Dried fruit and public health – what does the evidence tell us?

Taylor & Francis
Taylor & Francis Group

International Journal of Food Sciences and Nutrition

ISSN: 0963-7486 (Print) 1465-3478 (Online) Journal homepage: https://www.tandfonline.com/loi/iijf20

Dried fruit and public health – what does the evidence tell us?

Michele Jeanne Sadler, Sigrid Gibson, Kevin Whelan, Marie-Ann Ha, Julie Lovegrove & Jennette Higgs

INTERNATIONAL JOURNAL OF FOOD SCIENCES AND NUTRITION
2019, VOL. 70, NO. 6, 675–687
https://doi.org/10.1080/09637486.2019.1568398

CONFERENCE PAPER

OPEN ACCESS Check for updates

Dried fruit and public health – what does the evidence tell us?

Michele Jeanne Sadler[a], Sigrid Gibson[b], Kevin Whelan[c], Marie-Ann Ha[d], Julie Lovegrove[e] and Jennette Higgs[f]

[a]Rank Nutrition Ltd, Ashford, UK; [b]Sig-Nurture Ltd, Guildford, UK; [c]Department of Nutritional Sciences, King's College London, London, UK; [d]Spinney Nutrition, Devon, UK; [e]Hugh Sinclair Unit of Human Nutrition, University of Reading, Reading, UK; [f]Food To Fit Ltd, Greens Norton, UK

ABSTRACT

A scientific workshop held in the UK explored the potential contribution of traditional dried fruits to public health, identified gaps in the evidence and addressed priorities for research. Presentations considered the categorisation and composition of dried fruits; dried fruit and gastrointestinal health; the polyphenol content of dried fruits and their potential contribution to health; dried fruit and appetite in relation to the psychology of snacking and obesity; dried fruit and dental health including its role as a snack; and conflicts in public health advice for dried fruits. A round table discussion explored the contribution of dried fruit to "five a day" fruit and vegetable intake and fibre intake, whether dried fruits have equivalence with fresh in terms of dietary advice, advice on snacking in relation to dental health and appetite control, informing the public about different types of dried fruits and avoiding consumer confusion, and future research requirements.

ARTICLE HISTORY
Received 4 October 2018
Revised 8 January 2019
Accepted 8 January 2019

KEYWORDS
Dried fruit; composition; dental health; gastrointestinal health; satiety; polyphenols

Introduction

This paper is based on a scientific workshop, convened on 7 June 2018 at the Kings Fund, London, UK to explore key scientific issues relating to dried fruits. Dried fruits have been part of the diet for thousands of years as a means of preserving seasonal fruits and as a tradeable commodity. Key issues identified at the outset were the lack of consensus and general confusion over the definition of dried fruit, equivalence of the portion size to fresh fruit, and on account of dental health, whether dried fruit is suitable as a snack or should be restricted to meals. The key scientific aims were to explore the evidence base for the potential contribution of traditional dried fruits to public health, identify gaps in the evidence, and establish priorities for further research. The following is a summary of the main topics covered in the workshop, followed by a report of the round table discussion (titles of the presentations and related speakers are listed in "Acknowledgments" section).

Definition, categorisation and composition

The term "dried fruit" encompasses a range of different processing methods. Traditional, conventional dried fruits such as dates, figs, prunes, raisins, apricots, apples and pears have no added sugar or juice and are formed by the removal of water (Table 1). WHO classifies traditional dried fruits as "fruit", and like fresh fruit the sugars content is not defined as "free sugars" (WHO 2015; Swan et al. 2018). In contrast, some dried fruits such as blueberries, cranberries, cherries, strawberries and mangoes are usually infused with sugar syrup or fruit juices prior to drying – although these fruits can also be dried without any infusion, which adds to consumer confusion. Some types of dried fruits are brighter in colour compared with natural sun-dried fruits, as sulphur dioxide may be added. Other types of dried fruit include "candy" fruits such as pineapples and papaya, which have a high content of added sugar but are not necessarily labelled as such. Processed, dried-fruit snacks may contain added sugars, or may be made from macerated or pureed fruit that is then dried. There are a number of reasons for adding sugar and or/sugar syrups to dried fruit. In some cases, it increases palatability by adding sweetness (e.g. cranberries), whereas addition to dried fruit that is already sweetened helps the fruit to remain soft throughout its shelf life since

CONTACT Michele Jeanne Sadler msadler@btconnect.com Rank Nutrition Ltd, Long Barn, Etchden Court, Bethersden, Ashford TN26 3DP, UK.

Table 1. Categorisation of dried fruit.

Category of dried fruit	Characteristics	Examples
Traditional dried fruit	No added sugar; removal of some water content; moisture content range ∼14% (sultanas) to 24% (dried apricots)[a]	Apples, apricots, dates, figs, prunes, pears, raisins
Sugar-infused dried fruit	Sweetened with fruit sugar solution by osmotic pressure before drying; moisture content 18–20%[a], dry matter ∼80%	Blueberries, cherries, cranberries, mangoes, strawberries
Candied dried fruit	Includes candied (preserved in sugar syrup, dry), crystallized (frosted with caster sugar) and glazed or glacé (coated in sugar syrup) fruits	Melon, papaya, pineapple, kiwi, glacé cherries, candied peel – e.g. mandarin oranges
Processed fruit snacks	Processed from fruit purée and fruit juice concentrates, may have added sugars and other ingredients	Fruit leathers, fruit pieces, packaged fruit snacks

Depending on production method some fruits may be classified in more than one category – e.g. cranberries and blueberries without added sugar.
From: Dried fruits. Phytochemicals and health effects. Ed Alasalvar and Shahidi (2013).
[a]USDA (2018).

sugar and sugar syrups act as natural humectants. Sugar and or/sugar syrups also have a preservative function, by helping to reduce the water activity within the fruit (Goldfein and Slavin 2015).

The content of nutrients in traditional dried fruits remains similar to the equivalent fresh fruit, though more concentrated. Traditional dried fruits are therefore good sources of a number of micronutrients with the exception of vitamin C (Table 2). Some qualify for EU nutrition claims (EU 2006) (Table 3) and prunes have an authorised EU health claim in relation to normal bowel function (EU 2013).

Current nutritional challenges include how to increase consumption of fruit, vegetables and fibre, and reduce free sugars intake (though not sugars within plant cells, or milk sugars), within the context of a palatable and varied diet. Modelling has shown that these recommendations are not easy to achieve. The resulting diet, though wholesome, is quite austere and requires cooking skills. Reaching 30 g fibre a day requires consumption of about 8 portions of fruit and vegetables a day plus more fibre-rich snacks such as seeds, nuts and dried fruit (Hooper et al. 2015). Current EU Regulations require total sugars to be declared on labels and the reference intake (90 g a day) is also for total sugars, with no EU value for free or added sugars (EU 2011). This makes it difficult for consumers to distinguish between the free sugars they should be reducing, and sugars not targeted for reduction.

