

SEVERAL TOPICS OF INTEREST ARE EMERGING IN RELATION TO FJ CONSUMPTION AND THESE ARE BRIEFLY SUMMARISED BELOW.

8.1 SUPPORT FOR NORMAL IMMUNITY

In the wake of the COVID pandemic, there has been an understandable focus on the role of nutrition is supporting optimal immunity. While there are no high-quality studies on FJ and immune markers, or on infectious disease risk, there is a wealth of evidence that vitamin C and folate – both found in FJ – have a role in immune defence. Vitamin C influences the function of immune cells such as neutrophils, and is essential for the production of interferon - an immune cell protein which inhibits virus replication and promotes maturation of T-lymphocyte immune cells. Vitamin C also possesses anti-inflammatory activity which can counteract cell damage. Folate is important for antibody production and T helper cell response. Health claims for folate and vitamin C in relation to maintenance of normal immunity have been authorised in Europe.

A prospective cohort study in more than 23,000 European adults from eight countries found that higher vitamin C status (blood levels) was seen in people who consumed particular fruits or vegetables, with the greatest impact seen for consumption of FJ and 100% vegetable juice. This emphasises the positive role of FJ in delivering an effective source of vitamin C in the diet.

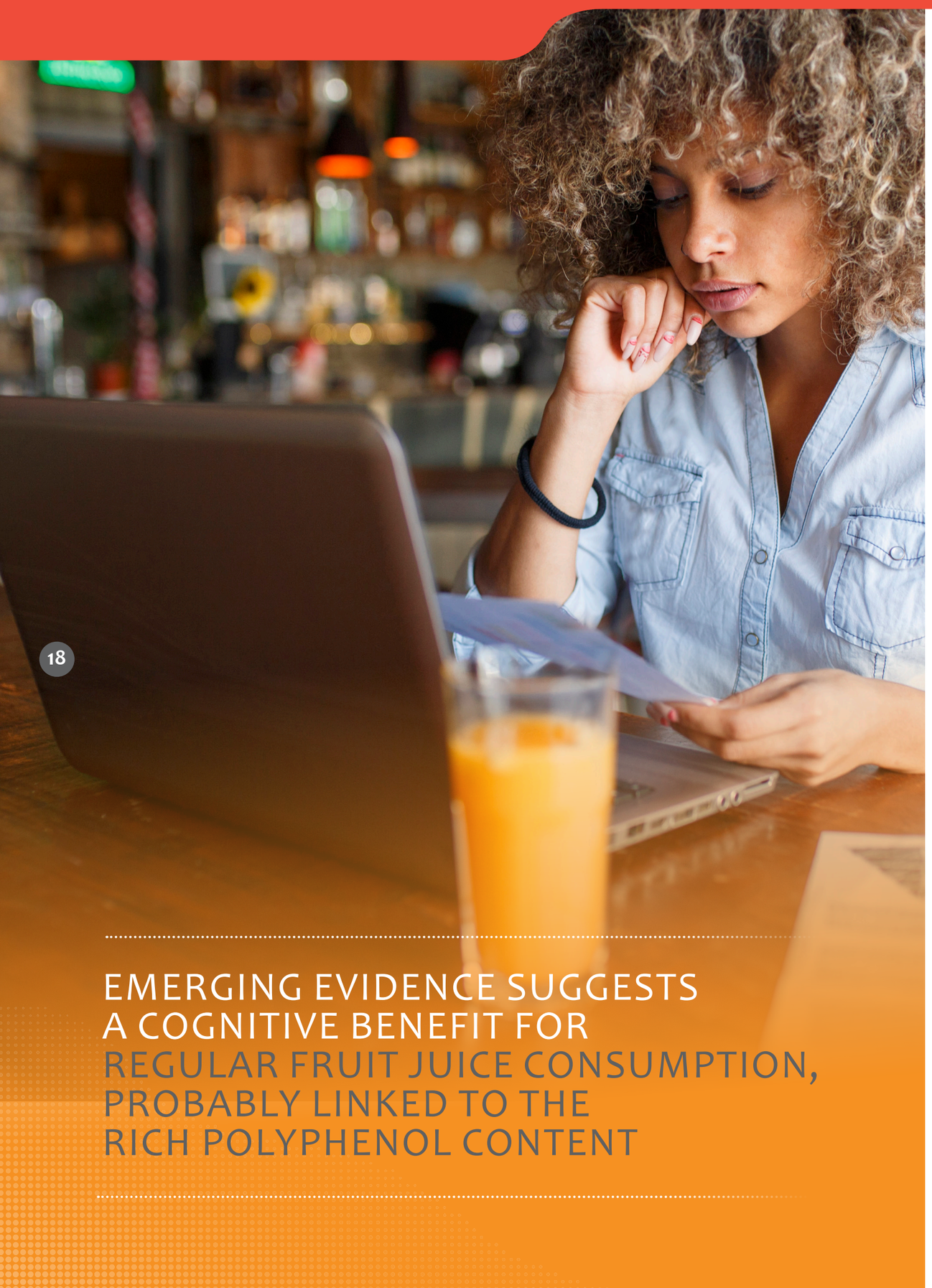
Recent in silica studies have modelled the potential role for hesperidin – a citrus polyphenol – in targeting coronavirus infection. As reviewed by Bellavite & Donzelli (2020), hesperidin has a high affinity for locking onto the SARS-CoV-2 spike and blocking viral enzymes that break down proteins in host cells. Hesperidin has anti-inflammatory effects which may be useful for targeting cytokine damage. At present, this evidence is more relevant for drug development and complementary treatments as the required dose of hesperidin to target SARS-CoV-2 is unclear and may be beyond the reach of a balanced diet. Further evidence is needed to better understand the anti-vital properties of hesperidin.

