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Dried fruit and dental health – how strong is the evidence?

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Abstract

Children's dental health in England has shown improvement in recent decades. However, 24.7% of 5 year-olds have obvious decay, with the average number of affected teeth being 3.4, and tooth decay is the most common reason for hospital admissions in 5–9 year-olds. Public Health England advises that foods and drinks containing free sugars are limited because of the increased risk of dental caries associated with frequent intakes. Although dried fruit contains more sugars than fresh fruit by weight due to the dehydration process, the portion size of dried fruit is 30 g compared with 80 g for fresh fruit. Additionally, these sugars are not defined as 'free' according to the current UK definition. However, unlike other sources of natural sugars, dried fruit is recommended to be eaten with meals only rather than as a snack because there is a supposition that it 'sticks' to teeth. A comprehensive review of the evidence published last year found a lack of good quality studies to support this advice. In the absence of data from intervention and cohort studies for effects of dried fruit on dental caries endpoints, studies of proxy measures of tooth demineralisation show inconsistent effects on plaque pH and acidogenicity. Measurement of net demineralisation, following consumption of raisins seven times a day for 10 days, showed comparable effects with fresh fruit and vegetables under similar conditions. Oral retention ('sticking') has been investigated in few subjects. The results do not demonstrate that dried fruit is worse in terms of oral clearance than alternative snack foods. More robust research with validated methods is needed before firm conclusions can be drawn about the retention of dried fruit, and hence its potential for adverse effects on teeth. This is important because eating traditional dried fruits can help towards the achievement of a number of dietary recommendations, including contributing to the 5 A DAY target and increasing fibre intake.

Keywords: acid production, demineralisation, dental caries, dried fruits, oral retention, snack foods

Introduction

Traditional dried fruits (apples, apricots, currants, dates, figs, peaches, pears, prunes and raisins) have many nutritional benefits. They are low in fat and contain only sugars naturally present in the fruit, which are not classified as free sugars. They are a source of dietary fibre, and national data suggest that average fibre intake in the UK needs to increase considerably to meet the current recommendations of 15 g/day for 2–5 year-olds, 20 g/day for 5–11 year-

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olds, 25 g/day for 11–16 year-olds and 30 g a day for those aged 16 years and above (SACN 2015). Although these recommendations can be achieved, the dietary pattern required includes plenty of fruit and vegetables, wholegrain foods, pulses and other fibre-rich foods for both meals and snacks, which would involve considerable dietary change for most of the population (BNF 2015; Hooper *et al.* 2015; Lockyer *et al.* 2016).

Dried fruits offer an easy and popular snack option to increase fibre intake. They also provide a range of vitamins and minerals which could be particularly useful for teenage girls, who often have inadequate micronutrient intakes. There is also evidence that dried fruits may usefully be included in weight management diets, possibly through effects on satiety (Farajian *et al.* 2010; Patel *et al.* 2013a, 2013b; Harrold *et al.* 2014).

Including more dried fruits in the diet could therefore help towards the achievement of a number of dietary recommendations. However, in the UK, it is recommended that dried fruit is eaten only at meal times because of concerns about its effect on dental health. This paper explores the current trends in dental health in children and examines the evidence investigating the relationship between dried fruit intake and dental caries.

Dental health in children

Data on the dental health of 5 year-olds in England show a generally improving picture compared with previous decades. In 2012, there was an overall improvement in the number of children free of tooth decay and 4-year trends showed a reduction in overall tooth decay from 30.9% in 2008 to 27.9%, with 72.1% of 5 year-olds free from tooth decay compared with 69.1% in 2008 (PHE 2013). In 2015, the third such survey (PHE 2015) showed that 75.2% of 5 year-old surveyed had no experience of obvious dental decay, the third consecutive survey to show an improvement, consistent with overall trends in dental health since fluoride toothpaste was introduced in 1976. However, in the 24.7% of 5 year-old children with obvious decay, the average number of teeth that were decayed, missing or filled was 3.4. Hence, despite the overall encouraging improvements seen over the last few decades, it remains the case that in affected children decay is a serious problem, particularly for socially disadvantaged children (PHE 2015; White 2017). In 2015–2016, tooth decay was the most common reason for hospital admissions in children aged 5–9 years and was the sixth most common procedure for children aged up to 4 years (White 2017).