Of total traditional dried fruit imports to the EU, 50% (180,000 metric tons) is exported to the UK. Traditional dried fruits account for the highest volume, with less than 10% of imports containing added sugar. Consumption of dried fruit is difficult to estimate because of multiple uses, for example, in baked goods, breakfast cereals and cereal bars, as well as a food in its own right. Retail sales data suggest that consumption of dried fruit as a snack has increased and use in baking has decreased, but this does not reflect use in manufactured products. Trends include an increase in sales of unsweetened naturally dried and freeze-dried fruit.

Food-based dietary guidelines globally encourage increased consumption of fruit and vegetables, and many countries recommend eating at least five portions of fruit and vegetables a day. In the UK, for example, dried fruit counts towards this target based on a portion size of approximately 30 g, compared with a portion size of approximately 80 g for fresh fruit or vegetables. However, the contribution of traditional dried fruits to overall fruit and vegetable intake is very low compared with fresh fruit. Data from the 2016 Health Survey for England (HSE 2017) show that reported consumption of dried fruit is lowest among 11- to 24-year-olds and highest among over 65-year-olds with dried fruit contributing around 0.1 portions/day compared with around two portions of fresh fruit (including juice)/day. Individual consumption of dried fruit alone as a snack is also on average very low, with only about 11% of the UK population consuming dried fruit in any one day. On average over the whole population, this equates to about a teaspoon (3–6 g)/day. These data are backed up by 4-day intake records from the most recent UK National Diet and Nutrition Survey (years 7/8) (PHE 2018) which show that mean dried fruit consumption among 4- to 18-year-olds is 2 g/day and in 65+ year-olds is 6 g/day. The general trend in dried fruit consumption, including from homemade composite dishes, shows a stable intake at around 3 g/person/day, averaged over all age groups (Gibson, personal communication). People over the age of 65 years consume approximately twice the average amount and children half the average amount. As these intakes do not include fruit

Table 2. Nutrient and polyphenol content and historical ORAC data for traditional dried fruits.

Nutrient composition	Raisins, seedless[a]	Dates, medjool[a]	Dates, deglet noor[a]	Prunes[a,b]	Apricots, dried, sulphured, uncooked[a,c]	Figs, dried, uncooked[a]
Water (g)	15.46	21.32	20.53	30.92	30.89	30.05
Energy (kJ)	1373	1251	1260	967	1033	1088
Energy (kcal)	324	295	297	229	244	257
Protein (g)	3.3	1.8	2.5	2.2	3.4	3.3
Carbohydrate (g)	74.8	68.3	67.0	56.8	55.6	54.1
Sugar (g)	65.2	66.5	63.4	38.1	53.4	47.9
Sorbitol (g)	n/a	n/a	n/a	15.1	6	n/a
Fat (g)	0.25	0.15	0.39	0.38	0.51	0.93
Saturated fat (g)	0.094	n/a	0.032	0.088	0.017	0.144
Fibre (g)	4.5	6.7	8.0	7.1	7.3	9.8
Salt (g)	0.065	0.003	0.005	0.005	0.025	0.025
Vitamin A (µg)	0	7	0	39	180	0
Vitamin D (µg)	0	0	0	0	0	0
Vitamin E (mg)	0.12	n/a	0.05	0.43	4.33	0.35
Vitamin K (µg)	0.5	2.7	2.7	59.5	3.1	15.6
Vitamin C (mg)	2.0	0.0	0.4	0.6	1.0	1.2
Thiamin (mg)	0.11	0.05	0.05	0.05	0.02	0.09
Riboflavin (mg)	0.13	0.06	0.07	0.19	0.07	0.08
Niacin (mg)	0.766	1.610	1.274	1.882	2.589	0.619
Vitamin B6 (mg)	0.174	0.249	0.165	0.205	0.143	0.106
Folic acid (µg)	5	15	19	4	10	9
Vitamin B12 (µg)	0	n/a	0	0	0	0
Biotin (µg)	n/a	n/a	n/a	n/a	n/a	n/a
Pantothenic acid (mg)	n/a	0.805	0.589	n/a	0.516	0.434
Potassium (mg)	744	696	656	732	1162	680
Chloride (mg)	n/a	n/a	n/a	n/a	n/a	n/a
Calcium (mg)	62	64	39	43	55	162
Phosphorus (mg)	98	62	62	69	71	67
Magnesium (mg)	36	54	43	41	32	68
Iron (mg)	1.79	0.90	1.02	0.93	2.66	2.03
Zinc (mg)	0.22	0.44	0.29	0.44	0.39	0.55
Copper (mg)	0.318	0.362	0.206	0.281	0.343	0.287
Manganese (mg)	0.281	0.296	0.262	0.299	0.235	0.510
Fluoride (mg)	0.2339	n/a	n/a	0.004	n/a	n/a
Selenium (µg)	0.6	n/a	3	0.3	2.2	0.6
Chromium (µg)	n/a	n/a	n/a	n/a	n/a	n/a
Molybdenum (µg)	n/a	n/a	n/a	n/a	n/a	n/a
Iodine (µg)	n/a	n/a	n/a	n/a	n/a	n/a
Total phenolics (mg of GAE)[d,e]	1065	572	661	745	248[f]	960
H-ORAC (µmol TE)[d,e,g]	3002	2360	3863	6463	3234[f]	3200
L-ORAC (µmol TE)[d,e,g]	35	27	32	179	n/a	183
Total-ORAC (µmol TE)[d,e,g]	3037	2387	3895	6552	3234[f]	3383

(dark grey)	In the EU "High in (fibre, vitamins and minerals)"; or "(fat, saturated fat and salt) free" claims are possible.
(light grey)	In the EU "Source of (fibre, vitamins and minerals)"; "contains carbohydrate"; or "(fat, saturated fat and salt) free" claims are possible.

ORAC: Oxygen radical absorbance capacity; GAE: Gallic acid equivalents.
[a]USDA (2018).
[b]Manufacturer's sorbitol data.
[c]Yao et al. (2014).
[d]Williamson and Carughi (2010).
[e]USDA (2007).
[f]Based on 40% moisture content.
[g]In 2012 USDA's Nutrient Data Laboratory (NDL) removed the USDA ORAC Database for Selected Foods from the NDL website due to mounting evidence that the values indicating antioxidant capacity have no relevance to the effects of specific bioactive compounds, including polyphenols on human health.

in manufactured foods, total consumption is more likely to be 5–6 g/day which is still much less than 1 portion/day.

