

Where are we with Smoothies? A Review of the Latest Guidelines, Nutritional Gaps and Evidence

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Abstract

The purpose of this paper is to acquaint the readers with the latest guidelines and research related to smoothies. This paper sets out to provide an update of evidence in the field and put findings into context. A secondary analysis of the UK National Diet and Nutrition Survey from Years 5 and 6 was undertaken to explore fruit and vegetable, fibre and micronutrient gaps amongst adults aged 20 to 59 years. Alongside this, a general review was conducted on smoothies and health published within the last 5 years. Secondary analysis showed that mean fruit and vegetable intakes were 275 g per day and an average of four portions eaten daily. Mean intakes of AOAC fibre were 18.5 g daily—considerably lower than guidelines of 30 g per day. Vitamin A, selenium, potassium, iron and magnesium were also under consumed. The review identified 9 studies evaluating inter-relationships between smoothies and health. Of these, two studies found that cell wall structures and fibre materials appear to be retained after smoothie processing. Other work suggests that smoothies could help to improve the nutrient density of the diet, have satiety effects and possible benefits on endothelial function. On-going research is needed along with continued innovation by smoothie producers with health outcomes in mind.

Keywords: Smoothies; Fruit and vegetables; Fibre; Micronutrients; Health

Introduction

Smoothies have been around since the 1990s and are one of the fastest-growing segments in the beverages industry [1]. The term ‘smoothie’ refers to the blending of constituents and whilst these have been predominantly fruit-based now take an array of different forms—with plant-based milks, vegetables, seeds and dairy bases all taking form [1]. Smoothies are typically made by blending whole fruits and vegetables which preserves fibre whilst juicing tends to leave behind a pulp containing fibre but otherwise retains its nutritional value [2]. Changing lifestyles, meal skipping, and their portability and being seen as a healthier snacking option all appear to be major drivers behind market growth [1].

With regard to smoothie intakes during the early years amongst those up to the age of 4 years, intakes of smoothies, fruit juices and purees daily are less than 96 ml [3]. As shown in Table 1, once smoothie data is extracted and analysed separately intakes become lower—37 ml daily amongst 3½ to 5½ years olds [4]. Unfortunately, smoothie intake data amongst UK adults is not reported in Years 5 and 6 of the UK National Diet and Nutrition Survey (NDNS). Fruit juice intake data, however, is included for which intakes are 46 ml per day amongst UK adults aged 19 to 64 years, declining to an average of 34 ml per day amongst those aged 65 years and over [5].

Recently, there has been much dispute and confusion about smoothies in the public press. This has largely been brought about by Public Health England’s updated Eatwell Guide. This specifies that “fruit juice and smoothies count towards fluid consumption but are a source of free sugars so consumption should be limited to no more than a combined total of 150 ml per day” [6]. These guidelines appear to have stemmed from Scientific Advisory Committee on Nutrition (SACN) Carbohydrate and Health report [7]. This advised that when referring to sugars we should now use the term ‘free sugars’—those added to foods e.g. sucrose (table sugar) or naturally present in honey, syrups and unsweetened fruit juices, but excluding lactose in milk and milk products. The SACN report also advised that the population average intake of free sugars should not exceed 5% of total dietary energy. This

cut-off was compiled with a view to reducing dental caries risk and lowering energy intakes from free sugars to address the problem of obesity [7].

Soon after the release of this report the updated Eatwell Guide was compiled which includes the 150 ml daily limit on smoothies and fruit juices, mainly due to these being a source of free sugars. However, as demonstrated in Table 1 amongst UK adults, fruit juice intakes are less than one-third of the 150 ml guidance [5]. There is also emerging literature indicating that polyphenols in some 100% fruit juices may inhibit the absorption of naturally occurring sugars [8]. Bearing this in mind this article sets out to acquaint readers with the latest guidelines and research related to smoothies, putting this into context for adults aged 20 to 59 years.

Guidelines

A summary of beverage guidelines from across the globe is included in Table 2. As can be seen, the UK is the only country to have quantitative guidelines specific to smoothies and fruit juices. Many of these guidelines mention soft drinks and have a general theme of reducing sugar intakes. Whilst we know that ‘free sugars’ are a cause for concern the substantiation behind the specific 150 ml per day benchmark for smoothies and fruit juices is less clear.

