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WEANING A BABY ONTO A VEGAN DIET

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Recently there has been an increase in the number of people adopting plant-based diets in many countries, mainly out of concern for animals but also for health and environmental reasons. The substantial reduction in chronic disease and the economic and climate-change benefits that would result from the widespread adoption of a vegan diet, highlight the positive aspects of this trend (Springmann et al., 2016). However, there is a lack of international consensus on the safety and desirability of such diets for infants and children. While some authorities, including the Academy of Nutrition and Dietetics (Melina et al., 2016), the British Dietetic Association (BDA, 2017) and Australia's National Health and Medical Research Council (NHMRC, 2013) hold the position that well-planned vegan diets can be suitable for all age groups, several European authorities have discouraged the use of vegan diets for children (Federal Commission for Nutrition (FCN), 2018; Fewtrell et al., 2017; Redecillas-Ferreiro et al., 2020; Richter et al., 2016). The purpose of this article is to provide evidence-based recommendations on meeting infants' and young children's nutrient needs on a vegan diet.

Keywords: vegan, vegetarian, plant-based, infants, weaning

There has been little research on the health or nutrient intake of vegan children. Studies from the United Kingdom (Sanders, 1988), the United States (O'Connell et al., 1989) and Germany (Weder et al., 2019) have reported normal growth and development, although vegan children tended to be leaner than the reference populations. A 2017 review (Schürmann et al., 2017) of vegetarian (including vegan) diets in children concluded that there was not sufficient evidence to draw firm conclusions on the health benefits or risks of vegetarian diets or on the nutritional status of vegetarian children.

Although there is evidence that children *can* grow and develop normally on a vegan diet, there have been reports of cases of vegan infants and children experiencing serious adverse consequences attributed to nutrient deficiencies.

Deficiencies of vitamin B_{12} have resulted in developmental and neurological issues (Honzik et al., 2010) and vitamin D deficiency has resulted in rickets (James et al., 1985). Clearly, as with any type of diet, adverse consequences can result if care is not taken to meet nutrient needs.

This is an emerging area of practice and there is a need for clear guidelines on weaning babies onto a plant-based diet.

INFANT FEEDING GUIDELINES FOR VEGAN PARENTS

Most of the guidelines for the general population relating to complementary feeding also apply to infants being weaned onto a vegan diet. These include:

- considering age and readiness for introducing 'solids'
- offering one new food at a time in a form and texture appropriate for the infant's feeding skills
- the continuation of breastfeeding or the use of a commercial infant formula until 12 months of age (and beyond for breastfeeding)
- early introduction of iron-rich foods
- repeated offering of foods that have been refused in the past
- avoiding adding salt or sugar to foods
- not delaying the introduction of potential allergens
- monitoring growth and development.

Although non-dairy formula may not be 100% vegan, it is the only safe alternative to breast milk for infants. While some health authorities have advised against the use of soy formula for infants under six months of age, a 2014 review in the British Journal of Nutrition did not find evidence of adverse effects of soy formula (Vandenplas et al., 2014).

The advice given by some child health nurses and doctors to introduce infants being weaned onto a vegan diet to potential allergens to "test" if they are allergic is not appropriate as there is a risk of increased sensitisation to subsequent allergy if foods such as fish, shellfish, eggs and dairy are not consumed regularly after introduction (West, 2017) which they will not be if the child is having a vegan diet. However, as wheat, soy products, peanuts, tree nuts and seeds are good sources of nutrients for children on plant-based diets, these should be introduced at an early stage of complementary feeding and given repeatedly after introduction if there are no adverse reactions (Ierodiakonou et al, 2016). Food allergies in infants weaned onto a vegan diet can make meeting nutrient needs more

challenging, and specialised dietary advice is strongly recommended in these cases.

MEETING KEY NUTRIENT NEEDS

The essential nutrients requiring specific attention on a vegan or plant-based diet can be categorised as:

(i) Nutrients that are rarely if ever found naturally in plants: vitamins B_{12} and D

(ii) Nutrients that may have lower availability in or absorption from plant-based foods: iron, zinc, protein, vitamin A

(iii) Nutrients typically supplied largely by animal products on a western omnivorous diet: calcium, protein, omega-3 fatty acids, energy

(iv) Nutrients that the soil in some areas is low in, resulting in foods grown there being low in these nutrients: iodine and potentially selenium.

Each of these nutrients will be considered in turn.

