PLANT-BASED EATING FOR CHILDREN: NUTRITIONAL CONSIDERATIONS

by Vanessa Clarkson, BSc Dietetics, MSc Food Policy
edited by Kate Roberts, MSc RD specialist dietitian in paediatrics and allergy

This fact sheet reviews the scientific evidence to ensure plant-based diets are nutritionally adequate for healthy and otherwise well children, from childhood through to and including adolescence (1-18 years old).

KEY POINTS

- There is scientific consensus that prioritising plants in the diet leads to better outcomes for the health of people and the planet.
- Plant-based diets encompass a spectrum of dietary patterns based predominantly on plant foods, including vegetables, wholegrains, legumes, nuts, seeds and fruits, and these may contain some or no animal-source foods.
- Even though the period of childhood through to adolescence presents unique challenges from a nutritional perspective, well-planned plant-based diets can meet dietary needs, even when animal-source foods are completely absent.
- The protein content and quality of plant-based diets is typically not a concern with children and adolescents, nor is the provision of sufficient total fat. However, if animal-sourced foods, particularly oily fish, are absent or minimal, attention should be given to ensuring adequate sources and proportions of essential fats are included.
- Irrespective of dietary patterns, it is advisable that all children in the UK aged 1-4 years and all at-risk groups take a year-round vitamin D supplement. Throughout the primary school years and into adolescence, a daily vitamin D supplement should be taken during the autumn and winter months (September through to April).
- Calcium intakes are typically not compromised with plant-based eating; well-absorbed calcium-fortified alternatives are readily available, as are plant food sources of calcium such as green leafy vegetables and cereal products.
- There does not appear to be a clear difference in iron and zinc status across vegetarian and omnivorous populations, suggesting it is plausible to consume adequate amounts of each with plant-based diets, even with potentially reduced bioavailability. However, attention should be paid to intakes in adolescents, particularly girls, as a considerable proportion of this population group in the UK consume suboptimal amounts.
- Vitamin B12 is found exclusively in foods of animal origin and is therefore completely absent in vegan diets. A reliable source is essential such as fortified foods, or more preferably, a regular supplement, must be included. Diets that contain varying amounts of animal-source foods may provide sufficient B12, and if not, this can be boosted by including fortified foods or a supplement, if necessary.
- In plant-based diets where milk and milk products and/or fish may be limited or completely excluded, consideration should be given to ensuring adequate iodine intakes, such as through the inclusion of iodine-fortified products or a supplement, depending on individual needs.

HEALTHY DIETS FROM SUSTAINABLE FOOD SYSTEMS

There is an urgent need to re-orientate the food system and dietary patterns to those that are sensitive to planetary health – that is the health of the people and natural systems on which humans depend. In practice, one part of this transition involves an overall shift towards producing and consuming more plant- and less animal-source foods. Animals are an integral part of earth system dynamics, however, as developed economies have shifted towards increased consumption of animal-source foods, this has created a potential to overshoot planetary boundaries (for water usage and quality, greenhouse gas emissions and so on), if they aren't already.

DEFINING SUSTAINABLE DIETS

The Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO) recently defined sustainable healthy diets as: *"Dietary patterns that promote all dimensions of individuals' health and wellbeing; have low environmental pressure and impact; are accessible, affordable, safe and equitable; and are culturally acceptable."* (1)

Within the recommendations from the FAO/WHO, is advice to prioritise plant foods: *"[healthy sustainable diets] include wholegrains, legumes, nuts and an abundance and variety of fruits and vegetables… and can include moderate amounts of eggs, dairy, poultry and fish; and small amounts of red meat".* (1) This predominantly plant-based guidance is consistent with the food-based dietary recommendations from many leading health authorities, including Public Health England's (PHE) Eatwell Guide, the EAT-Lancet Commission and the British Dietetic Association's (BDA) One Blue Dot® initiative.(2-4) ***It is important to note that plant-based diets do not need to completely exclude animal-source foods in order to be environmentally sustainable.***

The Eatwell Guide applies to children aged 5 years and over, and adults, and prioritises recommending plant foods, such that they should ordinarily comprise over 80% of the weight of food eaten. Equivalent guides are also available for those that choose to follow vegetarian or vegan diets.(5, 6)

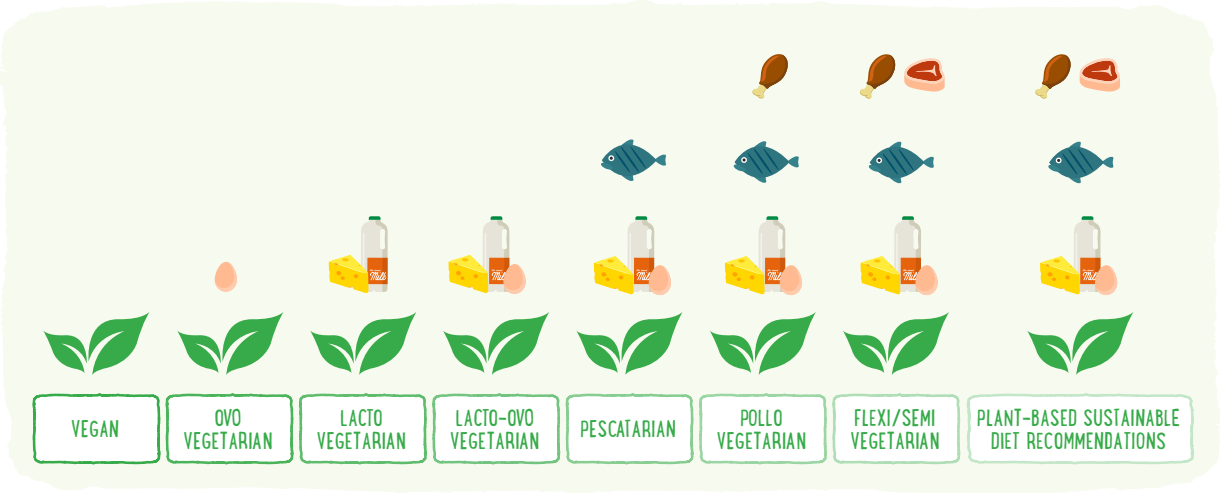
ONE BLUE DOT®

For more scientific and practical information about sustainable diets, visit the BDA OBD website (www.bda.uk.com/resource/one-blue-dot.html).(4)

DEFINING A PLANT-BASED DIET

There is no single agreed upon definition of plant-based diets *per se*, beyond the recognition that they are comprised predominantly of plant foods. The BDA defines such foodways as being *"based on foods derived from plants, including vegetables, wholegrains, legumes, nuts, seeds and fruits, with few or no animal products".*(7) Thus, plant-based dietary patterns exist on a spectrum from those that may include moderate amounts of animal-source foods, to those that are completely plant-based (Figure 1). Breastmilk is not excluded from any plant-based dietary pattern, including veganism.