In America the Dietary Guidelines for Americans (DGAs) are age-specific and it has been reported that children are consuming 100% fruit juice within recommendations (that is, 120 to 180 ml per day for children aged 1 to 6 years and 236 to 355 ml per day for children

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Age	Region/Study	Category	Amount	Source
1 year	Ireland	Fruit juice, smoothies and purees.	48 ml /day	O'Connor et al. [3]
2 years	Ireland	Fruit juice, smoothies and purees.	61 ml/ day	O'Connor et al. [3]
3 years	Ireland	Fruit juice, smoothies and purees.	86 ml/day	O'Connor et al. [3]
4 years	Ireland	Fruit juice, smoothies and purees.	96 ml/day	O'Connor et al. [3]
3 ½ to 5 ½ years	Europe	Smoothies	37 ml/day	Pinket et al. [4]
19-64 years Men	UK NDNS	Fruit juice	46 ml/day	FSA/PHE [5]
19-64 years Women	UK NDNS	Fruit juice	47 ml/day	FSA/PHE [5]
65 years+Men	UK NDNS	Fruit juice	39 ml/day	FSA/PHE [5]
65 years+Women	UK/NDNS	Fruit juice	30 ml/day	FSA/PHE [5]

Table 1: Smoothie, Fruit Juice and Pureé Intakes (ml/day).

Country	Guideline	Organisation
America	Choose nutrient-dense foods and beverages across and within all food groups in place of less healthy choices.	USDA [9,24]
Australia	Limit intake of foods and drinks containing added sugars such as confectionary, sugar-sweetened soft drinks and cordials, fruit drinks, vitamin waters, energy and sports drinks.	National Health and Medical Research Council [26]
Germany	Drink plenty of fluids, at least 1.5 L every day.	German Society for Nutrition [25]
Norway	Limit your consumption of food and drink with a high sugar content.	Norwegian Directorate of Health [27]
Sweden	Less sugar-Hold back on the sweets, pastries, ice creams and other products containing lots of sugar. Cut back on sweet drinks in particular.	Swedish National Food Agency [28]
UK	Smoothies and fruit juices should be consumed in no more than a combined total of 150 ml per day (a small glass).	Public Health England [6]

Table 2: Beverage Guidelines from across the Globe [24].

aged 7 to 18 years) [8]. Amongst adults in the U.S. generic advice that nutrient-dense foods and beverages across and within all food groups should be consumed in place of less healthy choices is provided [9].

Nutritional Gaps

The current UK NDNS pools data for adults aged 19 to 64 years as one category spanning across four decades of life. Unfortunately, this means that dietary intake data for age groups within this i.e. those in their 20s, 30s, 40s and 50s is overlooked. Subsequently, given that market data shows that adults aged 20 to 50 years are the main smoothie consumers a secondary analysis of the UK NDNS was undertaken to further study this demographic. Data from n=816 adults was analysed to study these age groups. In particular, the aim was to explore patterns of fruit and vegetable, fibre and micronutrient intakes within these specific age categories (Table 3).

Firstly, secondary analysis of the UK NDNS showed that intakes of fruits and vegetables were below World Health Organisation (WHO) advice of 400 g per day across the board [10]. This guidance forms the basis of the 5-A-DAY campaign in order to lower disease risk and help ensure an adequate intake of daily fibre [11]. FV intakes were highest at 310.7 g per day amongst those in their 50s and lowest at 230.4 g per day amongst those in their 20s. Overall fruit and vegetable intakes were 275.3 g per day–125 g below World Health Organisation advice to eat 400 g daily. The mean number of fruit and vegetable portions eaten daily was 4.0 amongst those aged 20 to 59 years with just over a quarter (26.4%) achieving 5-A-DAY. Amongst those in their 20s only 1 in 5 (19.2%) achieved the 5-A-DAY guidelines. Those in their 50s did better with around one third (32.3%) of this population group reaching 5-A-DAY, although under consumption is still evident.

Secondly, Englyst fibre intakes were 13.9 g daily. This is 4.1 g below the previous Englyst fibre Dietary Reference Value (DRV) of 18 g of Non-Starch Polysaccharide (NSP) per day. Figures for Englyst fibre were also converted to AOAC fibre which now forms the basis of updated guidance using a conversion factor (Englyst NSP value multiplied by 1.33). Estimated intakes of AOAC were 18.5 g daily–12.5

g lower than latest SACN guidance set at 30 g of dietary fibre per day analysed using AOAC methods [7]. Those in their 20s had the lowest AOAC fibre intakes at 17 g per day and those in their 50s the highest with mean intakes of 18.3 g daily. These findings indicate that there are substantial fibre gaps that exist in the UK population—even more so now those fibre guidelines have been increased.