VITAMIN B_{12}

Vitamin B_{12} is not naturally found in commonly consumed plant foods, and reports of it being found in useful amounts in mushrooms, tempeh or other fermented foods have been found to be erroneous, as most if not all of the vitamin present is in a biologically inactive analogue form (Dagnelie et al.,1991). Consequences of B_{12} deficiency in infants can include growth failure, microcephaly and developmental delay, and while response to vitamin therapy is normally rapid, delays in treatment have resulted in permanent developmental abnormalities (Honzik et al., 2010). Although breastmilk concentration of B12 is generally higher in women who are supplementing adequately, deficiency is still possible in breastfed infants in the absence of maternal deficiency, and breastmilk of vegan mothers may not be adequate to meet the needs of infants, especially from about four to six months of age (Pawlak et al., 2018). Supplementing vitamin B_{12} daily to breastfed infants of vegan mothers by no later than six months of age is recommended, and supplementing from birth is indicated if maternal intake during pregnancy was inconsistent or inadequate.

Vitamin B12 is best supplemented as a stand-alone supplement as some other nutrients in multi-nutrient supplements can convert up to 90% of the vitamin B12 into inactive analogues (Kondo et al., 1982). This can result in falsely raised levels of serum vitamin B12 and contribute to deficiency.

The amount of vitamin B12 that can be absorbed from a single dose of supplement is limited, so the amount that needs to be supplemented is much higher than the recommended intake from food.

VITAMIN D

Normally, plant-based foods do not contain vitamin D, although some foods may be fortified with it and UV-irradiated mushrooms can provide vitamin D (Cardwell et al., 2018). As vitamin D enhances the absorption of dietary calcium, deficiency can result in compromised bone growth and development. This can result in stunting and rickets, which is characterised by soft, weakened bones and can result in permanent skeletal deformities.

Traditionally, vitamin D was provided largely by the action of sunlight on bare skin, but modern lifestyles and concerns over skin damage and melanoma have resulted in reduced sun exposure and a high prevalence of deficiency globally, with 75% of newborns found to be deficient (Saraf et al., 2016). Darker skin, further distance from the equator and greater degree of skin coverage are known to be risk factors for vitamin D deficiency, but given the high prevalence of deficiency, supplementation of all infants and young children with vitamin D is prudent. There is a lack of international consensus on the dose of vitamin D supplementation for infants and children. The American Academy of Paediatrics recommends 400 IU and the UK National Health Service recommends 340-400 IU daily from birth for breastfed infants, and advises that this should continue past weaning and throughout childhood.

Not all vitamin D supplements are acceptable to vegans as vitamin D3 is typically derived from sheep's wool. However, vitamin D3 derived form vegan sources is available and vitamin D2 is generally vegan-friendly.

IRON

While iron is widespread in plant foods, the non-haem iron is not always as well absorbed as haem iron, largely due to the presence of phytates (naturally occurring compounds found in all plant foods which can reduce iron absorption). This effect of phytates can be reduced by soaking, fermenting, leavening and sprouting grains and legumes, and serving iron-rich plant foods with foods containing vitamin C and carotenes to further enhance the absorption of non-haem iron (Shubham et al., 2020). For example, parents can serve fortified cereal with berries, citrus, kiwifruit, mango, pawpaw or melon and include tofu or legumes and green vegetables in other meals and add a squeeze of lemon juice for vitamin C on serving (because vitamin C is heat sensitive and is degraded during cooking).

Deficiency of iron in infants and young children is relatively common worldwide and can result in anaemia, increased susceptibility to infections and impaired development (Shubham et al., 2020).

ZINC

As with iron, the presence of phytates in plant foods can decrease zinc absorption, while the presence of organic acids and protein can enhance absorption (Lönnerdal, 2000). Zinc deficiency can result in impaired immunity, poor wound healing, growth failure and neuro-cognitive disorders (Krebs, 2013). It is important that zinc-rich foods be provided at weaning and throughout childhood.

Zinc-fortified baby cereals (where available), tofu and other soy products, legumes and nut and seed butters should be introduced as early complementary foods and remain in the diets of vegan children. As with iron, including a source of vitamin C with each meal and limiting fibre intake will enhance absorption.

PROTEIN

While ample protein can be obtained from a varied plant-based diet, the somewhat lower digestibility and variable amino acid balance of plant proteins has led to suggestions that protein intake recommendations be increased by up to 30% for children relying on plant proteins (Mangels & Messina, 2001). Overall protein quality can be improved by ensuring different

plant sources of protein (e.g. grains and legumes) are included at each meal or no more than six hours apart (Young & Pellett, 1994).