Figure 1. Main variations of plant-based diets



Not all plant-based diets are equal

Beyond the balance of plant to animal-source foods, it is essential not to overlook the importance of the overall quality of dietary patterns. A recent review found that plant-based diets consisting of higher amounts of low-quality plant foods such as refined grains and sugary products, were associated with an increased risk of cardiovascular disease compared to diets containing high quality plant-foods such as wholegrains, fruit, vegetables, nuts and seeds.(8)

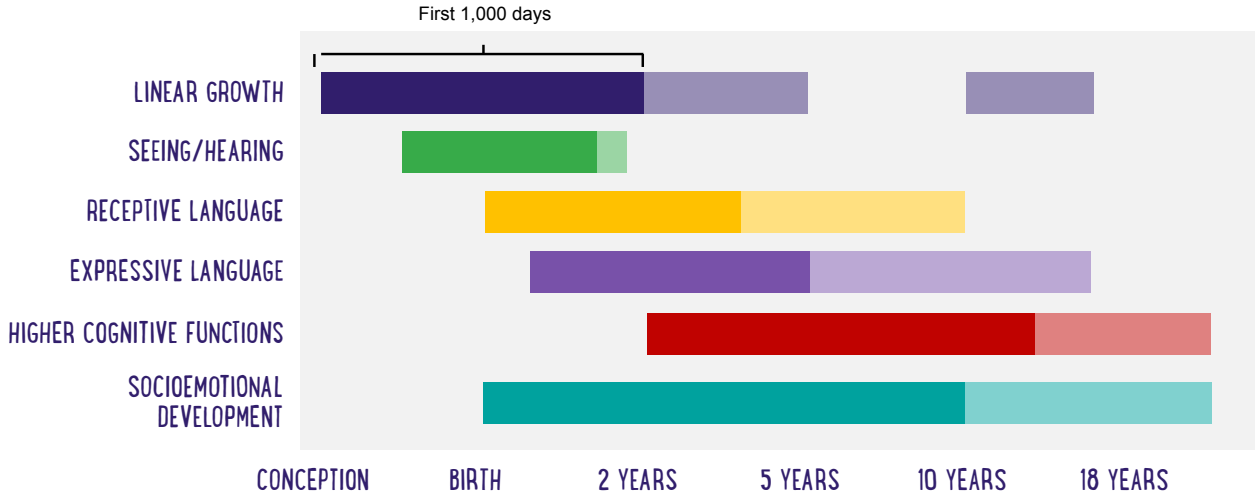
Further publications investigating plant-based diets support that the quality of the plant foods consumed play a fundamental role in mediating health outcomes.(9-11) Accordingly, a low quality, nutritionally poor plant-based diet may put an individual at a greater risk of adverse health outcomes, than an average omnivorous diet.

NUTRITION DURING CHILDHOOD & ADOLESCENCE

A recent report by the United Nations International Children's Fund (UNICEF) examined the high rates of childhood malnutrition (in all its forms) globally and noted that specifically in the UK, 1 in 3 children leave primary school in England at an unhealthy weight, with those in the most deprived areas more significantly affected.(12) At the same time, nearly 2 million children live in food poverty. Clearly, there is more work to do to improve national diets in younger generations, and supporting the consumption of more plant foods is one aspect of that.

The period from childhood through to adolescence presents unique challenges from a nutritional perspective, with requirements for many nutrients raised to optimise growth and development. The process of growth and development is punctuated by critical periods where close attention to nutritional intake is imperative (Figure 2). It is also a time during which eating behaviours including food likes and dislikes are learned, and are influenced by interactions with family members and peer groups, and these are situated within wider cultural expectations.

Figure 2. Critical periods for growth and development(13)



Notes: darker colours represent critical periods for growth and development; lighter colours are important periods and represent key opportunities for interventions. There may be potential to catch up in height relative to peers later in childhood, which is indicated by the lighter colour bar in adolescence.

SUSTAINABLE PLANT-BASED DIETS IN CHILDREN & ADOLESCENTS

Plant-based diets, even those where animal-source foods are completely absent, can meet nutritional requirements across the lifecourse.(14, 15) The majority of nutrients are found in plant foods, with only a handful of exceptions – vitamin A (retinol), vitamin B12, vitamin D, and some long-chain polyunsaturated fatty acids (PUFAs).(16) Retinol can be derived from carotenoids, which are abundant in plant foods and is therefore generally not an issue in plant-based diets provided ample colourful vegetables are included. Vitamin B12, vitamin D, PUFAs and some other nutrients such as iodine, iron, zinc and calcium, are either not present in plant foods, are found in lower quantities, are potentially less bioavailable, or are less widely distributed in the food supply. These factors, together with the specific nutritional considerations for younger age groups, are examined hereafter.

Table 1. Daily nutrient recommendations in childhood and adolescence(18)

AGE (YEARS)	1		2-3		4-6		7-10		11-14		15-18	
Gender	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Energy (kcal)	765	717	1088	1004	1482	1378	1817	1703	2500	2000	2500	2000
Fat (g)	-	-	-	-	58	54	71	66	97	78	97	78
Saturated Fat (g)	-	-	-	-	18	17	22	21	31	24	31	24
PUFA (g)	-	-	-	-	11	10	13	12	18	14	18	14
MUFA (g)	-	-	-	-	21	20	26	25	36	29	36	29
Protein (g)	15	15	15	15	20	20	28	28	42	41	55	45
Protein (% energy)	-	-	5	6	5	6	6	7	7	8	9	9
Calcium (mg)	350	350	350	350	450	450	550	550	1000	800	1000	800
Iron (mg)	6.9	6.9	6.9	6.9	6.1	6.1	8.7	8.7	11.3	14.8	11.3	14.8
Zinc (mg)	5.0	5.0	5.0	5.0	6.5	6.5	7.0	7.0	9.0	9.0	9.5	7.0
Iodine (mcg)	70	70	70	70	100	100	110	110	130	130	140	140
Selenium (mcg)	15	15	15	15	20	20	30	30	45	45	70	60
Vitamin B12 (mcg)	0.5	0.5	0.5	0.5	0.8	0.8	1.0	1.0	1.2	1.2	1.5	1.5

Note: protein % energy calculated as 1 gram protein = 4 kcal, all macronutrient data rounded to nearest whole number.