Dried fruit and gastrointestinal health

Gut health is of major public importance and low stool weight, delayed gut transit time and alterations in the gut microbiome along with their associated metabolites, for example, short-chain fatty acids (SCFAs), are key risk factors for gastrointestinal disorders, all of which can be manipulated via the diet. Increased stool weight is one of the major mechanisms underlying the causal relationship between high intakes of dietary fibre and reduced risk of colorectal cancer (Cummings et al. 1992). The relationship is not linear for all fibres, depending on their fermentability, but data from cohort studies indicate that 7 g additional fibre intake/person/day is associated with an expected

Table 3. Traditional dried fruits qualifying for EU authorised nutrition claims.

EU authorised nutrition claims[a]	Apricots	Dates	Raisins	Prunes	Figs
Only naturally occurring sugars, with no added sugar	Yes	Yes	Yes	Yes	
"Contains" claims:					
Fibre	High	High	Source	High	High
Iron	Source				
Potassium	High	High	High	High	
Copper	High	High	High	Source	Source
Manganese		Source		Source	Source
Calcium					Source
Magnesium					Source
Niacin	Source				
Vitamin A	Source				
Vitamin E	High				
Vitamin K				High	Source

The micronutrient content of dried fruits is taken from USDA food composition data, USDA (2018).
[a]EU (2006).

8% reduction in colorectal cancer risk (RR 0.92, $p = 0.002$) (SACN 2015).

Dried fruits are high in a range of dietary fibres and other bioactive compounds with prebiotic effects (e.g. polyphenols), while some dried fruits (e.g. prunes and apricots) also contain high levels of sorbitol, which has laxative properties and also increases stool weight. Inevitably studies have investigated the impact of dried fruit on faecal weight and transit time. A small, non-randomised, cross-over trial in 16 subjects failed to find a significant effect of three doses of raisins (85, 126 and 168 g/day) on faecal weight or reduced transit time, although this study had considerable limitations including non-randomised design and no wash-out periods between the doses (Spiller et al. 2003).

A more recent, well-designed randomised, cross-over trial in 21 healthy human volunteers found that 50 g dates (3.9 g fibre, 1 g sorbitol)/day for 3 weeks compared with a maltodextrin and dextrose control had a statistically significant benefit on stool frequency with no evidence of gastrointestinal side-effects (Eid et al. 2015). However, in contrast to stool weight, stool frequency is not associated with any known beneficial health effects. There were no statistically significant changes in the growth of selected bacterial groups or SCFA production in this study, but a post-hoc analysis found that volunteers with lower fibre intake (mean 6g/day) showed statistically significant increases in faecal bacterial numbers for six bacterial types, including *Bifidobacterium*, *Clostridium* and *Roseburia* subspecies, in contrast to volunteers with habitual higher fibre intakes (mean 18.5 g/day) who did not experience any changes in gut microbiome.

A meta-analysis of randomised controlled trials investigating the impact of prunes (dried plums) on stool output found a statistically significant increase in stool frequency of 1 stool/week, with no impact on stool consistency (Lever et al. 2014). Most of the effect was driven by volunteers with constipation with fewer effects in healthy people. A more recent, robust, randomised dose–response trial compared 80 g and 120 g prunes plus 300 ml water/day with a control of 300 ml water/day in 120 subjects habitually passing 3–6 stools/week and with a low fibre intake. The study showed a positive impact of prunes on the primary outcome of stool weight, and on change in stool weight. There was also a significant impact of 80 g prunes/day on increased stool frequency, despite no effect on whole gut transit time. Prunes also resulted in a greater increase in bifidobacteria compared with baseline (Lever et al. 2018).

With a limited number of human studies showing some benefit of traditional dried fruits in some areas of gut health, more studies are warranted to extend our knowledge of the potential beneficial impact for public health, particularly investigating other dried fruits and investigating the relative contribution of fibre and sorbitol to these effects. This highlights a challenge for public health advice that responses to dietary advice in individuals may differ depending upon genetics, lifestyle and typical dietary intake.

Polyphenols and dried fruit

A global analysis of deaths from non-communicable diseases attributable to behavioural and dietary risk factors has suggested that diets low in fruits are the third most important risk factor, behind high blood pressure (first), and active and passive smoking (second), with lifestyle risk factors acting either directly or through conditions such as elevated blood pressure, blood glucose and blood cholesterol. Of the individual dietary risk factors, low fruit consumption was suggested to be more important than high dietary salt, alcohol use, and diets low in nuts and seeds, vegetables, whole grains and fish/seafood (Ezzati and Riboli 2013). One possible explanation for the important role of fruits is their content of phytonutrients, including the major group termed polyphenols. These are naturally-occurring components of foods and beverages that can influence blood pressure and blood glucose, and have been proposed to reduce the risk of metabolic chronic conditions such as cardiovascular disease and type-2 diabetes (T2DM). Comparison of raisins and grapes shows that drying concentrates the content of polyphenols and thus antioxidant activity, and this is supported by comparison with other traditional dried fruits (Table 2). Comparison of raisins and prunes with grapes and fresh plums suggests that drying influences the content of individual polyphenols and highlights varietal differences.

The bioavailability of phytonutrients is now generally understood, but their benefits on health and mechanisms of action remain contentious. These were initially investigated in human cells *in vitro*, complemented by studies in experimental animal models and in healthy and at-risk human volunteers. Though many phytonutrients are antioxidants, this concept is based on *in vitro* studies assessing antioxidant content rather than functionality. Measuring antioxidant activity essentially indicates the polyphenol content, rather than providing information about its impact on health.

The mechanisms of action of polyphenols are much more complex than direct antioxidant activity and involve effects on blood vessel health through vasodilation, on various oxidative processes in cells such as superoxide production, and on nutrient absorption and energy metabolism, including glucose. Research has shown that polyphenols can blunt postprandial spikes in blood glucose, which is beneficial to health. A study comparing sedentary adults, pre-diabetics and endurance athletes found that the glucose response to raisins was not very different across these groups (Kim et al. 2008). However, there was much greater variation in the insulin response, demonstrating that healthy adults produce less insulin to obtain the same glycaemic response. This needs to be investigated in other population groups such as obese individuals as well as comparison of responses to fresh and dried fruits.

Polyphenols are fermented by the colonic microbiota and microbiome metabolites from polyphenols and other phytonutrients could potentially contribute to health benefits, in addition to the parent compounds present in dried fruit (Cardona et al. 2013). Little is currently known about this for dried fruits and this is another area for future research.

Dried fruit and appetite – the psychology of snacking in relation to obesity

Current trends in eating patterns show that snacking is becoming more ubiquitous. A study reported that the median number of eating occasions was 6 per day (decile range 3–10), reflecting erratic daily eating patterns spread over the day (Gill and Panda 2015). Snacking is associated with concepts such as "junk" food or empty calories, and snack foods are often referred to in the context of loss of appetite control, obesity and overconsumption. Food choices that constitute "healthy snacking" are therefore being recommended, and the identification of foods that help to improve appetite control is a key area of research. An avenue of current research is to investigate whether traditional dried fruits could be a useful strategy to improve appetite control on account of their high palatability and a low Glycaemic Index (GI).