As dental caries is a preventable disease, in 2016 Public Health England (PHE) launched the Children's Oral Health Improvement Programme Board with the aim of improving children's oral health and reducing the gap in socially deprived regions. Preventative measures include good dental hygiene, tooth brushing twice a day with fluoride toothpaste, regular dental checkups, fluoride varnish programmes and, of course, diet, particularly lowering intake of sugars. The latter is the target of the PHE sugar reduction programme (PHE 2017b) set out in the childhood obesity plan (DH 2016), which aims to help children and families consume less free sugars in order to reduce their risk of dental decay and obesity.

Sugars content of dried fruit

In 2015, classification of sugars in the UK was changed from non-milk extrinsic sugars (NMES) to 'free sugars', as used by the World Health Organization (WHO/FAO 2003; WHO 2015), and it is these types of sugars that the UK government recommends should be restricted to 5% of total dietary energy (SACN 2015). Free sugars are defined as all monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups, unsweetened fruit juices and fruit juice concentrates (WHO/FAO 2003; WHO 2015). In juices, the sugars present have been released from the cellular structure and are therefore considered to be 'free sugars', but the free sugars content of dried fruit is considered to be zero. However, chewing presumably releases sugars within cells into the mouth, and it is not clear when or if these are considered 'free' (Sadler 2016).

The sugars content of dried fruit is often described as 'high' or 'concentrated', although for traditional dried fruits, it is generally equivalent to the fresh fruit of the same initial size (*i.e.* one prune or one raisin has the same sugars content of dried fruit as one plum or one grape of equivalent variety and size). The drying process results in loss of water, and no sugars are added to traditional dried fruits. In contrast, sugars-infused dried fruits and candied fruit have added sucrose, as do some processed fruit snacks.

The concentration of individual sugars varies between dried fruits and the content of glucose and fructose is often higher than that of sucrose, which is

partly due to the drying process. However, although plaque bacteria show a preference for sucrose, they will metabolise any sugar. In the case of prunes, this particular dried fruit contains sorbitol (~15 g/100 g), a sugar alcohol that is not metabolised by the acidogenic bacteria and is thus non-cariogenic (Moynihan 2002).

Intake of dried fruit in the UK

Consumption of dried fruit appears to be quite low compared with other foods that are likely to be eaten between meals. Dried fruit intake is not reported separately in the *National Diet and Nutrition Survey* (*NDNS*), being included within total fruit intake (Bates *et al.* 2014). However, a proxy indication of dried fruit intake can be determined from *NDNS* data from the percentage contribution of total fruit intake to intake of NMES (sugars not located within the cellular structure of food excluding sugars that occur naturally in milk). This is possible because, for purposes of analysing *NDNS* data, fresh fruit is considered not to contain NMES and dried, canned, stewed and preserved fruits to contain 50% NMES (Buss *et al.* 1994). These data suggest that dried fruit intake is low across all age groups (Table 1). Compared with alternative snack foods, examples of which were tested in the studies referred to later, *NDNS* data show a higher contribution to NMES intake from biscuits, cakes and pastries, and confectionery than from total fruit intake (*i.e.* from dried, canned, stewed and preserved fruit) (Table 1).

Table 1 National Diet and Nutrition Survey data for percentage contribution of main snack foods to intake of non-milk extrinsic sugars (NMES)*

Snack food type	Contribution to average daily NMES intake (%)				
Age group (years)	1.5–3	4–10	11–18	19–64	65+
Fruit (all types)†	3	1	1	1	4
Biscuits	8	8	7	6	7
Buns, cakes, pastries and fruit pies	6	9	6	7	13
Sugar confectionery	5	7	5	2	1
Chocolate confectionery	7	7	8	7	4
Savoury snacks	0	0	0	0	0
Non-alcoholic beverages	27	30	40	25	16

Data from Years 1–4 of the Rolling Programme (Bates *et al.* 2014).
N.B. Other key contributors to NMES intake include puddings, breakfast cereals, dairy desserts, jams, preserves and sweet spreads, and alcoholic beverages – which are not generally eaten as snacks.
*Sugars not located within the cellular structure of food, excluding sugars that occur naturally in milk (almost entirely lactose) (DH 1989).
†Contribution to NMES from dried, canned, stewed and preserved fruits.