Thirdly, with regard to micronutrients, mean intakes can hide large sub-groups with very low intakes so it is important to look at the proportion of adults with intakes below the Lower Reference Nutrient Intake (LRNI; the level below which deficiencies are likely to occur). For vitamin A around 1 in ten (9.6%) of UK adults aged 20 to 50 years had vitamin A intakes below the LRNI. Amongst those in their 30s folic acid also fell below the LRNI in 5.9% of adults. Shortfalls were also apparent for riboflavin (vitamin B1) and vitamin B12.

For minerals, selenium intakes fell below the LRNI in around one-third (35%) of adults. Selenium shortfalls were highest amongst those in their 20s with 41.3% having intakes below the LRNI. Potassium deficits were also apparent, particularly amongst those in their 20s—with 22.6% having intakes below the LRNI. Just over 1 in 10 UK adults (13.2 and 11%) had iron and magnesium intakes below the LRNI during the working years. Iodine, calcium and zinc shortfalls were also evident.

Research

A PubMed search was undertaken to identify studies investigating inter-relationships between smoothies and health, which formed the basis of the search terms. Human studies published within the last 5 years were included within the analysis. Case studies or opinion papers were excluded. Data from UK Universities undertaking research related to smoothies and health has also been included.

A total of nine human studies were identified (Table 4). The outcomes studied were varied ranging from fruit/vegetable and nutrient contribution, fibre retention, satiety effects, glycaemic control, anthocyanin bioavailability, endothelial function, sugar content and erosive potential. With regard to FV contribution a study carried out

	20s	30s	40s	50s	Overall
Fruit and Vegetables					
FV Intake (g/day)	230.4	270.8	289.1	310.7	275.3
Mean No. FV portions eaten daily	3.4	3.9	4.1	4.4	4.0
% achieving 5-A-DAY	19.2	26.3	27.9	32.3	26.4
Englyst fibre (g/d)	12.8	14.0	14.4	14.5	13.9
AOAC fibre (g/d)	17.0	18.6	19.2	19.3	18.5
Vitamins % below the LRNI					
Folic acid	3.0	5.9	1.3	3.0	1.1
Riboflavin	6.7	9.0	3.3	9.1	7.0
Vitamin A	13.3	10.2	6.9	8.0	9.6
Vitamin B12	2.8	0.6	0.7	1.7	4.2
Vitamin B6	0.0	0.0	0.2	0.0	0.05
Vitamin C	0.3	2.2	1.9	0.5	1.2
Minerals % below the LRNI					
Calcium	7.0	6.0	6.4	5.5	6.2
Iodine	9.3	8.6	4.3	8.8	7.8
Iron	18.7	16.9	11.0	6.0	13.2
Magnesium	13.5	8.9	10.2	11.2	11.0
Potassium	22.6	15.8	18.8	13.7	17.7
Selenium	41.3	35.9	32.4	30.5	35
Zinc	5.7	6.3	5.0	4.6	5.4

Conversions based on 23-24 g AOAC dietary fibre being equivalent to the previous DRV of 18 g NSP per day (SACN, 2015 Section S.22, pp5). Until AOAC data is available AOAC content can be estimated by multiplying NSP values by 1.33

Table 3: Fruit and vegetable, fibre and micronutrient intakes during the working years.

Reference	Study design	Main Findings
Chu et al. [14]	Simulated gastro-intestinal digestion and homogenisation.	Cell wall structures are preserved during smoothie manufacture & retained during digestion. This may have implications for fibre quantification and fibre functionality in the gut.
Boulton et al. [18]	Evaluation of 203 soft FJJDS from seven supermarkets	Only five produced products were 150 ml in size. Concerns about the sugar content of FJJDS were reported.
Rogers and Shahrokni [16]	Pre-load test meals. 47 healthy men and women aged 18-37 years.	2 hours after milk or smoothie consumption feelings of increased fullness were greater compared with both the water and blackcurrant squash preloads.
Saltaouras et al. [15]	<i>In vitro</i> analysis	Fibre material was still present in the smoothies after processing. The GI was low for smoothies tested. The GL was medium and borderline-low.
Castillejo et al. [13]	Shelf-life and nutritional profile determined	A 250-g portion of smoothies played a key contribution to recommended daily nutrient intakes for dietary fibre, minerals and vitamin C of different population groups.
Bates and Price [12]	Observational study. Smoothies were introduced for breakfast at two Utah schools.	The fraction of students eating a full serving of whole fruit increased from 4.3% to 45.1%. Concluded that school districts should consider offering fruit smoothies to increase fruit consumption at school.
Kuntz et al. [17]	Randomised cross-over bioavailability study.	Plasma pharmacokinetics and recoveries of urinary metabolites of anthocyanins were no different for juice or smoothie; however, the phenolic acid 3,4-DHB was significantly more bioavailable from juice than the smoothie.
Stull et al. [23]	DB RCT. Allocated to receive a blueberry or placebo smoothie twice daily for six weeks.	The blueberry smoothie group had a greater improvement in endothelial function when compared to their counterpart ($p = 0.0023$).
Blacker and Chadwick [19]	Laboratory study. Erosive potential of 5 smoothies determined.	Some fruit smoothies have the potential to bring about dental erosion if consumed irresponsibly. This can be influenced by ingredient variations

