Dairy and plant-based milk alternatives as part of a more sustainable diet

Position statement of the German Nutrition Society (DGE)

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Abstract

This DGE position statement elucidates the significance of dairy (cow's milk and products produced from it) in dietary habits and provides a contextual framework for the comparison of plant-based milk alternatives (PBMA) with cow's milk in regard to the dimensions of a more sustainable diet, primarily health and environmental impact.

Dairy is a common component of the diet in Germany, providing essential nutrients, particularly calcium, iodine, vitamin B_{12} and riboflavin, and exerting other beneficial effects on human health. The nutrient profiles of PBMA differ considerably from that of cow's milk, particularly in the absence of fortification with nutrients. The bioavailability of added nutrients can vary. PBMA contain less saturated fatty acids than cow's milk and no cholesterol, but some contain phytochemicals and fibre. The heterogeneity of PBMA complicates the drawing of any definitive conclusions related to health.

Production of animal-source foods has a considerable environmental impact. On average, PBMA have lower values for greenhouse gas emissions, water and land use than cow's milk.

Given the beneficial effects of dairy on human health, the DGE recommends their daily intake. For individuals who consume minimal or no dairy or who exceed the recommended intake, the DGE advocates the use of PBMA. This contributes to reduce the diet-induced impact on the environment. When choosing PBMA, it is crucial to consider the fortification with essential nutrients (particularly calcium, iodine, vitamin B_{12} and riboflavin) or to ensure the intake of these nutrients from alternative sources. This is particularly relevant for individuals who opt for PBMA instead of cow's milk, either partially or entirely.

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Introduction

Dairy, which comprises cow's milk and products produced from it, is a common component of the diet in Germany. On average, milk (products) (◆ Box 1) account for 10% of daily energy intake [1–3]. The 2023 Nutrition Report of the Federal Ministry of Food and Agriculture (*Bundesministerium für Ernährung und Landwirtschaft*, BMEL) revealed that 58% of respondents consume milk products on a daily basis [4]. Dairy provides essential nutrients, particularly calcium, iodine, vitamin B_{12} and riboflavin. Its intake is associated with a lower risk of nutrition-related diseases such as colorectal cancer and high blood pressure as

well as improved bone mineral density. Given these benefits, milk (products) are also included in the food-based dietary guidelines (FBDGs) of the German Nutrition Society (DGE) [5].
A variety of plant-based alternatives to milk (products) are currently commercially available. The largest category of these products consists of plant-based milk alternatives (PBMA) (also known as plant-based drinks) [6]. A market survey conducted by the Consumer Association of North Rhine-Westphalia *(Verbraucherzentrale NRW)* in 2021 identified 71 PBMA [7]. Both, within this product group as well as in the comparison to plant-based alternatives to milk products, there are considerable differences in the composition of these foods. While plant-based drinks and yoghurt alternatives are primarily produced from legumes, nuts or grains, the predominant ingredient of numerous plant-based cheese alternatives is vegetable oil [8, 9]. Moreover, the market for these products is characterised by rapid product development and changes of composition, with significant modifications within a few years. [10]. In the past, these products were primarily consumed by individuals with lactose intolerance, cow's milk protein allergies or in a vegan diet [11, 12]. Recently, trends in advertising for these foods have shifted towards addressing the environmental impact and animal welfare compared with dairy [12], as well as health aspects [8].

The aim of this DGE position statement is to elucidate the significance of cow's milk and products produced from it in the diet of the German population and to provide a contextual framework for the comparison of plant-based milk alternatives with cow's milk in regard to the dimensions of a more sustainable diet. The dimensions of health and environment are the primary focus. Certain facets of the dimensions of social aspects and animal welfare are also considered (see [13]).

Given the large heterogeneity of plant-based dairy alternatives and the evolving supply, a comprehensive comparison of all product groups is not feasible. This DGE position statement thus concentrates on plant-based drinks, which constitute the largest product group among plant-based dairy alternatives. Conversely, an exclusive focus on cow's milk is insufficient. Dairy products are made from cow's milk. Thus, cow's milk utilised in their production must be considered, especially in assessment of the environmental impact of cow's milk, but also in the supply of nutrients. Furthermore, a notable shift in the consumption of milk towards cheese has been observed in recent years [14].
Considering the aforementioned factors, recommendations for action are made for the selection and intake of PBMA as part of a healthy and sustainable diet. It should be noted that the scope of the DGE position statement does not extend to the evaluation of individual product groups such as oat drinks nor specific raw materials for PBMA such as soy, their suitability for specific population groups (especially infants) or plant-based yoghurt and cheese alternatives.

Box 1: **Definitions**

The term milk is legally protected in European law: "'Milk' means exclusively the normal mammary secretion obtained from one or more milkings [...]." [15].
This DGE position statement addresses intake of **cow's milk**. However, in some publications, particularly nutrition surveys, no distinction is made between intake of milk (products) derived from cows and those from other animals. Milk (products) made from cow's milk are in this paper referred to as dairy. The term **milk (products)** is used when it is unclear whether the milk and products in question are exclusively from cows. Cow's milk and products produced from it are the predominant form of consumption.