Current advice on dried fruit

Current PHE advice from the Eatwell Guide is to 'Eat plenty of fruit and vegetables. Aim for at least five portions of a variety of fruit and vegetables every day. Remember that a portion of dried fruit is 30 g and should be kept to mealtimes. Limit fruit juice and smoothies to a combined total of 150 ml which counts as one of your 5 A DAY' (PHE 2016). Other than fruit juice, vegetable juice and smoothies, all fruit and vegetables included in the 5 A DAY message can count more than once a day and this includes dried fruit. However, PHE does recommend that dried fruit is only consumed at mealtimes on the grounds that 'it can stick to teeth, increasing the risk of tooth decay'. Similar advice is provided by dental health organisations (*e.g.* Oral Health Foundation: http://bit.ly/1JS03GC). The portion size is 30 g because this is the weight equivalent of 80 g of fresh fruit.

Expanding on advice in the Eatwell Guide, the *Quick Guide to the Government's Healthy Eating Recommendations* gives advice on restricting consumption of dried fruit, fruit and vegetable juices and smoothies to meals, rather than having them between meals, in order to reduce the risk of tooth decay (PHE 2017a). While advice is given to eat foods that are high in fat, salt and sugars (products such as chocolate, cakes, biscuits and sugars-sweetened soft drinks) 'less often and in small amounts', 'infrequently' and to 'avoid' them (PHE 2017a), no specific advice is applied about timing of consumption – yet these foods, which contain free sugars, are likely to be eaten between meals. Additionally, to encourage consumers to cut down on sugar, in relation to snacking NHS choices advises cutting down to one biscuit or one snack bar instead of two, while stating that dried fruit is best kept to mealtimes (NHS Choices 2017). However, dried fruit may offer a relatively 'healthy' alternative for snacking, as a source of fibre and several micronutrients.

Summary of the evidence on dried fruit and dental health

Dental caries result from the action of organic acids (such as lactic acid) at the tooth surfaces. These acids

result from fermentation (by bacteria present in dental plaque) of dietary sugars and of sugars released from fermentable carbohydrates by the action of amylase (Touger-Decker & van Loveren 2003; Moynihan & Petersen 2004; van Loveren *et al.* 2012). A recent review of the evidence on dried fruit and dental health found a lack of good quality studies to support the advice to restrict intake to mealtimes (Sadler 2016). Relevant endpoints in studies assessing effects of foods on dental health are dental caries *per se*, net demineralisation and acidogenicity (measured by interproximal plaque pH, acid production or plaque pH *per se*). Another relevant measure is food retention or oral clearance, which has been investigated in terms of carbohydrate retention, weight of food retained and rate of oral clearance (Table 2).

As would be expected, no intervention studies were found that tested the effects of dried fruit on dental caries endpoints as gaining ethical approval would be difficult (Horowitz 1976). The relationship between dried fruit intake and dental health can be assessed in epidemiological studies, but no informative cohort studies were identified in the review. One issue that makes epidemiological studies in this area challenging is the generally low consumption of dried fruits. Animal studies might be potentially useful in filling this gap, but how meaningful the results are to humans is questionable since animals have different salivary flow rates and tooth morphology (Moynihan & Petersen 2004) and the generally high frequency of consumption of individual test foods in the studies (17–18 times per day) provides an unrealistic comparison with human eating patterns (Touyz 1983; Mundorff *et al.* 1990).