VITAMIN A

Whereas animal products contain pre-formed vitamin A, plants provide what is known as pro-vitamin A from carotenes, which needs to be converted into vitamin A. This conversion varies between individuals, with around 45% of people having a genetic make-up that can result in a substantial reduction in their ability to convert pro-vitamin A to vitamin A (Leung et al., 2009). Therefore, those eating a vegan diet may need a higher intake of beta-carotene equivalents than typically recommended if their ability to convert to vitamin A is diminished. The foods richest in carotenes suitable for infants are cooked and pureed/mashed carrots, sweet potato, kale and spinach.

Vitamin A deficiency can result in impaired growth and development, increased susceptibility to infections, night blindness and ultimately blindness (Wiseman et al., 2017). Care should therefore be taken to include vitamin A-rich foods in weaning diets and throughout childhood.

CALCIUM

Consumers of western-style diets have traditionally obtained a substantial proportion of their total calcium intake from dairy products. However, adequate calcium can be obtained on dairy-free diets, with recommended intakes being more easily met if some calcium-fortified foods are included. For infants under 12 months, adequate calcium can be obtained from breastmilk or formula (Bae & Kratzsch, 2018). A full fat fortified soy milk can be given as a drink from 12 months of age. Other plant milks are not as rich in protein, iron and other key nutrients and are not normally recommended for infants and small children. Additional sources of calcium include calcium-set tofu, tahini, almond butter, kale, Asian greens, figs and in some areas, 'hard' calcium-rich water.

IODINE AND OTHER TRACE MINERALS

The amount of iodine in plant foods depends on where they were grown. In some parts of the world, the soil is depleted of these nutrients, resulting in a high prevalence of iodine deficiency. Deficiency in infants and young children can result in growth failure, intellectual impairment and thyroid inadequacy (Pearce et al., 2013). Seafood (including seaweeds) tends to be rich in iodine, but some seaweeds (particularly kelp/kombu) can contain dangerously high amounts of iodine and are not recommended, while others may contain excessive amounts of arsenic and other heavy metals (Cherry et al., 2019).

Lactating vegan women should supplement with 200-250 mcg of iodine per day to ensure adequate breastmilk concentration (Dror & Allen, 2018). From 12 months of age, iodised salt can be used as a reliable source of iodine for children on vegan diets. In areas where iodine intake tends to be inadequate and/or where iodised salt is unavailable or fortification levels are low, an iodine supplement may be required to meet the recommended intake.

Selenium is another essential trace element that the diets of some adult vegans have been found to be low in, although evidence of frank deficiency is lacking (Kristensen et al., 2015; Lightowler & Davies, 2000). In areas where selenium levels are low in plant foods,

the inclusion of brazil nut paste will boost intake considerably.

ESSENTIAL FATTY ACIDS

Vegan diets tend to be rich in omega-6 fatty acids, but most plant-based foods are not rich in the omega-3 fatty acids. While adequate amounts of omega-3 alpha-linolenic acid (ALA) can be obtained from a well-planned vegan diet, plants lack omega-3 docosahexaenoic acid (DHA). DHA is important for development of the brain and retina, and it appears that DHA supplementation of infants can result in long-term improvements in mental and psychomotor developmental indices and visual acuity (Shulkin et al., 2018). Most DHA supplements are derived from fish oil, but fish obtain their DHA from algae, and algal-derived DHA supplements suitable for vegans are available.

ENERGY

Meeting energy needs on a vegan diet need not be difficult but can be hampered by (i) an excessively high fibre intake and (ii) an inadequate fat intake. Legumes and whole grains are rich in fibre and low in fat, and for this reason it has been recommended that infants should be initially introduced to refined rather than whole grains, that the skin of beans be removed and high fat foods be included daily (Baroni et al., 2019).

FOOD & SUPPLEMENT INTAKE RECOMMENDATIONS

Various food planning guides specific to children on plant-based diets have been developed (Baroni et al., 2019a; Menal-Puey et al., 2019). The details vary, but it is typically recommended that vegan diets are composed predominately of foods from each of these groups:

- legumes and soy products
- grains and cereals (including iron-fortified) and potato
- vegetables
  fruit
  nut and seed pastes
  fortified plant milk (for older infants and for children)

The guidelines and meal plans below are designed to help meet infants' needs for essential nutrients and help establish them on a healthy vegan eating pattern.