Not all individuals are at risk of weight gain from snacking, but homeostatic and hedonic phenotypes exist within obese populations. Identification of susceptible phenotypes for appetite control and determining the role of snacking behaviour in these phenotypes is the subject of current research. Susceptible phenotypes might express appetite through weak satiation, fragile satiety, obesogenic food choices, or excessive wanting and liking. A low satiety phenotype has been identified, characterised by poorer weight loss outcomes and a greater tendency to snack when given access to high energy density foods (Barkeling et al. 2007; Drapeau et al. 2013). Research has also identified a "binge-eating type" characterised by consumption of a large amount of food in a short period of time (Bruce and Wilfley 1996), and this is present in 25–50% of obese individuals. A trial found that the excess energy consumed by "binge-eaters" was almost entirely accounted for by intake of snacks, particularly high-fat, sweet snacks (Dalton et al. 2013).

Hence food-based approaches may help normalise homeostatic and hedonic appetite responses in susceptible individuals. Highly satiating meals or snacks that are high in fibre, protein or volume, and low in energy can counteract loss of appetite control and limit energy intake. Snacking behaviour is thus a viable target for intervention in susceptible individuals, and the selection of suitable snacks is a potential strategy to improve appetite control. Beneficial characteristics of traditional dried fruits as a suitable snack include high sweetness and palatability, higher fibre content, low to moderate GI, and chewiness which delivers oral and sensory satiety. Hence consumption of traditional dried fruit could be a useful strategy to improve appetite control.

Dried fruit as a snack and dental health

Attention has been drawn by some authorities to the potential impact of dried fruit on dental health, particularly dental caries – a dynamic and cumulative disease (Sheiham and James 2014) in which bacteria in dental plaque ferment oral sugars resulting in acid production. pH falls in the mouth below 5.5 can soften tooth enamel and after repeated insults can result in the formation of tooth cavities, eventually resulting in dental caries. In contrast, the mechanism of tooth erosion does not involve bacteria, but results from the presence of acid in foods and drinks which generally soften the enamel leading to sensitivity and exposure of dentine. As well as the effects of diet, poor oral hygiene is an important risk factor for dental caries (Gibson and Williams 1999).

For dried fruit to contribute to dental caries, the sugars present in the food matrix need to be solubilised and diffuse into dental plaque. The rate of solubilisation depends on the location of the sugars in the dried fruit matrix (inside or outside the cellular structure), the fruit texture, and the force and frequency of chewing. Other influential factors include plaque thickness, the length of time dried fruit stays in the mouth allowing the sugars to dissolve, and the buffering capacity of saliva. The different categories of dried fruit may, therefore, behave differently in the mouth. However, it is unlikely that the dental profession, as well as the public, has full understanding of the compositional differences between traditional dried fruits and those that have added sugar.

With a pH of 7, saliva is the tooth's natural protective mechanism, buffering the effect of oral acids. Following each eating episode, there is a time lapse of approximately 40 min before resting oral pH is restored (Stephan and Miller 1943). This suggests that the frequency of sugars consumption would be the main causal factor for dental decay. However, a systematic review concluded that there is consistent evidence of moderate quality supporting a relationship between the total amount of sugars consumed and dental caries (Moynihan and Kelly 2014). Since reducing the frequency of consumption is an effective way to reduce the total amount of sugars consumed, these two risk factors are interlinked. With the current trend towards increased snacking, teeth are subject to more frequent episodes of acid exposure, and depending on the proximity of each eating episode, may not have time to recover to resting pH between snacks. Though the ideal for dental health would be not to eat between meals, this is unrealistic and advice from Public Health England in the UK, for example, is to have three meals and no more than two snacks a day. Additionally, dental professionals recommend that sugary snacks are kept to mealtimes.

As fruits, in general, are acidic and potentially damaging to teeth (PHE 2017), there is a tension between oral health advice and the recommendations to eat at least five portions of fruit and vegetables a day and to increase dietary fibre intake, suggesting an inevitable trade-off between oral health and gastrointestinal health. The UK public health advice to limit intake of dried fruit to mealtimes, is based on the assumption that dried fruit can be high in sugars and thus damaging to teeth, although the sugar content per individual piece of dried fruit is no different to the fresh equivalent. Fruit juices, vegetable juices and smoothies, in which sugars and fruit acids have been released from the structure of the cells, are targeted for restriction to mealtimes, with further advice to limit consumption to 150 ml/day. Restriction to mealtimes should also apply to pureed-dried fruit snacks in which the cellular structure has been broken down, resulting in release of sugars and fruit acids.

A systematic review (Sadler 2016) has addressed the perception that dried fruit adheres to teeth and is detrimental to teeth because of its sugars content. Overall there was limited evidence evaluating the relationship between traditional dried fruits and dental health. No intervention studies were identified that explored dental caries as an outcome *per se*, as this would be unethical. One cohort study was identified but the intake of dried fruit was too low for any meaningful analysis (Clancy et al. 1977). One study investigated the effect of whole and juiced fruits and vegetables and whole raisins individually on net demineralisation of enamel compared with positive and negative controls, and found statistically significant ($p < 0.05$) net demineralisation with all test foods compared with the negative control, suggesting that raisins were not more detrimental to teeth than fresh fruits and vegetables (Issa et al. 2011). Animal studies and studies providing indirect evidence for an effect of dried fruits on plaque acidogenicity had severe limitations – many of the studies were quite old, few dried fruits were investigated, portion sizes were not always stated, positive and/or negative controls were not always used, groups had few subjects ($n = 3–20$), large standard deviations were frequently reported, and statistical analysis was often lacking between comparator foods. In the two animal studies identified, minced dried apple (Touyz 1983) and raisins (Mundorff et al. 1990) showed cariogenic potential. However, the test foods were consumed 17–18 times/day, representing an unrealistic comparison for patterns of human intake of individual foods.

In vivo plaque acid measurements (Jensen 1986; Park et al. 1990; Utreja et al. 2009) showed inconsistent evidence for the demineralisation potential of raisins. In an *in vitro* study of plaque acidogenicity comparing raisins and dates with 52 other snack foods, such as hard and soft candies, baked goods and beverages, dried fruits were not worse for teeth than other snack foods (Edgar et al. 1975). Park et al. (1990) also demonstrated that starch-based snacks show demineralisation potential as well as sugars-containing snacks.