Measuring net demineralisation is the most useful proxy measure of the potential to cause dental caries as this encompasses the balance of effects occurring in the mouth following an eating occasion, including the protective effects of saliva and remineralisation, as well as demineralisation of the tooth enamel. A study using this methodology compared the effects of whole raisins with various fresh fruit and vegetables, presented in both juice and whole forms (Issa *et al.* 2011). The test foods were consumed seven times a day over 10 days, which is unlikely to represent typical consumption patterns of such foods. Statistically significant net demineralisation was observed for all test foods compared with the sorbitol control, and the results were not significantly different from the positive control (sucrose), suggesting that dried fruits were no worse for teeth than fresh fruit under these consumption conditions. It is generally considered that fresh fruit is of low cariogenicity (*i.e.* has low potential to produce dental caries) (Rugg-Gunn 1993). Although the results in the study by Issa *et al.* (2011) seem contrary to conventional wisdom, Edgar (1993) noted that the cariogenic potential of fresh fruit may be influenced by their frequency of consumption.

Studies investigating the effects of dried fruits on interproximal plaque pH, a measure of acidogenic potential, have shown inconsistent results. Two studies with only five subjects each found that pH fell below 5.5 after eating raisins (Jensen 1986; Park *et al.* 1990). It is considered harmful to teeth if pH falls below 5.5 within 30 minutes after consumption of a food (area under the Stephan curve; Stephan & Miller 1943). However, a third study in 20 children found that pH remained above 5.5 for each of the test foods, which included raisins alone and raisins with bran flakes (Utreja *et al.* 2009).

A study involving 19 subjects measured pH in plaque samples after consumption of 54 snack foods, which included dates and raisins (Edgar *et al.* 1975). The foods were assigned to six groups according to the minimum plaque pH measured, adjusted for the type of pH curve observed (normal, prolonged pH fall or brief pH fall). Raisins and dates were assigned to group 4 (group 1 foods being of low acidogenic potential) along with cereal, wholemeal bread, apple juice and orange juice, which were found to be less acidogenic than apple pie (group 5) and hard candies (group 6). A further study measured glucose and lactic acid concentrations in oral fluid samples following consumption of six test foods, including raisins, but did not measure pH changes (Linke *et al.* 1997). Mean lactic acid production over 2 hours was highest for raisins, peaking at 30 minutes, whereas lactic acid production at the time point of 120 minutes was lowest for raisins. A sixth study that met the inclusion criteria for the review by Sadler (2016) did not provide any reliable information as it was designed to develop experimental techniques (Bibby *et al.* 1951).

The main reason for the advice to restrict dried fruits to meal occasions is that they are thought to 'stick' to teeth. However, very few studies have investigated this. One was the early study (Bibby *et al.* 1951) that set out to develop methodology, so no reliable conclusions on retention can be drawn from this study. Edgar *et al.* (1975) ranked 48 different foods by retention of carbohydrate 5 minutes after eating, the lowest ranking being the least retained. Each of the 48 foods was tested in three young adults. Dates were ranked 15th and raisins 29th. Kashket *et al.* (1991) compared subjective consumer perceptions of

Table 2 Effects of snack foods on plaque pH, acidogenicity and oral clearance in studies testing dried fruit