8.2 COGNITIVE FUNCTION

Vascular effects do not just relate to cardiovascular health but also impact on brain and cognitive health since the brain is sensitive to levels of oxygen and nutrients. Metabolites of certain dietary compounds, such as polyphenols, can cross the blood:brain barrier leading to speculation that fruits, vegetables and other polyphenol-rich foods could have a positive impact on brain health and cognitive function. Some mechanisms for polyphenols have been identified through laboratory trials, for example boosting cerebral blood flow and increasing blood nitric oxide levels and oxygenation.

A systematic literature review on fruits, vegetables and FJ reported that 17 out of 19 observational studies – as well as three out of six intervention studies – reported significant improvements in cognitive performance. Greater benefits were seen for chronic consumption of fruits, vegetables, and juices in healthy older adults.

Turning to specific RCT, an acute crossover trial found that a berry smoothie maintained cognitive function in young adults during 6 hours of fatiguing tests compared with an energy-matched control drink which resulted in cognitive decline. Another acute RCT in young adults reported increased cerebral blood flow and improved cognitive performance in a test for speed, sustained attention and visual spatial skills following a single serving of flavonoid-rich orange juice relative to placebo.



EMERGING EVIDENCE SUGGESTS A COGNITIVE BENEFIT FOR REGULAR FRUIT JUICE CONSUMPTION, PROBABLY LINKED TO THE RICH POLYPHENOL CONTENT

In healthy older adults, an 8-week crossover RCT found that daily flavanone-rich orange juice significantly increased global cognitive function tests, while an acute RCT in middle-aged men concluded that a single serving of flavonoid-rich orange juice significantly improved executive function, alertness and psychomotor speed compared with placebo. A 12-week crossover RCT in healthy, middle-aged women reported that a daily serving of purple grape juice significantly improved spatial memory and driving performance relative to placebo. Finally, a 12-week RCT in older adults revealed that cognitive performance in a battery of tests improved after daily consumption of tart cherry juice compared with placebo. Visual sustained attention and spatial working memory also significantly improved compared with baseline in the cherry juice group.