ABOUT SIX MONTHS OF AGE

When the infant is ready, at around six months of age (and never less than four months) it is recommended that complementary feeding is initiated (NHMRC, 2012a). Breastmilk or formula will continue on demand/several times during the day and generally at night also.

GUIDELINES FOR INTRODUCING 'SOLIDS' (NHMRC, 2012b):

- Introduce one new food at a time, every two to three days, in a form appropriate for the baby (i.e. pureed/mashed soft foods).
- Offer foods about an hour after breastfeeding, when the baby is relaxed and not too hungry.
- Iron-rich foods are recommended as first foods.
- The following foods are suitable to introduce in the first month or so of feeding: iron fortified cereals, well-cooked pureed green and other colourful vegetables, silken tofu, red lentils, peanut butter and other nut pastes, cooked/soft fruits.

ABOUT SEVEN MONTHS OF AGE

At seven months of age, foods from each of the plant food groups can be offered every day. The recommendations and suggested meal plans below are based on current recommendations, adapted for infants on plant-based diets.

Sample meal pattern by about 7 months of age:

Meal 1: Iron-fortified baby cereal (made with water, breastmilk or formula) + fruit + 0.5 tsp flaxseed oil

Meal 2: Iron-fortified cereal + vegetable/s + tofu/red lentils + nut butter or tahini

Supplements: Vitamins. B_{12} & D, DHA as per Table 2.

EIGHT TO TWELVE MONTHS OF AGE

At eight months of age, it is recommended that food is offered before breastmilk or formula. An increasing variety of foods from each of the plant food groups should be offered every day. The amount of foods consumed will increase according to appetite. Full fat fortified soy milk can be used on cereal and in cooking

but should not replace breastmilk or formula or be used as a drink until 12 months of age.

Sample meal pattern by about 9 months of age:

Breakfast: Iron-fortified baby cereal (made with fortified soy milk) + vitamin C-rich fruit + 0.5 tsp flaxseed oil + 1 tsp peanut butter

Lunch: Iron-fortified cereal or other grain or potato + soy product/legume + colourful vegetables + a squeeze of lemon/lime juice (for vitamin C)

Dinner: Iron-fortified cereal or other grain or potato + soy product/legume + colourful vegetables + 1 tsp tahini + a squeeze of lemon/lime juice (for vitamin C)

Supplements: See Table 2 below.

FROM 12 MONTHS OF AGE

Children should be able to eat most family meals with minimal modifications. Fortified soy milk can be given as a drink, as well as used on cereal and in cooking. It is normally recommended that is formula and bottle-feeding cease at 12 months of age.

Sample meal pattern from about age 12 months:

Breakfast: Iron-fortified cereal with fortified soy milk + vitamin C-rich fruit + peanut butter + 1/2 tsp flaxseed oil (or a tsp of ground flaxseeds or chia seeds)

Snack: Drink of fortified soy milk + crackers or bread with nut butter or hummus

Lunch: Grain product + soy product/legume* + green vegetable + red/orange/yellow vegetable + source of vitamin C (e.g. raw tomato)

Snack: Drink of fortified soy milk plus fresh fruit

Dinner: Grain/ potato + soy product/legume* + green vegetable + red/orange/yellow vegetable + high fat food (e.g. nut butter, tahini, avocado) + source of vitamin C (e.g. lemon/lime juice)

*Many commercial 'meat alternative' products are now available, some of which may be suitable for occasional use as main meal foods. Ideally, they should have legumes or soy product as the main ingredient, be fortified with iron and zinc, and be low in sodium.

Supplements: See Table 2 below.

SUGGESTED AMOUNTS OF FOODS

As infants (under 12 months) obtain a substantial proportion of their nutrition from breastmilk or formula, specific quantities of foods are not normally provided in infant feeding guides. The guidelines in Table 1 for children from 12 months of age are designed to meet recommended intakes of essential nutrients as laid down by the European Food Safety Authority (2017), the British Nutrition Foundation

(2015), the NHMRC in Australia (2014) and the Institute of Medicine (2006) in North America.

The amounts are minimums and are expressed in standard metric cups (250 ml) for ease of use. Upper limits are given for iodised salt (due to the need to limit sodium intake), fruit (due to its lower nutrient content and tendency to displace other more nutritious foods) and soy milk (due to its tendency to displace solid food).