	Method	No. subjects	Test foods	Results
Retention/oral clearance				
Edgar *et al.* (1975)	Mouth rinses and tooth brushing, 5 minutes after eating test food; foods ranked by 5-minute carbohydrate retained	*n* = 3 per test food	Ju-ju toys; orange giant jellies; sandwich cookies; unsalted crackers; mint candy; plain cookies; graham crackers; pound cake; dark chocolate; chocolate cake; oil-sprayed crackers; bread and jelly (jam); Twinkies; apple pie; caramel; milk chocolate; sponge cake; saltine crackers; sugar-coated gum; raisins; angel food cake; bread and butter; white bread; licorice drops; orange sourballs; wholewheat bread; doughnut; astro food; cereal; bagel; cherry sucker; potato chips; banana; dates; apple; chocolate graham; rock candy; milk; Coca-Cola; chocolate milk; apple juice; licorice bites; 7Up; Dentyne; peanuts; orange juice; sweetees; Trident	48 snack foods tested are listed in order of ranking (highest carbohydrate retention first)
Bibby *et al.* (1951)	Mouth and tooth-brushing washings collected for measurement of retained weight of food particles	*n* = 5	Breads and bread products; cereal products; crackers; cookies; desserts; candies and soda; fruit and vegetables	Study designed to develop methodology; no reliable conclusions could be drawn
Kashket *et al.* (1991)	Subjective consumer perception of 'stickiness' of 21 foods	*n* = 315	Caramels; jelly beans; chocolate-caramel-peanut bars; chocolate-caramel bars; hot fudge sundaes; peanut butter crackers; dried figs; milk chocolate bars; raisins; granola bars; creme sandwich cookies; creme-filled sponge cake; oatmeal cookies; plain doughnuts; sugared cereal flakes; white bread; potato chips; salted crackers; bananas; puffed oat cereal; apples	Test foods are listed in order of perceived stickiness from most sticky (first) to least sticky (last)
Kashket *et al.* (1991)	Oral clearance rate (regression coefficient) based on weight of food retained	*n* = 5	Granola bars; oatmeal cookies; sugared cereal flakes; potato chips; salted crackers; puffed oat cereal; creme sandwich cookies; peanut butter crackers; dried figs; plain doughnuts; jelly beans chocolate-caramel-peanut bars; raisins; chocolate-caramel bars; white bread; caramels; creme-filled sponge cake; bananas*; hot fudge sundaes*; apples*; milk chocolate bars*	Test foods are listed in order of calculated clearance rate from most slowly cleared (first) to most rapidly cleared (last) Correlation coefficient for clearance rate and perceived stickiness = 0.46
Plaque pH and acidogenicity				
Jensen (1986)	Measure of interproximal plaque pH using microelectrode	*n* = 5	Raisins; milk chocolate bar; cupcake with icing; cherry pie; chocolate wafer cookie	Plaque pH fell below 5.5 within 30 minutes for all test foods; all foods thus showed demineralisation potential
Park *et al.* (1990)	Measure of interproximal plaque pH using microelectrode	*n* = 5	*Starch-containing snacks*: pretzels; potato chips; corn chips; oat cereal; granola bars *Sugar-containing snacks*: chocolate bar; cream-filled cupcake; cream-filled cookie; raisins, cherry pie	Minimum plaque pH fell below 5.5 measured over 2 hours for all test foods
Utreja *et al.* (2009)	Measure of interproximal plaque pH using microelectrode	*n* = 20	Experimental raisin bran cereal (no added sugar); raisins; bran flakes; commercial raisin bran cereal	Test foods listed in order of promoting plaque acidogenicity (least first)

Table 2 *Continued*

	Method	No. subjects	Test foods	Results
Linke *et al.* (1997)	Acidogenicity of saliva/oral fluid	*n* = 8	25 g portions of Milky Way bar; potato chips; Oreo chocolate sandwich cookie; sugar cube; raisins and jelly beans	Mean lactic acid production was highest for raisins and lowest for potato chips. Lactic acid production at 120 minutes was lowest for raisins and highest for potato chips
Edgar *et al.* (1975)	Plaque sampling and pH determination undertaken before and immediately after chewing, and at 5, 10, 15, 20 and 30 minutes after spitting the food	*n* = 19	54 foods from six food categories: beverages; fruit; bread, cookies and crackers; cakes; hard candies; soft candies	Foods were ranked into six groups of ascending acid-provoking potential according to pH minimum, adjusted for type of pH curve (normal, prolonged pH fall or brief pH fall) Group 6 (most acid-provoking potential): candies; Group 5: candies, apple pie and angel food cake; Group 4: raisins, dates, bread and jam, wholewheat bread, plain cookies, most cakes; Group 3: banana, crackers, cookies; Group 2: bread and butter, potato chips, apple, soft candies; Group 1: milk, peanuts, sugarless gum
Bibby *et al.* (1951)	*In vitro* incubation of suspensions of test foods in human saliva samples	*n* = 5	Breads and bread products, cereal products, crackers, cookies, desserts, candies and soda, fruits and vegetables	No reliable results could be drawn