PROTEIN QUANTITY AND QUALITY

Though energy requirements in younger age groups are considerably higher than adults (relative to body weight) due to growth demands, the vast majority of dietary protein is needed for maintenance rather than growth. Consequently, when expressed as a percentage of energy intake, protein requirements for children are considerably less than adults; with requirements gradually increasing from 5% at 2 years to 9% at 18 years (Table 1).(17)

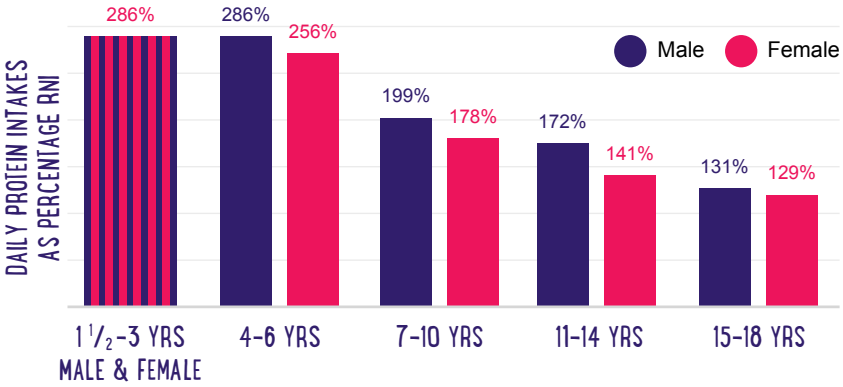
Plant sources of protein also have more rounded nutritional profiles than animal-sources, containing a broader mix of macronutrients. This means that weight-for-weight, plant foods are lower in protein than animal-sources. The overall trend in amount of protein consumed is generally as follows – meat-eaters > fish-eaters > lacto-ovo-vegetarians > vegans.(17)

Additionally, it remains a common misconception that plant foods are lacking in particular amino acids, even though this has long been determined to be false. All plant foods contain all 20 amino acids, including all 9 essential amino acids.(17, 19) In the case of lysine and methionine, in grains and legumes respectively, these are present in lower amounts in plant foods proportionate to amino acid needs. However, if these are consumed in the same 24-hour period, then their amino acid profiles will complement each other.(19)

These phenomena related to protein quantity and quality should be measured against a backdrop of increased animal-source food consumption, particularly meat, being a notable feature of the nutrition transition; the shift that populations undergo as they move to more Westernised dietary patterns. One result of the nutrition transition is that protein intakes for the general population are far in excess of estimated average requirements.

This is illustrated by the most recent data from the UK National Diet and Nutrition Survey (NDNS) which reports that mean daily protein intakes of children aged 1½-3 years is 42g, 4-10 years is 53g, and 11-18 years is 65g – all significantly more than requirements (Figure 3).(20) It is against this backdrop of elevated protein intakes, that one must consider that though protein intakes may be lower in groups that consume few or no animal-source foods, protein intakes will still be sufficient.(17) *Indeed, researchers note that it is practically impossible to fall short of protein needs when energy requirements are met and protein malnutrition is unlikely for healthy children following a balanced diet meeting energy requirements.(17)*

Figure 3. Average daily protein intakes of 1½ to 18-year-olds in the UK exceeding dietary recommendations(20)



SUMMARY

Providing energy needs are met, plant-based diets do not ordinarily present an issue in terms of providing adequate protein quantity or quality throughout childhood and adolescence.

Table 2. Plant-based food sources of protein and omega-3 (ALA) (32, 33)

PLANT FOOD SOURCES OF KEY NUTRIENTS	SERVING SIZE	QUANTITY OF NUTRIENT PER SERVING
Protein		
Soya mince/chunks¥	75g	15.7g
Tofu, firm	75g	6.1g
Mycoprotein (Quorn™)§	75g	8.2g
Legumes including peas, baked beans, and lentils (boiled and drained)	80g	4.0-7.0g
Nuts incl. peanuts*	15g	3.6g
Peanut butter	20g	4.6g
Seeds e.g. sunflower, poppy, linseeds, pumpkin and chia*	1 tbsp	2.0-2.2g
Quinoa (cooked/raw)#	75g/~25g	3.3g
Omega-3 (ALA)		
Linseeds/flaxseeds, chia seeds and hemp seeds#	1 tbsp	0.9-2.3g
Walnuts*	15g	1.1g
Rapeseed (vegetable) oil	1 tsp/3ml	0.3g
Algal oil and capsules: vegan source of EPA and DHA++	1 capsule/2ml	200-900mg EPA and DHA

Notes: *ensure nuts and large seeds are ground for younger children.
Portion sizes will vary depending on meal frequency, age, sex and level of physical activity etc.

¥Based on 6 ready-to use brands chilled or frozen. §Average across a selection of leading market brands – online.
++Based on 14 supplements currently on the market. #USDA. FoodData Central https://fdc.nal.usda.gov/

FATS

Total and saturated fats

Fats are important in the diets of children and adolescents, not least because of their energy density; they enable the provision of sufficient energy to fuel growth and development. Current nutritional recommendations assert that dietary fats should comprise 35% of energy intakes from 4 years and over. Noting that in young children, explicit advice to limit fat consumption is absent (Table 1).(18) Low fat diets (less than 25% of energy) have been shown to adversely affect weight gain and longitudinal growth in young children.(21)

The dietary fatty acid profile and food sources are also pertinent to consider. High intakes of saturated fats are associated with an increased risk of adverse health outcomes in adults and younger age groups, and therefore recommendations are that intakes should be kept within 11% of energy for 4 years and above (Table 1).(22) The NDNS reports that mean total fat intakes across younger age groups are broadly in line with recommendations at 33-34% of energy, but children and adolescents are typically consuming more saturated fat than advised.(20) A considerable amount of this comes from the consumption of nutrient-poor baked goods such as cakes, biscuits, buns and pastries, and processed meats. Reducing the consumption of these in place of more nutritious foods is an important goal.

Studies with adult populations show that vegetarian and vegan diets are usually lower in total and saturated fat than omnivorous diets, though with total fat still within a range that is typical for the broader population.(23, 24) Indeed, the lower saturated fat content of plant-based diets is one of their many features that have been highlighted as mediating better health outcomes.

Essential fats and long-chain PUFAs

Humans can synthesise saturated, monounsaturated (MUFAs) and PUFAs including the long-chain omega-3 fatty acids, eicosapentaenoic acid (20:5, EPA) and docosahexaenoic acid (22:6, DHA). However, humans cannot synthesise the plant-based short-chain omega-3 and omega-6 fatty acids – alpha-linolenic acid (18:3 omega-3, ALA) and linoleic acid (18:2 omega-6, LA). Consequently, these short-chain essential fats must be provided in the diet from plant foods

Food sources

EPA and DHA are predominantly found in oily fish. Algal oils are a notable plant-based exception as a source of EPA and DHA (algal supplements are now available).(25)

Both ALA and LA are present in plant foods; LA is ubiquitous, with sources including nuts and seeds and their oils, and cereals. Food sources of ALA are considerably more limited, and sources include linseeds (flaxseeds), chia seeds, hemp seeds, walnuts, canola/rapeseed oil, and some soya products (Table 2).