Table 1: Amount of foods required to meet recommended intakes of most key essential nutrients for one to three-year old children (European Food Safety Authority, 2017; British Nutrition Foundation, 2015; NHMRC, 2014; Institute of Medicine, 2006)

Food Group	Recommended amount per day*
Iron-fortified cereals/ other iron-fortified grain-based foods	½ cup+
Other grain products (eg pasta, rice, bread), potato. (1 sl. bread equiv. to ½ cup cooked grain)	½ cup+
Green vegetables	½ cup+
Red/orange/yellow vegetables	½ cup+
Tofu, tempeh, legumes	½ cup+
Nut and seed pastes**	1 tbsp+
Fresh fruit	½ - 1 cup
Fortified soy milk	1.5-2 cups
Iodised salt	¼ - 1/3 tsp***
Other high fat foods (e.g. avocado, coconut yoghurt/ cream, oil)	0-discretionary/ as required
*measured in form eaten (e.g. cooked), 1 cup = 250 ml. + these are minimum amounts, and more can be offered according to appetite **include equivalent of ¼ brazil nut in areas where soil selenium is low, and 1 tsp ground flaxseeds/ chia seeds if DHA is not supplemented regularly ***amount will depend on local fortification practices	

The lower amounts specified in Table 1 provide 35 grams of protein and 3325 kJ (795 calories). This meets the estimated requirements of a moderately active one-year old. Additional energy can be provided with extra servings of grains, legumes/soy products and high fat foods, as required. The plan provides 18% of energy from protein and 36% of energy from fat and meets the recommended intake for the following nutrients for a one to three-year old: protein, total fat, fibre, vitamins A, B_1, B_2, B_3, B_6, B_9, B_{12}, C, E, iron, zinc, calcium, phosphorus, magnesium, iodine, selenium, linoleic acid and ALA. The plan does not meet the recommended amount of vitamin D or DHA, and although the fortified soy milk may provide the recommended daily intake (RDI) of vitamin B_{12}, it is recommended that this also be supplemented as a precaution.

Table 2: Recommended supplementation for infants and children on a vegan diet to meet intake recommendations for essential nutrients (European Food Safety Authority, 2017; British Nutrition Foundation, 2015; NHMRC, 2014; Institute of Medicine, 2006)

NUTRIENT	AGE	
	6-12 months	**1-3 years**
Vitamin B_{12}	5 mcg	5 mcg
Vitamin D	400 IU if breastfed	400-600 IU
Iodine	From breastmilk* / formula	Approx. 90 mcg from iodised salt/ fortified foods/ supplement
ALA	0.5 tsp flaxseed oil	0.5 tsp flaxseed oil or 1 tsp flaxseeds or chia seeds
DHA*	100 mg	100 -250 mg
Calcium	From breastmilk and formula	From fortified foods (e.g. fortified soy milk, approx. 375 ml/day)
Iron	Iron-fortified baby cereal	Iron-fortified foods/ iron-rich foods at every meal, served with a source of vitamin C; otherwise supplement may be required
*If DHA is not supplemented regularly (e.g. due to cost constraints), increasing the amount of ALA may help compensate.		

POINTS TO NOTE

- **Nutrient content of foods varies depending on where they were grown and whether fortified.**
- **Food fortification legislation and practices vary widely between regions.**
- **It is important to read labels carefully when choosing fortified foods.**
- **Recommendations developed for one region may be unsuitable for another.**

All authorities agree that a vegan diet for infants and children should be well-planned and nutrient supplementation (via fortified foods or supplements) is essential.

SUMMARY

The diets of infants weaned onto a vegan diet need to be appropriately planned to ensure requirements are met for key nutrients. Vitamins B_{12} and D should be supplemented, and care taken to ensure an adequate intake of iron, zinc, protein, energy, vitamin A and omega-3 fatty acids. Breastmilk or formula can provide adequate calcium and iodine for infants, but from 12 months of age, foods fortified in these nutrients should be included to assist in meeting requirements. Calcium-fortified soy milk can be given as a drink and iodised salt used from 12 months of age. In some countries, iodine supplements may be required to meet recommended intakes. While flaxseed oil can provide adequate amounts of omega-3 alpha-linolenic acid (ALA), supplementation with docosa-hexanoic acid (DHA) is required to meet WHO

recommended intakes. Care should be taken to avoid excessive fibre intake and to provide adequate high fat foods to enhance calorie intake.

The variable rates of fortification of foods and content of trace minerals between countries add complexity to the attainment of an adequate nutrient intake for vegans. It is recommended that if possible, specialised advice be sought from local nutrition experts well-versed in plant-based nutrition when infants are to be weaned onto a vegan diet.

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