*Milk chocolate, apple, hot fudge sundae and banana were rapidly cleared such that the clearance rate could not be calculated.

the stickiness of different foods against an objective measure of oral clearance based on weight of food retained. For the subjective measure, 315 adults within a wide age range were asked to rank 21 foods in order of perceived stickiness, whereas the objective measure was assessed in only five subjects, aged 18–22 years. Oral clearance of raisins was similar to that of fresh apple and banana, and lower than that of other snacks such as potato chips, crackers, biscuits and doughnuts. There was a weak correlation between the oral clearance rate and perceived stickiness ($r = 0.46$) and between perceived stickiness and salivary carbohydrate ($r = 0.54$), indicating that consumers' perception of the actual stickiness of different foods is poor.

In summary, results for an effect of dried fruit (mainly raisins) on proxy measures of demineralisation (plaque pH and acidogenicity) are inconsistent, and when net demineralisation was measured following consumption of raisins seven times a day over 10 days, fresh fruits and vegetables showed comparable effects to dried fruit, under similar conditions. As retention has been investigated in very few subjects and using different methodologies, more robust research with validated methods is needed before firm conclusions can be drawn about the retention of dried fruit and its stickiness, and hence the potential for adverse effects of dried fruit retention on teeth.

Comparison with alternative snack foods

Many of the papers investigating the effects of dried fruits, reviewed by Sadler (2016), compared the effects of a number of different snack foods on dental outcomes (Table 2). In the study by Edgar *et al.* (1975), for the endpoint of 'stickiness', a number of alternative snack foods were ranked higher for 5-minute carbohydrate retention compared with raisins, including crackers, chocolate, bread and jelly (jam), cake, cookies and various candies. Similarly, Kashket *et al.* (1991) found that oral clearance rates of cookies, potato chips and crackers were slower than for dried figs.

Studies measuring plaque pH and acidogenicity reported that all foods tested showed demineralisation potential (Jensen 1986; Park *et al.* 1990), including savoury snack foods. Further, in the study by Edgar *et al.* (1975), some sweet foods showed more potential

to reduce plaque pH than raisins. Edgar *et al.* (1975) recommended that cookies, cakes, pies and candies, which in their study resulted in the greatest falls in plaque pH, should be avoided as between-meal snacks, with the proviso that the data related to acidogenesis and not to cariogenicity at a clinical level. Although Edgar *et al.* (1975) concluded over 40 years ago that further research was needed, progress has been slow and more research is still required.

Traditional dried fruits are thus vulnerable to negative comparisons with alternative snacks that may be less nutritionally beneficial. Although many savoury snacks do not contribute to free sugars intake, some contain fermentable carbohydrate which may also have a negative impact on teeth (Moynihan & Petersen 2004).

Conclusions and further research

Overall, few studies have investigated the effects of dried fruit on dental health, and few have investigated cariogenicity and net demineralisation of dried fruit as opposed to investigation of acidogenicity. Potentially positive attributes of dried fruit for teeth are related to the production of saliva and the impact this may have on the balance between tooth demineralisation and remineralisation (Moynihan & Petersen 2004), and to polyphenol content, which may have anti-microbial effects on oral bacteria (Rivero-Cruz *et al.* 2008). These need to be considered together with potentially negative effects in further scientific studies. More in-depth investigation of adherence to teeth of foods such as dried fruit and other snack foods, in larger numbers of subjects, and the impact of adherence on dental health are also warranted, as adherence is one of the main arguments as to why dried fruit is recommended to be restricted to meals. This supposition is based on few data, and to date, there is little evidence to suggest that dried fruit is particularly worse in terms of oral clearance than alternative snack foods. As diet is important for dental health, overall there is a need for high-quality research to understand the impact of different foods and drinks on dental endpoints (Sadler 2017). More data are needed about the amount, frequency and timing of consumption of different foods and drinks, to underpin robust, evidence-based advice in this area.

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