The role of short and long-chain PUFAs

Omega-6 and omega-3 fatty acids are an important structural components of cell membranes, serve as precursors to bioactive lipid mediators, and provide a source of energy. The long-chain PUFAs have multiple physiological benefits on the cardiovascular system and DHA also plays a crucial role in the development and function of the brain and retina, wherein it rapidly accumulates across the first 2 years of life.(21, 26) Another long-chain PUFA, arachidonic acid (20:4 omega-6, ARA) is also accreted in the infant brain, as well as being widely distributed throughout other vital organs and tissues in the body.(27)

The essential short-chain fatty acids (ALA and LA) can be converted to EPA and DHA in the body, thus contributing to their physiological functions. In addition, ALA has been associated with improved heart health outcomes in adults.

Conversion of ALA and LA to the long-chain omega-3 fatty acids

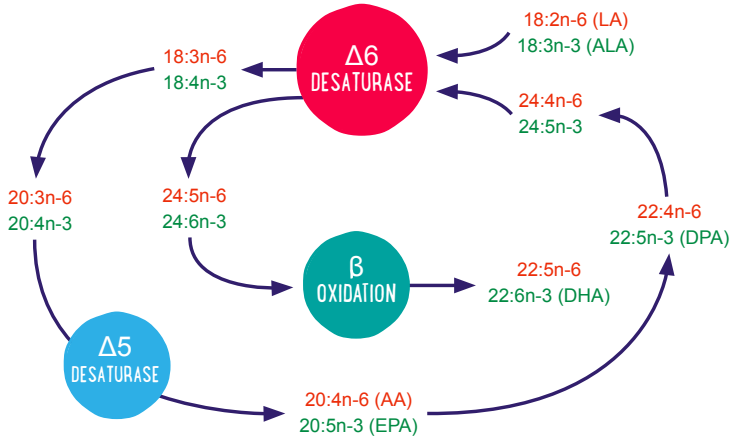
ALA and LA from plant food sources can be converted to the longer-chain EPA and DHA. However, the matter of essential fats in plant-based diets is complicated by the observation that high intakes of LA can compete with ALA for enzyme use (delta-6-desaturase), and reduce the conversion of ALA to DHA and EPA (Figure 4). Moreover, and perhaps counter-intuitively, an ALA-rich diet can actually suppress DHA synthesis, so the focus is on addressing the balance of LA to ALA and maximise the efficiency of the long-chain omega-3 metabolic pathway. It has been shown that the relative proportions of LA to ALA in the diets of infants and children can have major effects on the fatty acid profile of tissues, although the functional significance of this is unknown at the time.(29)

Getting the right balance of PUFAs from a plant-based diet

Long-chain PUFAs are not considered essential as they can be synthesised from ALA and LA. However, some concerns have been raised around the implications of a near or total reliance on ALA to synthesise sufficient long-chain PUFAs, in diets that contain few or no animal-source foods, especially fish. These concerns may be raised in young children, who may have higher requirements than adults to support the new structural lipid synthesis associated with growth.

Whilst LA is ubiquitous in the diet, food sources of ALA are considerably more limited and attention should be paid to ensure provision of appreciable amounts from plant foods, when little or no animal-source foods, particularly fish, are included in the diet.(28)

Figure 4. Synthetic pathway of long-chain omega-3 and omega-6 fatty acids(29)



Notes: delta-6-desaturase is the key regulatory enzyme because it is used twice in the conversion of ALA to DHA. On the first 'loop' it creates EPA, then DPA, and the 24 carbon metabolite derived from DPA (24:5 omega-3), is then converted to DHA on the second 'loop'. Observe the competition for this enzyme from LA, ALA and the 24:5 omega-3 precursor, to enable DHA production.

OPTIMISING PUFA INTAKES

- Government recommendations for specific PUFA intakes relate to older children and adults; 0.45g EPA/DHA daily and ALA intakes to provide at least 0.2% and LA 1% of total energy intakes.
- For children following a diet with little or no oily rich fish, the focus should be to optimise the balance of ALA to LA. Individuals should be encouraged to choose oils that are predominantly comprised of MUFAs such as olive oil, sesame oil or avocado oil, and/or ALA, including standard vegetable (rapeseed) oil, walnuts and seeds (Table 2), in preference to those that favour LA e.g. sunflower and corn oils and spreads.(30, 31)
- A review of current evidence by Sanders found that data is insufficient to justify supplementing long-chain omega-3 fatty acids in the diets of vegan or vegetarian adults, and by extension, plant-based eaters.(28) Equivalent data in children and adolescents is lacking. There are no government recommendations for omega-3 supplements.
- Such considerations are likely to be less of an issue if the diet contains appreciable amounts of DHA and EPA, such as with pesco-vegetarians and plant-based diets that include fish to PHE recommendations. It should be noted however, that fish stocks are insufficient to support such intakes for everyone, even if they are 'sustainably' managed.

SUMMARY

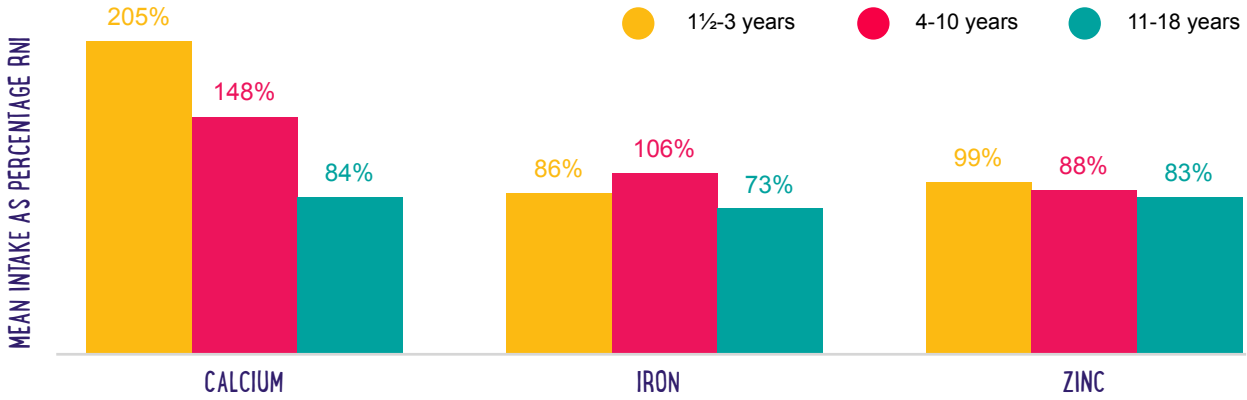
Total fat and saturated fat intakes are generally not a concern with plant-based diets, however, consideration should be given to ensuring adequate ALA when oily fish is limited or absent from the diet.