Studies of oral clearance have used different methods and endpoints, and improved techniques for assessment are needed. One study compared subjective perceptions of the stickiness of 21 foods in 315 adults with an objective measure of retention of 9–30 g portions of the same foods in 5 young adults (Kashket et al. 1991). The low correlation between perceived stickiness and oral clearance rates ($r = 0.46$) suggests that subjects cannot accurately assess the stickiness of foods, which is also likely to be true for health professionals. This study also showed low to intermediate retention (based on dry weight retained) for raisins and figs respectively, and intermediate clearance rates (weight retained with time). Edgar et al. (1975) also measured food retention of 48 snacks in 3 subjects/food, in which dates were ranked 15/48 for carbohydrate retention at 5 min (0 = low), and raisins were ranked 29. This study also suggested that dried fruits do not adhere to teeth more than alternative snacks, such as cookies, crackers, apple pie and candies. A third study that measured the quantity of oral lactic acid production as a marker of oral clearance concluded that foods containing sugars but no starch clear the oral cavity more rapidly than starch-containing foods (Linke et al. 1997). It would, therefore, seem prudent to re-evaluate the concept of "sticky" foods. No studies were identified that explored the impact of dried fruit on dental erosion.

Overall the systematic review (Sadler 2016) suggested there is limited data on which to give evidence-based advice on the unsuitability of traditional dried fruits as a snack. Since perceptions are difficult to change, a number of gaps in the evidence need to be addressed to ensure that advice on dried fruit and dental health is truly evidence-based.

One important question concerns the impact of drying fruit on the location of sugars within the cells, which is currently unknown, and whether sugars are released in the mouth or released elsewhere in the gastrointestinal tract. In the UK, it was previously assumed by some authorities that dried fruit contains extrinsic sugars. This was based on the general concept that when foods are processed the cell walls are broken down, for example, mashing potatoes, and that drying fruit would result in sugars leaching out of the cells. An arbitrary value of 50% was assigned for the conversion of intrinsic to extrinsic sugars (Buss et al. 1994) with no evidence to support this assumption. However, this assumption has been influential in setting advice to consume dried fruits only at meals. Present knowledge indicates that when fruit is dried water is lost, and hence fruit acids, fibre and sugars become concentrated. The moisture content of dried fruit ranges from about 14–24% depending on variety. Research in grasses has shown that when cells are dried below 10%, cellulose in the walls can collapse making rehydration difficult (Fang and Catchmark 2014). Depending on the extent of drying, if these effects are transferable to dried fruits this would reduce "stickiness" and may mean that sugars are not easily released from within the cellular structure. Other work undertaken on non-food items has shown that turgid cells break open when pressure is applied, but flaccid cells are likely to sheer apart at the middle lamellae (Jarvis and McCann 2000). If this effect is applied to chewing dried fruit, sugars and fruit acids would be unlikely to be released in the mouth. These two examples of research from other areas demonstrate how little is known about the impact of the drying process on the cellular structure of fruit and about the impact of chewing both fresh and dried fruits on the release of sugars from the fruit cells in the mouth.

Supporting information can be provided by comparison of GI values which show that some dried fruits (apricots, peaches, prunes/plums, apple) typically have lower or equivalent values to those of their fresh equivalents, suggesting that sugars have not leached from the cells. Prunus fruits are unusual as they have lower GI values when dried, whereas Rosacea fruits have similar GI values when dried, which suggests different patterns may exist on a

Table 4. Summary of key learning points.

The term "dried fruit" encompasses a range of different processing methods. Traditional dried fruits do not contain added sugars, and the sugars they contain are not within the currently used definition of free sugars.
The content of nutrients in traditional dried fruits remains similar to the equivalent fresh fruit, though more concentrated, with the exception of having a lower vitamin C content. Dried fruits are high in a range of dietary fibres and other bioactive compounds with prebiotic effects (e.g. polyphenols); some dried fruits (e.g. prunes and apricots) contain high levels of sorbitol, which has laxative properties and increases stool weight. Drying concentrates the content of polyphenols and thus antioxidant activity.
Consumption of dried fruit is difficult to estimate because of multiple uses but intakes are generally low.
Snacking behaviour may be a viable target for intervention in susceptible individuals, and the selection of suitable snacks is a potential strategy to improve appetite control.
There is limited evidence exploring the relationship between traditional dried fruits and dental health; the concept of "sticky" foods needs to be re-evaluated.
The proportion of dental caries caused by dried fruit in the general UK population is likely to be very low if any, because of low intakes, yet in some countries oral health is influencing public health messaging based on minimal evidence.
The impact of drying fruit on the location of sugars within the cells and whether sugars are released in the mouth or elsewhere in the gastrointestinal tract, is currently unknown.
Increasing consumption of traditional dried fruits from current low levels of intake would contribute to 30g/day fibre recommendations, the intake associated with decreased risk of non-communicable diseases such as colorectal cancer, coronary heart disease and T2DM.
Encouraging intake of dried fruit could help consumers achieve recommended 5-a-day fruit and vegetable intakes. Dietary advice could usefully integrate both dried fruit and fresh fruit to help a switch from confectionery towards fruit, to help consumers consume a healthier diet.

botanical basis. This is a point of interest for further research, which would also need to take account of potential differences between varieties, as any comparisons between dried and fresh fruits need to be made on the basis of the same variety. Dried fruit is classified as high glycaemic load ($GL = GI \times$ carbohydrate content/weight of food tested), though there is currently little information about its impact on non-communicable diseases – in the few available studies fresh and dried fruit intakes were analysed together because intake of dried fruit was so low.

Perceived conflicts in public health advice

Increasing consumption of traditional dried fruits from current low levels of intake would contribute to the 30g/day fibre recommendations, the intake associated with decreased risk of non-communicable diseases such as colorectal cancer, coronary heart disease and T2DM (SACN 2015). Increasing intake of traditional dried fruits may also contribute to other potential mechanisms for reducing risk of T2DM such as the impact of polyphenols on modulation of sugar absorption and metabolism and any potential benefit of dried fruit as a snack on appetite and weight control. However, dried fruit is a sugar-containing food and for those with T2DM this may not be advantageous.

Advice in the UK that it is better to consume dried fruit as part of a meal and not as a between-meal snack on dental health grounds (PHE 2017) reduces the opportunities for its contribution to increase fibre intake. The snacking advice is based on the two assumptions that traditional dried fruits contain extrinsic sugars, and that dried fruit can stick to the teeth, both of which require confirmation. Therefore, research is clearly needed to ascertain whether the location of sugars in traditional dried fruits is different to that in fresh fruit and whether or not dried fruit sticks to teeth relatively more than other snack foods. However, a view was expressed that, despite the paucity of current evidence, without evidence to the contrary it may be prudent to continue with the current advice to consume dried fruit with a meal, rather than making new assumptions that may prove to be incorrect in the future.