DB: Double-blind; FJJDS: Fruit Juices, Juice Drinks and Smoothies; GI: Glycaemic Index; GL: Glycaemic Load; RCT: Randomised Controlled Trial

Table 4: Research related to smoothies and health (last 5 years).

in Utah providing fruit smoothies during school breakfast amongst middle school and high school children found that the proportion of students eating a full serving of whole fruit increased from 4.3% to 45.1% over a 10-week period [12]. Other work found that consuming a 250 ml portion of a red smoothie containing tomato, carrots, pepper and broccoli played a key role in contributing to recommended daily nutrient intakes for dietary fibre, minerals and vitamin C of different population groups [13].

Two studies have shown that fibre material is retained in smoothies. Scientists from the University of Leeds found that that cell wall structure of smoothies remained intact after they had been manufactured and exposed to simulated digestion for up to 16 h [14]. It was also

observed that smoothie mixing led to a 68% reduction in viscosity, 30% reduction in total dietary fibre and 10% increase in soluble dietary fibre [14]. Equally, another trial found that fibre material is still present in the smoothies after processing-16.9% and 17.5% fruit cellular material by weight in the two smoothies tested [15]. These findings revealed that the fibre content retained in the smoothies resembled that similar to the process of chewing fruit, with this potentially having its own health effects.

Other work has focused on glycaemic control and satiety. With regard to glycaemic control, the Glycaemic Index (GI) is a rating system for foods and drinks showing how quickly the carbohydrate from these affects blood sugar (glucose) levels when eaten on its own. In terms of

glycaemic control a human crossover study on 12 participants (mean age 26.6 years) showed that Mango & Passion fruit and Strawberry and Banana type smoothies had a low GI of less than 55 whilst the glycaemic load was medium and borderline-low, respectively [15]. Focusing of satiety, one study found that after 2 h following smoothie and milk ingestion feelings of fullness were greater compared with both the water and blackcurrant squash preloads [16]. Smoothies were rated high on liking, desire to consume, enjoyment and satisfaction, and it was valued (amount-willing-to-pay measure) substantially higher than the other 'drinks' and similarly to the fruit salad [16].

Other research has determined anthocyanin bioavailability from a grape/blueberry juice and smoothie finding that these were similar except that the phenolic acid 3,4-DHB was significantly more bioavailable from juice. Authors concluded that smoothies as well as juices could be recommended to increase the intake of potentially health-promoting anthocyanins and other polyphenols although this requires consideration in relation to other ingredients such as sugar content [17]. A randomised controlled trial also allocated 44 adults with metabolic syndrome to receive a blueberry or placebo smoothie twice daily for six weeks finding that the blueberry group had a greater improvement in endothelial function when compared to their counterpart ($p=0.0023$).

With regard to sugar content a UK study analysing 203 Fruit Juices, Juice Drinks and Smoothies (FJJDS) marketed to children using their labels found that smoothies provided around 13 g of sugar per 100 ml. It was, however, also noted that there was large variation between brands and that future studies should focus on determining 'free sugars' using laboratory methods [18]. An *in vitro* laboratory study has measured the erosive potential of five shop bought fruit smoothies, comparing these to water and orange juice. It was found that whilst some had a pH below the critical pH of enamel (5.5) yoghurt based smoothies, or "thickies" had a higher pH and were less likely to reduce the surface hardness of tooth samples. These findings demonstrate that ingredient variations used in smoothies can alter the erosive potential of smoothies [19].

Discussion

Smoothies and juices are different products, with different benefits and so should be analysed and treated separately. This includes the potential to have different serving sizes and intake recommendations in the future. As seen from the guidelines evaluated the UK is the only country to have a daily limit on fruit juice and smoothie intakes (Table 2) which relate to 'fruit-based' smoothies. More studies are needed to quantify smoothie intakes in the UK as a separate category and not to combine these with juices or other types of beverage. However, it should be considered that the smoothie market is evolving and is much broader than this with an array of dairy and vegetable-based smoothie drinks (amongst many others) now available, all of which will have varying nutritional and pH profiles. Subsequently, these may not all necessarily fall under the same bracket.