CALCIUM

Requirements for calcium are raised during childhood and adolescence to support bone deposition. Unlike with iron, where low status or increased requirements can generate increased uptake, the ability for the body to adapt to low calcium intakes is limited.(34) Adolescence is a particularly critical time when 40% of lifetime bone mass is accumulated.(34) Peak calcium-accretion rate is typically attained at 12½ years of age in girls and 14 years of age in boys.(34)

Hypocalcaemia and calcium-deficiency rickets are uncommon in healthy infants, children and adolescents.(34) According to the NDNS, calcium intakes are generally not a concern across younger age groups in the UK, with mean intakes of 718mg/day in 1½-3 years (205% Reference Nutrient Intake/RNI) and 739mg/day in 4-10 years (148% RNI) (Figure 3). Calcium is supplied primarily by milk and milk products, with these providing 57% and 44% of calcium intakes respectively.

Figure 5. Average daily intakes of key nutrients during childhood and adolescence(20)



During adolescence, when calcium requirements are at their highest, mean intakes are suboptimal at 762mg/day (84% RNI), and 11% of boys and 22% of girls aged 11-18 years have intakes below the Lower Reference Nutrient Intakes (LRNI).(20)

A large proportion of the calcium that is consumed is provided by dairy sources, with milk and milk products contributing 34% of calcium intakes in 11 to 18-year-olds. Theoretically therefore, if no, or fewer milk or milk products are consumed and not replaced by, or complemented with alternative good sources of calcium, intakes may be compromised in plant-based diets.

However, in practice, calcium-containing dairy alternative drinks and yogurts are readily available, with these usually fortified to provide an equivalent amount of calcium as is found in cow's milk (120mg/100ml), with no appreciable difference in bioavailability.(35, 36) Plant-based drinks are often also fortified with vitamin D to aid calcium absorption and support bone health. Furthermore, white and brown flour milled in the UK is fortified with calcium (alongside thiamine, nicotinic acid and iron), and therefore cereal products contribute significantly to UK diets; 36% and 39% of total dietary calcium for 4 to 10 and 11 to 18-year-olds respectively.

With dairy not entering diets until around 10,000 years ago, plants, and more specifically, wild leafy greens, provided most of the calcium in human diets across history.(37) Even in contemporary diets, it is worth noting that beyond infancy, most calcium is provided from foods other than dairy, and there is also no long-term data to suggest that calcium from dairy products is superior to other sources of calcium in terms of promoting bone health.(34) Most vegetables contain small amounts of calcium and the bioavailability of calcium from green vegetables is generally high, if not superior to calcium in dairy products, particularly if the oxalate content is low, such as with broccoli, kale, pak choi and collard greens.(38)

Reviews grouping vegans and vegetarians together as homogenous cohorts and reporting low bone health status and increased fracture risk are problematical from the outset of their design because they overlook the central role of dietary quality. Dietary patterns may contribute to diverse biological mechanisms that affect bone mineral density and risk of fracture.(39, 40) It is only recently that researchers are paying closer attention to the make-up of various plant-based dietary patterns and bone health. In a recent meta-analysis, only one included study assessed dietary quality and found that vegans in general had a better overall quality, and that when this was accounted for, there was no difference in measures of bone health across the spectrum of plant intake from vegans through to omnivores.(41, 42)

Plant-based drinks

Toddlers need less milk than in their first year of life and it is important that they do not fill up on milk before their meals; as doing so can reduce appetite and displace other foods, particularly those that are iron-rich from the protein food group.

Unsweetened, calcium-fortified plant-based drinks can be introduced as an alternative to cow's milk from age 1, in the diets of healthy toddlers, consistent with advice from PHE and others.(15, 43) The only exception to this is rice drink, which is not suitable for young children due to its inorganic arsenic content.(44) Soya drinks are higher in protein than other plant-based drinks, however, the necessary reliance on milk or plant-based alternatives as a protein source in the diets of children and adolescents in developed countries like the UK has been overstated. Plant-based drinks are generally lower in energy and fat than cow's milk, thus, for the very young consuming plant-based drinks as a main drink, consideration should be given to ensuring adequate intakes of these nutrients from other dietary sources.

As a guide, preschoolers should have around 2-3 servings from the dairy and alternatives food group where a serving is roughly:

- 120ml milk as a drink or a calcium-fortified plant-based drink
- A small (125g) pot of yogurt or calcium-fortified alternative to yogurt
- 2 small 60g pots of calcium-fortified fromage frais
- 2-4 tablespoons of grated cheese
- 2 x 60g servings of non-organic firm tofu (with calcium setting agent)

The WHO recommends that mothers should be supported to continue breastfeeding for up to 2 years and beyond, should they wish to. Breastfeeding beyond the first year to complement food intake may be particularly advantageous **for vegan infants**, as some of the components of breastmilk are not found in exclusively plant-based diets, such as long-chain PUFAs and B12.(45) Vegan infants who are not breastfed may benefit from continuation of a soya-based infant formula or a readily available soya drink with additional fortification, through to 2 years, depending on the wider dietary composition. For children not following a vegan diet, a calcium fortified plant-based drink can be introduced from 1 year.

SUMMARY

Humans have historically met their calcium needs through vegetable consumption, specifically wild leafy greens, therefore, plant-based diets can provide adequate calcium, even when dairy products are minimal or absent from the diet. Today, there is also a wide range of calcium and vitamin D-fortified plant-based drinks and other products that can be used in place of dairy products.

IRON

Iron is important to consider in plant-based diets as this is readily supplied by animal-source foods. Iron supports growth and development in childhood and recommended intakes increase considerably during adolescence, especially in girls, where the RNI is the highest across the lifecourse at 14.8mg/day (Table 1). Iron is a principal component of haemoglobin in red blood cells and as such is integral for transporting oxygen around the body. Even mild iron deficiency in younger age groups is a particular concern because if it progresses to iron deficiency anaemia, impairments in cognitive development arise, and it is unclear whether these are reversible with iron therapy.(46)

The latest NDNS data reports that iron intakes of 11 to 18-year-old girls is just half of their RNI:

- Mean intakes 8.3mg/day, 56% RNI
- Median intakes 7.9mg/day, 53% RNI

More than half (54%) of girls in this age group consume less than the LRNI of 8.0mg/day.(20)

Paying close attention to achieving adequate iron intakes during adolescence in girls is notably important. Intakes are less of a concern with teenage boys, with the data showing mean and median intakes of 89% and 86% of the RNI of 11.3mg/day respectively. In sharp contrast to girls, 12% of boys age 11-18 consume less than the LRNI of 6.1mg/day.