Round table discussion

Following the presentations, which highlighted current knowledge (Table 4), the workshop chair co-ordinated a discussion between the speakers, health professionals and industry representatives in the audience, which focussed on five key topics. In the context of a discussion, the suggestions and ideas expressed may not all be supported by published literature. The following summary of the discussion of both the panel and attendees does not necessarily represent the views of all speakers.

The contribution of dried fruit to "five a day" and fibre intake

There was general agreement that traditional dried fruits could be given greater promotion as part of the diet, as they are high in fibre, low in fat and a concentrated source of various micronutrients. Relative to some fresh fruit, dried fruit is convenient for consumers and has a long shelf life. While it may be perceived as expensive relative to fresh fruit or other alternatives, the portion size is smaller than that of fresh fruit which may help some consumers to attain a higher overall intake of fruit. In countries with a recommendation to eat a minimum of five portions of fruit and vegetables a day, dried fruit does not need to be eaten in place of fresh fruit or vegetables and can be included in addition. If substitution is necessary, the view was expressed that dried fruit would be better in place of fruit juice and smoothies. It was suggested that a different recommendation may be appropriate for dried fruits with added sugars or candied fruits to that for traditional dried fruits.

It was suggested that a key objective could be to encourage the nine out of ten consumers who are not currently eating any dried fruit (HSE 2017) to include it as part of their diet, as well as encouraging consumers to eat two portions to benefit their diet. However, the relevance of advice ultimately depends upon the individual and their own dietary pattern. It was thought that a risk-benefit analysis would be unlikely to suggest that people with a low intake of fruit and vegetables and at increased risk of chronic disease would need to avoid dried fruit because of dental caries risk, since incorporating dried fruit into the diet is a useful method of increasing fibre intake. This creates a challenge for governments of how to communicate appropriate advice for population subsets.

Equivalence of dried fruit to fresh

Changes to micronutrients that occur in drying include loss of vitamin C and concentration of other nutrients. There is little change in total polyphenol content, but changes occur in individual polyphenols, including modification by the microbiome.

As well as equivalence in nutritional composition, equivalence in the potential detrimental effects of sugars content should also be considered. It was suggested that whether sugars are released from the plant cells during the drying process could be investigated with microscopy. A related question is whether dried fruits are equivalent to frozen fruits. When water in frozen fruit thaws the cells burst, releasing sugars, and release of sugars could also occur in canned fruits because the canning process softens and breaks down the cell wall structure. Since dried fruit tastes sweet, some release of sugar must occur in the mouth, though the same is also true of fresh fruit. The question is how much sugar is released and does it result in a fall in dental plaque pH sufficient to damage the teeth? It was suggested that further investigation of this aspect would be worthwhile.

Regarding equivalence in terms of satiety, two main differences between dried and fresh fruit are changes in volume and water content. These are both important for gut distension and for release of satiety hormones which suppress appetite, as there is an interaction between nutrients entering the gastrointestinal tract and the extent to which the stomach fills. It was suggested that advice around dried fruit as a snack might usefully include advice to consume with water to increase volume in the stomach.

Equivalence in terms of cost, storage, wastage, palatability and uptake from the food environment are equally important issues for consumers. Dried fruits can be stored longer than fresh fruit with potentially less waste. Because of the lower weight of dried fruit per portion, it may be easier to eat two portions than to eat two portions of whole fruit, increasing ability to consume nutrients within a lower volume.

Snacking advice

On the wider question of overall advice for snacking in relation to dental health, it was suggested that most snacking is potentially detrimental to teeth and dentists would rather nothing was eaten between meals. A recommendation for more nutrition-based advice for dentists in the future would be helpful. Clearly, more research is needed, as good evidence to underpin advice not to snack on dried fruit is currently lacking. The evidence is also lacking for combinations of dried fruit with other foods – for example, whether dried fruit eaten with unsweetened yoghurt impacts dental health.

A view was expressed that it is important to temper consumers' current snacking patterns and encourage small beneficial changes. In the interests of public health, it would be better for consumers to substitute one high-sugar, high-fat snack with a dried fruit snack. This does not mean dried fruit snacks are "good" in the absolute sense and others are "bad", but the importance of encouraging sensible swaps was recognised. The proportion of dental caries caused by dried fruit is likely to be very low if any at all because of low intakes, yet in some countries, oral health concerns are influencing public health messaging based on minimal evidence. Sugar-sweetened beverages and other acidic drinks are a greater contributor to poor dental health and replacing them with dried fruit which contributes to fibre intakes would represent a sensible swap. It was also suggested that since the focus of public health advice is for the reduction of free sugars rather than reduction of total sugars, and since positive messages are more likely to help consumers, advice could usefully integrate both dried fruit and fresh fruit to help a switch from confectionery and biscuits towards fruit, to help consumers consume a healthier diet.

Another key aspect of snacking advice is in relation to satiety and appetite control and it needs to be confirmed in research whether dried fruit may be beneficial for appetite control and the management of hunger, when substituted in place of high-fat snacks or in place of snacks that are easy to over-consume because of difficultly in controlling portion size. It was suggested that restrictive advice in relation to dental health has been made in the absence of any full consideration of the use of dried fruit snacks for appetite control.

Consumer messaging

Discussion also focussed on key consumer messages for the dried fruit and wider food industry and how consumer confusion can be avoided should public health advice be changed. A key challenge is consumer understanding of the different types of dried fruit in the food environment, along with the general misconception that most dried fruits contain added sugars. Standard messaging advising consumers to read the ingredients list and the nutrition information is likely to be the most helpful way to ensure consumers can understand and distinguish different categories of dried fruits. How dried fruits are positioned and marketed in the food environment in order to provide consumer choice may also be influential, for example, as a composite food ingredient, as a meal ingredient or as a snack. Developmental work is mainly focussed on small snacking occasions, but there is also an opportunity to add fibre to diets by adding chopped dried fruits to meals, and to add nutritional value to processed foods and baked goods by the inclusion of dried fruits.

The scenario was highlighted in the care sector whereby older people and those receiving palliative care are often given laxatives, whereas improving the diet is a more favourable solution, for example, providing prunes with breakfast. There is also an opportunity to improve the fibre content of children's diets through school meals and packed lunches.

Possible areas for future research

To bring about change in existing public health advice for snacking, it was agreed that robust evidence is needed. There was a call for properly-constructed research in the human mouth, using up-to-date methods, rather than *in vitro* studies. Gaps in the evidence include the rate of solubilisation of sugars from dried fruit in the oral fluid and diffusion into oral plaque; whether fruit acids are released in the mouth and are equally damaging to teeth as free acids in fruit-based drinks; whether dried fruit sticks to teeth more than alternative snacks; whether sugars in dried fruit are cleared as quickly from the mouth as those in fresh fruit; and whether all dried fruits behave the same. More studies of the fall in pH following dried fruit consumption, how long the pH change lasts, and how chewing dried fruit may influence saliva production and hence mitigate a fall in pH are also required. Since foods such as cheese, raw vegetables and nuts are regarded as "safe" snacks for teeth by dentists, investigation of food combinations such as dried dates with cheese, nuts and raisins, and prunes with unsweetened yoghurt, for example, would give useful information as well as possibly better reflecting everyday eating patterns.