Further research is now required to test the cognitive impact of FJ polyphenols in longer-term human trials and determine specific mechanistic pathways to explain the effects.

8.3 GUT MICROBIOTA

Interest in the role of the gut microbiota is at a premium with more than 8000 studies being published annually since 2018. The balance of microbes in the gut is believed to impact on key aspects of health, for example bowel function, immunity, mineral absorption, metabolic health and risk of obesity. Several studies now propose that certain FJ act as a prebiotic on account of their rich polyphenol content. A prebiotic is defined as a "a selectively fermented ingredient that results in specific changes in the composition and/or activity of the gastrointestinal microbiota, thus conferring benefit(s) upon host health ".

In a 9-week RCT in 57 healthy men consumed 750 ml daily of a berry juice versus an energy-matched control drink. The composition of the gut microbiota was significantly impacted by the anthocyanin-rich juice intervention, relative to the placebo, while antioxidant capacity was increased focusing on Nrf2, the master regulator of oxidative stress. Moreover, the individual genetic variability of Nrf2 gene seemed to affect how people responded to FJ consumption.

An 8-week RCT was carried out in 40 young adults with depression to test the hypothesis that gut microbiota changes could mediate alterations in mood. Samples were taken after participants consumed either a flavonoid-rich orange juice or an energy-matched placebo drink (380 ml per day). Orange juice consumption increased the proportion of Lachnospiraceae, Bacteroides and Bifidobacterium species in faeces and Lachnospiraceae in particular was associated with blood levels of brain-derived neurotrophic factor which is believed to improve therapeutic outcomes in depression.

In a non-controlled RCT in 10 healthy women, gut microbiota was assessed before and after daily consumption of 300 ml pasteurised orange juice. After 60 days, there were significant differences in the composition and metabolic activity of the microbiota, increasing the population of faecal species of Bifidobacterium and Lactobacillus. Assessments of microbial metabolism showed a reduction in ammonia and an increase in short-chain fatty acids, substances linked to metabolic benefits, such as fat oxidation, insulin sensitivity and appetite hormone production.

This intervention was repeated by the same laboratory in a further 10 women who followed a diet free from orange juice for 30 days before consuming 300 ml orange juice daily for 60 days as part of a regular diet. The orange juice-free diet was then continued for a further 30 days. Faecal samples revealed significant increases in species of Lactobacillus, Akkermansia and Ruminococcus during the diet which contained orange juice.

Another small study in 20 healthy adults examined the effects of a FJ-only diet for three days using stool sampling. Significant reductions were seen in the proportion of less favourable firmicutes and proteobacteria species while Bacteroidetes (favourable) and cyanobacteria species increased. As there was a statistically significant weight loss during the study, the impact of this on gut microbiota composition cannot be discounted.

At present, while there seems to be a consistent favourable impact on gut microbiota following FJ consumption, the benefits to human health remain unclear and mechanisms are not fully understood. This will remain an area of research to watch over the coming years.

9: CONCLUSIONS

THE EVIDENCE FROM HIGH QUALITY STUDIES, PARTICULARLY SYSTEMATIC REVIEWS AND META-ANALYSES, REVEALS THAT REGULAR CONSUMPTION OF 100% FRUIT JUICE AT A RANGE OF MODERATE INTAKES REPRESENTS A NEGLIGIBLE RISK IN TERMS OF METABOLIC HEALTH, BODY WEIGHT CONTROL AND RISK OF TYPE 2 DIABETES.

In contrast, drinking fruit juice appears to deliver a benefit for cardiovascular health by favourably modulating blood pressure and vascular function, with the potential for long-term effects on stroke risk. Fruit juices are a source of vitamin C, folate and potassium which are the subject of several authorised health claims in the EU. In some European countries, a daily glass of fruit juice is viewed as complementary to fruit and vegetable consumption. Other areas of research, for example the role of fruit juice in cognitive function, immunity and the gut microbiota, have provided promising early results but are still evolving.

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