A review of data from industrialised countries shows that for vegetarians up to adolescence, intakes of iron are similar or higher than omnivores. This similarity may reflect the fact that cereal products are the main source of iron during childhood, and intakes of meat, even among omnivores, are usually small in early childhood.(47)

Iron bioavailability

Figures on intake do not necessarily reflect iron status. The haem iron found exclusively in animal-source foods including meat, poultry and fish, is found in higher amounts and is more readily absorbed than the non-haem iron of plant foods. Furthermore, there are components in plant foods that can act as inhibitors to iron uptake, including phenolic compounds, oxalates and phytates, which are present in some wholegrains, beans, nuts and some vegetables including spinach. Conversely, plant foods also contain an abundance of enhancers such as vitamin C, citric acid, and other organic acids that support the absorption of non-haem iron. The inclusion of some meat, poultry or fish will also enhance non-haem iron absorption.

Physiological adaptation to optimise iron status

Also of interest is that the maintenance of iron stores is controlled through the rate of absorption from the diet, with the implication being that when iron status is compromised, the body will absorb more non-haem iron from the diet. Data shows that absorption can increase 10-fold in iron-deficient compared with iron-replete individuals.(14) It has also been shown that iron replete individuals can adapt to diets with lower bioavailability. In one study, absorption increased by almost 40% from a 'low bioavailability diet' over a 10-week period.(48)

A recent systematic review of studies assessing the iron status in populations from infancy through to adolescence found wide variations in the data, although evidence from 3 of the 4 included studies on British children were suggestive that iron deficiency is an issue for some vegetarian children.(49)

SUMMARY

Iron intakes can be a particular issue for teenage girls, irrespective of whether animal-source foods are included in their diet, and therefore, particular attention needs to be taken with this group. More broadly, while iron intakes are often greater in vegetarian populations compared to omnivorous, iron status in the former seem to be lower. Whether this presents a genuine health issue is uncertain at this time. Iron intakes can be optimised through the inclusion of iron-rich plant foods at all meals (Table 3), including some animal-source foods, and/or including plenty of vitamin C in the diet through fruit and vegetables.

Table 3. Plant-based food sources for calcium, iron and zinc(33)

PLANT FOOD SOURCES OF KEY NUTRIENTS	SERVING SIZE	QUANTITY OF NUTRIENT PER SERVING
No supplements recommended for calcium, iron or zinc unless clinically indicated		
Calcium		
A handful of fortified breakfast cereals[§]	30g	142-238mg
Ready Brek[§]	20g	268mg
Calcium-fortified plant-based drinks and alternatives to yogurt[§]	100ml	120mg
Firm tofu set with calcium sulfate/chloride (E509/E516)	75g	149-300mg
Firm tofu set with Nigari (most organic variants)	75g	65mg
Baked beans, chick peas, red lentils, red kidney beans (canned and drained)	80g	34-57mg
Okra/ladies fingers and kale (cooked)	40g	48-60mg
Pak choi (cooked)	40g	29mg
Broccoli (cooked)	40g	14mg
Bakery products made with white or brown UK milled flour. Mandatory fortification with calcium carbonate	100g flour	235-390mg
Iron		
A handful of fortified breakfast cereals[§]	30g	2.2-4.4mg
Hard tofu, steamed	75g	0.9mg
Red kidney beans (canned), soya beans/red lentils (boiled)	75g	1.5-2.3mg
Baked beans	100g	1.4mg
Kale (cooked)	40g	0.8mg
Peas, baby spinach	40g	0.75mg
Dried raisins, figs, apricots, and prunes	30g	0.8-1.2mg
Nuts* incl. cashews, hazelnuts, almonds, walnuts	30g	0.9-1.9mg
Sesame or pumpkin seeds*	1 tbsp	0.7-1mg
Tahini paste	1 heaped tsp (19g)	2mg
Zinc		
Mycoprotein (Quorn™)[§]	75g	5.7mg
Wheatgerm or wholemeal bread	2 slices	1.3-1.8mg
Firm tofu	75g	0.53mg
Red lentils (boiled)	75g	0.8-1.1mg
Pecans and cashews*	15g	0.8-0.9mg
Hempseeds[#] and pumpkin seeds*	1 tbsp	0.7-1mg
Peanut butter	20g	0.6mg
Peanuts and almonds*	15g	0.5mg

Notes: *ensure nuts and large seeds are ground for younger children.
Portion sizes will vary depending on meal frequency, age, sex and level of physical activity etc.

[¥] Based on ready-to use chilled or frozen. Average from 3 leading supermarket brands. [§]Average across a selection of leading market brands – online. [#]USDA nutrient database.

ZINC

Iron and zinc share several considerations with plant-based diets in terms of dietary sources, bioavailability and requirements. Like iron, zinc is also essential and is involved in a multitude of biological processes, meaning that the health effects of deficiency can be wide ranging.(50)

In the UK, around half of zinc intakes throughout childhood and adolescence are derived from animal-source foods (meat, milk and milk products), with a further quarter to a third coming from cereals and cereal products.(20) Like iron, zinc intakes are similarly compromised in teenage girls, with more than a quarter (27%) consuming below the LRNI and mean intakes of 80% RNI (6.3mg/day) (Figure 2).(20)

Zinc may be an issue with plant-based diets depending on the amount of animal-source foods included. Plant sources of zinc also, generally, contain phytates, which inhibit zinc absorption in a similar way to iron, by forming insoluble complexes in the gut that cannot be absorbed.(47) Adopting various preparation techniques can minimise the amount of phytates in foods, boosting absorption of zinc (and iron). Examples include treatment with high temperatures (canned products), toasting, soaking and discarding the water, souring (such as grains when making bread - sourdough), and sprouting. The introduction of mycoproteins in the diet do offer an exceptionally good plant source of zinc at 5.7mg/75g compared to 5.7-7.2mg/75g for red meat.
There is also evidence that there is some adaptation to lower zinc intakes, although data in children and adolescents are lacking.(47, 51) Studies in infants and children suggest no appreciable difference in zinc intake status across omnivorous and vegetarian populations.(50) Findings are inconsistent in adolescence, and given this is a time when zinc requirements peak, additional attention should be paid at this time to ensure intakes are optimised (Table 3).(50)

SUMMARY

In a similar way to iron, zinc intakes may be compromised with plant-based diets depending on the overall dietary composition. Attention should be paid to intakes in teenage girls, and more broadly, intakes can be optimised through the regular inclusion of zinc containing foods and adapted food preparation techniques.