Whether the sugars in dried fruit are intrinsic or extrinsic is also important in terms of GI, GL and the glycaemic response of dried fruit compared with fresh fruit, as is understanding the effects in consumers with different lifestyles. For example, investigating the time lapse before sugars are released from dried fruits so that an extreme sports person might benefit in relation to alternatives such as carbohydrate gels. Since dried fruit needs to rehydrate for digestive enzymes to release sugars, more research on the relative release of sugars from dried fruit at different sites in the gastrointestinal tract is needed.

From a gut-health perspective, more needs to be known about the impact of different dried fruits and the relative contributions of fibre and sorbitol to constipation and bowel health. The juxtaposition of potential health benefits of dried fruit against concerns about dental health suggests a need to investigate the impact of doubling or eating an extra 30 g a day of dried fruit, using modelling to calculate the impact on chronic diseases and conditions such as constipation, compared with the impact on dental caries, even assuming all the sugars present in the dried fruit would harm the teeth. It would be useful to compare mortality, because not many people die of dental caries, how many hospital days are saved, and the impact on healthcare cost savings. It was suggested that the UK, for example, does not have an epidemic of dental caries, whereas reducing rates of chronic disease such as colorectal cancer is an important target.

Since dried fruit is a nutritious, high fibre food, low intakes could be targeted for improvement. More needs to be understood about dried fruit consumption to assess the contribution of composite foods to intakes through dietary modelling. This could include comparison of sources and consumption patterns in high and low consumers to identify what high consumers are doing well and barriers to consumption for low consumers. Investigation of what consumers understand by "traditional" and other descriptors used for dried fruits along with consumer understanding of food labels, particularly the distinction between total and free sugars, and nutritional values per portion and per 100 g, would help to identify effective ways to communicate with consumers. Investigating the impact of personalised advice in population subgroups that may benefit from a targeted approach is also important.

Acknowledgments

Presentations and speakers:

Professor Julie Lovegrove (Chair) – Introduction to the workshop

Mrs Sigrid Gibson – Composition and classification of dried fruit, and contribution to intakes of fibre and sugars

Professor Kevin Whelan – Dried fruit and digestive health

Dr Michele Sadler – Dried fruit and dental health – what is the evidence

Dr Marie-Ann Ha – Consistency of public health advice for fruit and dried fruit

The authors wish to thank additional speakers at the workshop for their contributions:

Professor Graham Finlayson, School of Psychology, University of Leeds – *Dried fruit and appetite – the psychology of snacking in relation to obes*ity, and Professor Gary Williamson, School of Food Science and Nutrition, University of Leeds – *Antioxidants and phytonutrients in dried fruit and their potential to contribute to public health.*

Disclosure statement

The workshop was funded by the National Dried Fruit Trade Association, the California Prune Board, the Raisin Administrative Committee, Whitworths and Sunmaid Raisins.

The funders had no involvement in the drafting or content of the manuscript. MS works as a consultant nutritionist and receives consulting fees from a wide range of industry clients and trade associations, and has previously received funding from the Californian Prune Board for various projects including submission of the EU authorised health claim for prunes. SG works as a consultant nutritionist and has received consulting fees from industry clients. KW has received research grants from the California Dried Plum Board and the International Nut and Dried Fruit Council. MAH has no interests to declare. JL sits on the UK Government's Scientific Advisory Committee for Nutrition (SACN). JH provides nutritional consultancy services to the dried fruit industry.

References

Alasalvar C, Shahidi F (Eds). 2013. Dried fruits: phytochemicals and health effects. Oxford: Wiley-Blackwell. (Functional Food Science and Technology series).

Barkeling B, King NA, Naslund E, Blundell JE. 2007. Characterization of obese individuals who claim to detect no relationship between their eating pattern and sensations of hunger or fullness. Int J Obes (Lond). 31: 435–439.

Bruce B, Wilfley D. 1996. Binge eating among the overweight population: a serious and prevalent problem. J Am Dietet Assoc. 96:58–61.

Buss DH, Lewis J, Smithers G. 1994. Non-milk extrinsic sugars (letter). J Hum Nutr & Dietet. 7:87.

Cardona F, Andres-Lacueva C, Tulipani S, Tinahones FJ, Queipo-Ortuna MI. 2013. Benefits of polyphenols on gut microbiota and implications in human health. J Nutr Biochem. 24:1415–1422.

Clancy KL, Bibby BG, Goldberg HJV, Ripa LW, Barenie J. 1977. Snack food intake of adolescents and caries development. J Dent Res. 56:568–573.

Cummings JH, Bingham SA, Heaton KW, Eastwood MA. 1992. Fecal weight, colon cancer risk, and dietary intake of nonstarch polysaccharides (Dietary fiber). Gastroenterology. 103:1783–1789.

Dalton M, Blundell J, Finlayson GS. 2013. Examination of food reward and energy intake under laboratory and free-living conditions in a trait binge eating subtype of obesity. Frontiers in Psychol. 4:757–765.

Drapeau V, Blundell J, Glaant AR, Arguin H, Despres JP, Lamarche B, Tremblay A. 2013. Behavioural and metabolic characterisation of the low satiety phenotype. Appetite. 7:67–72.

Edgar WM, Bibby BG, Mundorff S, Rowley J. 1975. Acid production in plaques after eating snacks: modifying factors in foods. J Am Dent Assoc. 90:418–425.

Eid N, Osmanova H, Natchez C, Walton G, Costabile A, Gibson G, Rowland I, Spencer JP. 2015. Impact of palm date consumption on microbiota growth and large intestinal health: a randomised, controlled, cross-over, human intervention study. Br J Nutr. 114:1226–1236.

[EU] European Union. 2006. Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods. Official Journal of the European Union 30.12.2006, L 404.

[EU] European Union. 2011. Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers amending Regulations (EC) No 1924/2006 and (EC) No 1925/2006 of the European Parliament and of the Council, and repealing Commission Directive 87/

250/EEC, Council Directive 90/496/EEC, Commission Directive 1999/10/EC, Directive 2000/13/EC of the European Parliament and of the Council, Commission Directives 2002/67/EC and 2008/5/EC and Commission Regulation (EC) No 608/2004. Official Journal of the European Union 22.11.2011, L 304/18.

[EU] European Union. 2013. Commission Regulation (EU) No 536/2013 of 11 June 2013 amending Regulation (EU) No 432/2012 establishing a list of per mitted health claims made on foods other than those referring to the reduction of disease risk and to children's development and health. Official Journal of the European Union 12.06.2013, L 160/4.