The secondary analysis of UK NDNS data showed that fruit and vegetable intakes are under consumed (less than 400 g per day) by UK adults aged 20 to 59 years, especially amongst those in their 20s who had a mean daily intake of 230 g. Interestingly, the mean number of fruit and vegetable portions eaten daily was 4.0. Subsequently, consuming 1-A-DAY which would provide one daily portion of FV could help with the achievement of 5-A-DAY guidelines for those in this age category. Equally, it should also be considered in future guidelines that smoothies unlike juice are often made from more than 1 portion (80 g) fruit as they are the juice plus whole fruits and vegetables [20].

With regard to habitual micronutrient intakes certain shortfalls are apparent. For example, around 1 in 10 UK adults (9.6%) have vitamin A intakes below the LRNI. Folic acid also fell below the LRNI in 5.9% of adults which is concerning given the role of this nutrient in neural tube defect prevention in the periconceptional period [21]. For the minerals, selenium was under consumed by one-third (35%) of working adults. Selenium has antioxidant and anti-inflammatory roles and is also involved in thyroid hormone production [22]. Potassium shortfalls were also evident with 17.7% of 20 to 59 year olds having intakes below the LRNI. Similarly, iron and magnesium intakes were also inadequate with 13.2% and 11.0% of adults having intakes below the LRNI, respectively. Iodine, calcium and zinc shortfalls were also evident. These findings indicate that smoothies have a potential role to play in narrowing gaps where dietary fibre and micronutrient shortfalls exist. For example, in one study red vegetable smoothie consumption provided a substantial proportion of the recommended daily nutrient intake for dietary fibre, minerals and vitamin C across different population groups [13].

The review of evidence showed that cell wall structures and fibre materials appear to be preserved during smoothie manufacture and retained during digestion [14,15]. This, in turn, appears to contribute to a lower glycaemic index [15]. Equally, UK NDNS analysis shows that fibre intakes are consistently lower than guidelines across adults aged 20 to 59 years (an average of 18.5 g/day), with the updated AOAC fibre guidance of 30 g of fibre daily widening this gap even further [7]. Other work suggests that smoothies could have satiety effects [16] and possible benefits on endothelial function [23].

In terms of next stages better data collection methods are needed which determine intakes of smoothies per se rather than bundling these together with fruit juices and purees in the case of young children. Equally, it should be recognised that there are an array of different smoothies now available. For example, one paper evaluating the sugar content of smoothies recognised that new varieties of fruit juices, juice drinks and smoothies are appearing in the market steadily and may be different [18]. The varying compositions of smoothies are likely to have divergent health effects and should be considered when developing health-related guidelines. For example, we have seen that yoghurt-based "thickie" smoothies have a lower pH and are less likely to reduce the surface hardness of tooth samples [19]. Innovations in ingredient variations and pH testing to bring these to pH 5.5 or higher (the critical pH of enamel) could further help to minimise risks of dental erosion without omitting the nutritional benefits of smoothie consumption [19].

In summary, smoothies have received unfair commentary recently. Before clear judgments can be made the following is recommended: 1) Accurate data relating to smoothie intakes per se are needed, 2) Intakes of 'free sugars' needs to be measured using analytical methods rather than speculative judgements based on food labels, 3) Different smoothies have different pH and nutritional profiles so should not be categorised under one umbrella, 4) Population-specific guidelines should be compiled rather than one size fits all benchmarks. Finally, recent work focusing on 100% fruit juices has found that these individuals are closer to meeting daily fruit needs and have a better overall diet quality [8]. On this basis it has been predicted that the reduction or elimination of fruit juices (and therefore smoothies) could have possible unintended consequences [8]. As we have seen in the present paper, that micronutrient and fibre shortfalls are apparent across those aged 20 to 50 years and minimising smoothie intakes may impact on these further.

Conclusion

It has recently been advised that fruit juice and smoothie consumption should be no more than 150 ml per day. This advice is largely based on 'free sugar' guidance and energy intake concerns. Nevertheless, this paper highlights that consuming smoothies within guidelines as '1-A-DAY' could be another essential way of topping up fruit and vegetable, fibre and micronutrient intakes, especially vitamin A, selenium, potassium, iron and magnesium. Finally, smoothie producers should look to formulating products that have pH and free sugar levels tested whilst delivering specific nutritional components.

Acknowledgment

Innocent stuck to what they do best, making juice and smoothies and left Dr Emma Derbyshire writing this paper.

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