IODINE

Concerns have been raised about the iodine status of various population subgroups in the UK including school children, with the UK even being classified as a mildly iodine-deficient country.(52) Iodine is an essential mineral needed for the production of thyroid hormones (T4 and T3) and is indispensable for brain and neurological development. Two meta-analyses have established that iodine-deficient populations are 12-13.5 IQ points lower than in replete communities.(52) However, even marginally impaired iodine status in school children has been shown to affect cognition and school performance.(53)

Iodine is found in a range of food, however, food composition data is generally unreliable to enable an accurate assessment of intakes, as levels vary according to the iodine content of the soil in which it is grown.(54) Fish and seaweed are rich sources of iodine, though particularly in the case of marine produce, levels can vary considerably. Other key dietary sources are milk and milk products. In these, iodine is naturally only present at low levels, with the majority of it supplied through indirect fortification from animal feeds and iodine-containing antiseptic use.(53)

The NDNS reports that milk and milk products contribute 62%, 51%, and 40% of iodine intakes in 1.5-3, 4-10, and 11-18 years respectively.(20) Fish, especially white fish, are also key contributors of iodine intakes, with fish and fish dishes contributing 9%, 11%, and 10% of intakes in 1.5-3, 4-10, and 11-18 years respectively. Median urinary iodine concentrations met the WHO criteria for adequate iodine status in all age/sex groups, however, 9% of children aged 4-10 years and 12% of children aged 11-18 years had concentrations below 50mcg/L.(20)

In diets where milk and milk products, and/or fish may be limited or completely excluded, consideration should be given to ensuring adequate iodine intakes. A 2016 small sample study (n=5) using data gathered in 2012-13, found that children aged 8 to 10 years consuming plant-based drinks not fortified with iodine had significantly lower iodine status than those consuming cow's milk.(55) However, a follow-up study by the same research group concluded that iodine-fortified plant-based drinks could be considered reasonable replacements for cow's milk in terms of iodine provision.(56) Some manufacturers now fortify plant-based drinks with iodine, usually in the region of 22.5-30.0mcg/100ml.

ASSESSING IODINE STATUS

Due to the significant variability, dietary intake is not viewed as a reliable measure of iodine status. Median Urinary Iodine Concentration (UIC) is more appropriate as a status marker.

MEDIAN UIC FOR ALL AGES FROM 6 YEARS UPWARDS:

- 100-199mcg/L, considered replete
- <100mcg/L, mild deficiency
- <50mcg/L, moderate deficiency
- <20mcg/L, severe deficiency

SUMMARY

Including some dairy products and/or fish in plant-based diets can support with providing sufficient iodine. In instances where this is not the case, regular inclusion of iodine-fortified products such as some plant-based drinks, or seaweed products such as nori would be beneficial and an iodine supplement should be considered that does not exceed the RNI for the relevant age group (Table 1). Due to the risk of toxicity, seaweed-based supplements are not recommended.

Table 4. Plant-based food sources for selenium and iodine(33)

PLANT FOOD SOURCES OF KEY NUTRIENTS	SERVING SIZE	QUANTITY OF NUTRIENT PER SERVING
Selenium		
Brazil nuts*	15g (2-3)	38mcg
Sunflower or chia seeds*#	1 tbsp	3.9-5mcg
Green or brown lentils (cooked)	50g	20mcg
Rice and pasta (cooked)	75g	3.8-4mcg
Iodine		
Kelp and Kombu – not recommended. Exceptionally high in iodine (up to 5,000mcg/g dry weight) and could cause toxicity		
Red seaweed such as nori (used on sushi) and dulse contain much lower levels(32)	3g (1 sheet)	88-1,650mcg
Iodine-fortified plant-based drinks§	100ml	22.5-30mcg
Iodine supplements are recommended for children and adolescents whose diets are devoid of fish, seaweed, dairy and iodine-fortified plant-based drinks. Supplements should not exceed their daily recommended intakes (Table 1) nor should they be seaweed-based		

Notes: *ensure nuts and large seeds are ground for younger children.
Portion sizes will vary depending on meal frequency, age, sex and level of physical activity etc.

¥ Based on ready-to use chilled or frozen. Average from 3 leading supermarket brands. §Average across a selection of leading market brands – online. #USDA nutrient database.

SELENIUM

Selenium is a trace element that, like iodine, is particularly important in thyroid metabolism. It is found in both plant and animal-source foods, entering the food chain through plants, seafood (via algae), and selenium-supplemented animal feed.(57) However, the provision from foods is variable depending on the selenium content of the soil where the plants are grown.

Selenium intakes are typically adequate during childhood in the UK, with the NDNS reporting mean intakes in children age 1.5-3 years as 154% RNI, and in children age 4-10 years of 123% RNI, however, in adolescence, mean intakes are 75% RNI.(20) Selenium requirements increase in late adolescence to support growth, and this may partly reflect the suboptimal intakes seen in older age groups (Figure 5).

Most selenium in UK diets comes from cereals, meat and seafood, and intakes may be compromised if animal-source foods are limited; with the latter two together comprising between a third to half of selenium intakes, depending on age group.(20) Despite the variability in selenium content, Brazil nuts are a good source of note, with 3-6 nuts (30g) providing 76mcg, exceeding a teenager's RNI. There is limited research on selenium in childhood and adolescence and impacts of plant-based dietary patterns.

SUMMARY

Whether selenium intakes are compromised in plant-based diets depends on the overall dietary pattern, and there is limited research to suggest whether selenium intakes are compromised in vegetarian or vegan populations. Sources of selenium are shown in Table 4.

VITAMIN B12

Vitamin B12 (also known as cobalamin) is a water-soluble vitamin that is essential for DNA synthesis and prevention of megaloblastic anaemia. Deficiencies can cause problems with myelination of nerve tissue. Requirement for B12 during childhood and adolescence is relatively higher than in adults to support increased demands for growth. Exclusively found in animal-source foods including meat, poultry, seafood, eggs and dairy products, B12 is completely lacking in vegan diets unless supplements and/or fortified foods are eaten.

It is not possible to generalise as to whether B12 intakes are ordinarily sufficient in plant-based diets, where animal-source foods can make up varying amounts of the total diet. It is conceivable for vegetarians while avoiding all meat, poultry and seafood, to consume sufficient B12 through milk, yogurt, cheese and eggs, and fortified products (and by extension, people consuming all of these, plus meat more sparingly). However, the risk of suboptimal intake can be raised with plant-based diets devoid of animal-source foods, as the natural sources of B12 are lower.

The NDNS provides data on serum B12 for 4 years and over, but does not stratify this beyond age group and sex. The latest survey reported that none of the tested sample of children aged 4-10 years were deficient in B12 (<150pmol/L) and 5% of adolescents aged 11-18 years were deficient.(20)

Low or marginal B12 status is relatively more common, particularly in population groups that consume limited amounts or no animal-source foods.(58) Impaired B12 status has been shown to compromise cognitive and neurological development in children.(59) A recent systematic review assessing serum B12 levels in a spectrum of plant-based diets found very limited examination of younger age groups, and the included studies typically assessed very small sample sizes.(60) Only one study on infants and toddlers aged 10 to 20 months met the inclusion criteria. It reported B12 deficiency (defined as serum B12 <136pmol/L) in 45% of this group who were following a macrobiotic diet.