Ezzati M, Riboli E. 2013. Behavioral and dietary risk factors for noncommunicable diseases. N Engl J Med. 369: 954–964.

Fang L, Catchmark JM. 2014. Structure characterization of native cellulose during dehydration and rehydration. Cellulose. 21:3951–3963.

Gibson S, Williams S. 1999. Dental caries in pre-school children: associations with social class, toothbrushing habit and consumption of sugars and sugar-containing foods. Further analysis of data from the National Diet and Nutrition Survey of children aged 1.5–4.5 years. Caries Res. 33:101–113.

Gill S, Panda S. 2015. A smartphone app reveals erratic diurnal eating patterns in humans that can be modulated for health benefits. Cell Metab. 22:789–798.

Goldfein KR, Slavin JL. 2015. Why sugar is added to food: food science 101. Compr Rev Food Sci Food Saf. 14: 644–656.

[HSE] Health Survey for England. 2017. Health Survey for England 2016; published 13 December 2017 [cited 2018 Oct 04]. Available from: https://digital.nhs.uk/data-and-information/publications/statistical/health-survey-for-england/health-survey-for-england-2016

Hooper B, Spiro A, Stanner S. 2015. 30g of fibre a day: an achievable recommendation? Nutr Bull. 40:118–129.

Issa AI, Toumba KJ, Preston AJ, Duggal MS. 2011. Comparison of the effects of whole and juiced fruits and vegetables on enamel demineralisation in situ. Caries Res. 45:448–452.

Jarvis MC, McCann M. 2000. Macromolecular biophysics of the plant cell wall: concepts and methodology. Plant Physiol Biochem. 38:1–13.

Jensen ME. 1986. Responses of interproximal plaque pH to snack foods and effect of chewing sorbitol-containing gum. J Am Dent Assoc. 113:262–266.

Kashket S, Van Houte J, Lopez LR, Stocks S. 1991. Lack of correlation between food retention on the human dentition and consumer perception of food stickiness. J Dent Res. 70:1314–1319.

Kim Y, Hertzler SR, Byrne HK, Mattern CO. 2008. Raisins are a low to moderate glycemic index food with a correspondingly low insulin index. Nutr Res. 28:304–308.

Lever E, Cole J, Scott SM, Emery PW, Whelan K. 2014. Systematic review: the effect of prunes on gastrointestinal function. Alim Pharm Ther. 40:750–758.

Lever E, Scott SM, Louis P, Emery PW, Whelan K. 2018. The effect of prunes on stool output, gut transit time and gastrointestinal microbiota: a randomised controlled trial. Clin Nutr. [cited 2018 Oct 04]. Available from: https://doi.org/10.1016/j.clnu.2018.01.003

Linke HA, Moss SJ, Arav L, Chiu P-M. 1997. Intra-oral lactic acid production during clearance of different foods containing various carbohydrates. Zeitschrift Für Ernährungswissenschaft. 36:191–197.

Moynihan PJ, Kelly SAM. 2014. Effect on caries of restricting sugars intake; systematic review to inform WHO Guidelines. J Dent Res. 93:8–18.

Mundorff SA, Featherstone JD, Bibby BG, Curzon MEJ, Eisenberg AD, Espeland MA. 1990. Cariogenic potential of foods. I. Caries in the rat model. Caries Res. 24: 344–355.

Park KK, Schemehorn BR, Bolton JW, Stookey GK. 1990. Effect of sorbitol gum chewing on plaque pH response after ingesting snacks containing predominantly sucrose or starch. Am J Dent. 3:185–191.

[PHE] Public Health England. 2017. Delivering better oral health: an evidence-based toolkit for prevention. 3rd ed. London: Public Health England; [cited 2018 Oct 04]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/605266/Delivering_better_oral_health.pdf

[PHE] Public Health England. 2018 March. National Diet and Nutrition Survey Results from Years 7 and 8 (combined) of the Rolling Programme (2014/2015 – 2015/2016). A survey carried out on behalf of Public Health England and the Food Standards Agency. [cited 2018 Oct 04]. Available from: https://www.gov.uk/government/statistics/ndns-results-from-years-7-and-8-combined

Sadler MJ. 2016. Dried fruit and dental health. Int J Food Sci Nutr.67:944–959.

[SACN] Scientific Advisory Committee on Nutrition. 2015. Carbohydrates and Health. Public Health England; [cited 2018 Oct 04]. Available from: https://www.gov.uk/government/publications/sacn-carbohydrates-and-health-report

Sheiham A, James WP. 2014. A new understanding of the relationship between sugars, dental caries and fluoride use: implications for limits on sugars consumption. Public Health Nutr. 17:2176–2184.

Spiller G, Story J, Lodics TA, Pollack M, Monyan S, Butterfield G, Spiller M. 2003. Effect of sun-dried raisins on bile acid excretion, intestinal transit time and fecal weight: a dose–response study. J Medicinal Food. 6:87–91.

Stephan RM, Miller BFA. 1943. Quantitative method for evaluating physical and chemical agents which modify production of acids in bacterial plaques on human teeth. J Dent Res. 22:45–51.

Swan GE, Powell NA, Knowles BL, Bush MT, Levy LB. 2018. A definition of free sugars for the UK. Public Health Nutr. 21:1636–1638.

Touyz LZG. 1983. The initiation of the effect of commercially-prepared dried apple on dental caries in albino rats. Arch Oral Biol. 28:369–370.

[USDA] United States Department of Agriculture, Agricultural Research Service. 2007. USDA Database on the Flavonoid Content of Selected Foods, Release 2.1. [cited 2018 Dec 17]. Available from: Nutrient Data Laboratory Web site: http://www.ars.usda.gov/nutrientdata.

[USDA] United States Department of Agriculture, Agricultural Research Service. 2018. Food Composition Databases. USDA National Nutrient Database for Standard Reference Legacy Release, April 2018. [cited 2018 Dec 17]. Available from: https://ndb.nal.usda.gov/ndb/

Utreja A, Lingström P, Evans CA, Saltmann LB, Wu CD. 2009. The effect of raisin-containing cereals on the pH of dental plaque in young children. Pediatr Dent. 31: 498–503.

WHO. 2015. Guideline: sugars intake for adults and children. Geneva (Switzerland): World Health Organization.

Williamson G, Carughi A. 2010. Polyphenol content and health benefits of raisins. Nutr Res. 30:511–519.

Yao CK, Tan H-L, van Langenberg DR, Barrett JS, Rose R, Liels K, Gibson PR, Muir JG. 2014. Dietary sorbitol and mannitol: food content and distinct absorption patterns between healthy individuals and patients with irritable bowel syndrome. J Hum Nutr Diet. 27:263–275.