There are foods fortified with B12 which when regularly included can support with meeting B12 recommendations on plant-based diets (Table 5).(5) It is essential for vegan children and adolescents to include a reliable source of B12 in their diet, preferably a supplement (for surety), though theoretically adequate amounts can be consumed through 2-3 daily servings of fortified foods. It is desirable for parents of children consuming a vegan diet to see a registered dietitian, and for the children and adolescents to have their B12 status checked via their GP.

SUMMARY

Plant-based diets do not necessarily pose a risk to B12 intakes, with this dependent on the overall dietary pattern and inclusion of animal-source foods, which are the only natural source of this nutrient. Vitamin B12 is certainly an issue when no animal-source foods are included in the diet and in such cases, a reliable source of B12 is recommended, through fortified foods and/or preferably a daily supplement.

Table 5. Plant-based food sources for vitamins B12 and D(33)

PLANT FOOD SOURCES OF KEY NUTRIENTS	SERVING SIZE	QUANTITY OF NUTRIENT PER SERVING
Vitamin B12-fortified products		
Some breakfast cereals§	30g	0.63mcg
Plant-based drinks§	200ml	0.76mcg
Plant-based alternatives to yogurt§	150g	0.57mcg
Nutritional yeast flakes	1½g (1 tsp)	0.7mcg
Yeast extract – can be high in salt so labels should be checked	4g (spread on 2 slices)	0.96mcg
A reliable source of vitamin B12 is essential for vegan children and adolescents, preferably a supplement, although requirements may be met by including 2-3 daily servings of fortified products a day		
Vitamin D		
Sunlight exposure from April through to September in the UK is our main source of vitamin D		
Fortified breakfast cereals including multi-grain hoop variants, bran flakes, corn flakes, and most children's brands§	30g	0.75-2.5mcg
Fortified plant-based drinks§	200ml	1.5mcg
Fortified plant-based alternatives to yogurt	150g	1.1mcg
Margarine	20g	1.5mcg
A daily vitamin D supplement of 10mcg all year round for: Children age 1-4 years (consuming less than 500ml infant or follow-on formula daily) AND at risk children and adolescents with little or no sun exposure e.g. individuals whose everyday clothing covers most of their skin or those with dark skin. **A daily vitamin D supplement of 10mcg between October and March for older children and teenagers**		

Notes: *ensure nuts and large seeds are ground for younger children.

Portion sizes will vary depending on meal frequency, age, sex and level of physical activity etc.

¥Based on ready-to use chilled or frozen. Average from 3 leading supermarket brands. §Average across a selection of leading market brands – online. ǂUSDA nutrient database.

VITAMIN D

Vitamin D is a key nutrient, along with calcium, needed for bone, dental and immune health and is one of the components of oily fish that has been partly attributed to some of its positive health effects. With the exception of oily fish and cod liver oil, there are few other dietary sources, such as egg yolks, meat and liver, which provide appreciably lower quantities of vitamin D.

Some foods are now fortified such as margarines (noting previous discussion of essential fatty acids), a few breakfast cereals, plant-based drinks and yogurt alternatives. Mushrooms are an interesting exception as a unique plant source, which can contain appreciable amounts of vitamin D upon exposure to UV light (above 10mcg/100g fresh weight).(61) Unlike the US and some other European countries, dairy products in the UK are not a source of vitamin D as they are not fortified as standard.

The key source of vitamin D is the conversion of 7-dehydrocholesterol under the skin by UVB sunrays of specific wavelengths, which in the UK occur from April through to September. Dietary sources and supplements of vitamin D become more important in the autumn and winter months (from October to early March). Unfortunately, food sources of vitamin D are limited, and intakes are poor across all dietary patterns in the UK.

The government recommends an all-year round daily supplement containing 10mcg of vitamin D for:(62)

- All 1 to 4-year-olds taking less than 500ml infant or follow-on formula daily
- All at-risk children and adolescents with little or no sun exposure such as individuals whose everyday clothing covers most of their skin or those with dark skin (e.g. African or South Asian background). High melanin levels interfere with dermal vitamin D production

SUMMARY

There are few natural food sources of vitamin D, and intakes in the UK are generally poor across all dietary patterns. The government recommends a year-round vitamin D supplement for all children age 1-4 years, and from 5 years and over, supplementation continues in at-risk groups, and from September to April for the general population.

SUPPLEMENT RECOMMENDATIONS

All children aged 6 months to 5 years. The government recommends a daily vitamin supplement containing **vitamins A, C and D** unless 500ml or more of infant formula is being consumed daily.

All children (5 years and older) and adolescents, during the months of September through to March, the government recommends a daily 10mcg **vitamin D** supplement.

Children (5 years and older) and adolescents with dark skin, those who wear clothing that cover up the majority of their skin and those who have little to no exposure to sunlight from March through to September. The government recommends an all-year **vitamin D** daily supplement of 10mcg.

Children and adolescents not consuming fish, seaweed, dairy and iodine fortified plant-based drinks. An **iodine** supplement that does not exceed their daily recommended intake (Table 1) and one not based on seaweed is advised.

Children and adolescents following a vegan plant-based dietary plan:

- A **vitamin B12** supplement is recommended.
- The **Vegan Society produces a chewable vitamin supplement called VEG 1**. Half of a supplement provides 12.5mcg vitamin B12, 10mcg vitamin D, 0.8mg riboflavin, 100mcg folic acid, 1mcg vitamin B6, 30mcg selenium and 75mcg of iodine. 1-2 years, a quarter to one third tablet crushed and mixed in with food; 2-12 years, half a tablet; >12 years, 1 tablet.

CHOLINE

Choline plays a critical role in brain development and while the body can synthesise it, the extent of this is insufficient to meet requirements.(63) The US Institute of Medicine recognised choline as an essential nutrient in 1998, however, the UK does not currently outline requirements nor report on intakes through the NDNS. Choline is ubiquitous in the diet although notably high sources are liver and eggs.(63) Choline is also found in appreciable amounts in wheat germ, soya products, quinoa and broccoli.(64) Choline intakes are unlikely to be an issue in healthy, varied diets, even if completely plant-based.(65)

CONCLUSION

Reducing consumption of animal-source foods at a population level in the UK, and prioritising high quality plant foods in the diet will lead to better outcomes for people and the planet. High quality plant-based diets are appropriate for the whole population, including during childhood and adolescence, with specific nutritional considerations varying according to where on the spectrum of plant- to animal-source food consumption, an individual sits.

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