Intake and consumption of milk (products) in Germany

The expression of food quantities can be classified according to the objective, and thus food quantities can be expressed as intake or consumption, depending on the context. Intake data are obtained from nutritional surveys and are usually reported as average intakes. Consumption data indicate the amount of food available in a country over a given period of time. They also include quantities not consumed as food, such as those used as industrial raw materials or discarded before intake. Consumption data are used, for example, to assess the environmental impact of agricultural production. However, they are not suitable to assess the actual nutrient supply of the population [16–18]. It is possible to approximate consumption data to the actual food intake by applying appropriate factors, e.g., for waste [19]. In some cases, the same terminology is used to describe both consumption and intake.

Intake of milk (products) in Germany

The most recent representative dietary survey of the adult population in Germany was conducted as part of the German National Nutrition Survey II (*Nationale Verzehrsstudie II*, NVS II) between November 2005 and January

2007. The average amount of milk (products) consumed[1] was approximately 200 g per day, with milk accounting for almost half of this amount [2]. The German National Nutrition Monitoring (*Nationales Ernährungsmonitoring*, NEMONIT), which was set up as a follow-up survey, found no statistically significant changes in milk (product) intake between 2005 and 2013 [3].

The EsKiMo II study (the eating study as a KiGGS [German Health Interview and Examination Survey for Children and Adolescents, *Studie zur Gesundheit von Kindern und Jugendlichen in Deutschland*] module; 2015–2017) collected representative data on dietary intakes of children and adolescents in Germany aged between 6 and 17 years. According to the data, the average daily intake of milk (products) by girls and boys in this age group was around 200–320 g. A comparison of the data from the first EsKiMo study (2003–2006) with the subsequent dataset showed a decline in the average intake of milk (products) by children and adolescents, with a reduction of 15–31% observed for both girls and boys [1].

The Children's Nutrition Survey to Record Food Consumption (*Ernährungsstudie zur Erfassung des Lebensmittelverzehrs*, KiESEL – study as part of the second wave of KiGGS) recorded the diet of children aged from 6 months to 5 years between 2014 and 2017. The average intake of milk (products)[3], expressed in milk equivalents, was 206–234 g per day, and including sweetened milk products[2] 265–307 g per day [20]. The food frequency questionnaire also included the frequency of intake of PBMA derived from soy, oats and rice. In total, 7% of the children consumed PBMA made from soy or oats and 4% based on rice. About 4% of infants and 1% of children frequently ("once a week" or more) consumed PBMA made from oats, while about 3% of children frequently consumed PBMA made from soy [21, 22]. To date, there has been no publication of data on the intake of PBMA.

No data on the intake of PBMA were published in the results of the NVS II or EsKiMo II study [1, 2].

Consumption of milk (products) in Germany

In Germany, the BMEL is responsible for the publication of annual consumption data in the Statistical Yearbook of Food, Agriculture and Forestry *(Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten)* [16]. This agricultural statistic is therefore the basis for analysing trends in food consumption.

In 2022, the amount of fresh milk products[5] available for human consumption per capita in Germany according to agricultural statistics[6] was approximately 83 kg per year, which corresponds to about 230 g per day. The available amount of drinking milk per capita was about 46 kg per year, which equals to about 130 g per day. The available amount of cheese per capita was about 25 kg per year, which corresponds to about 70 g per day. Between 2000 and 2022, the amount of milk available decreased and the amount of cheese available increased [14].

Milk per capita consumption is much higher than the actual intake. In addition to human consumption, milk is used to produce animal feeds such as milk replacer and cat milk. It is also used to produce adhesives and bioplastics. When comparing different data, it is important to take into account the reference year, the food products included (e.g., milk only or including milk products; with or without butter in the case of milk products) and the database.

Comparison of dairy and plant-based milk alternatives in the dimensions of a more sustainable diet

PBMA resemble cow's milk in terms of their sensory properties and their use in cooking and baking, as well as hot and cold intake. In terms of taste, they differ to varying extents from cow's milk [23]. In some cases, PBMA are selectively matched to the nutritional profile of cow's milk by fortification with vitamins and minerals. The range of products is expanding. For example, some products are enriched with additional protein or with functional properties that are required to produce certain coffee drinks. In addition, some products are available as full-fat and low-fat alternatives [12, 24]. Organic PBMA are normally not fortified. According to the EU Organic Regulation, fortification with vitamins and minerals is only allowed if required by law. Therefore, PBMA could only be fortified with nutrients by adding nutrient-rich ingredients such as algae[7] [25].

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[1] Milk, mixed milk drinks and milk products including yoghurt, (sour) cream, buttermilk, kefir, whey, cheese, quark and butter

[2] Milk and milk products including yoghurt, buttermilk, cheese and quark

[3] Milk and milk products: unsweetened milk and dairy products, quark, cheese, breast milk, milk-based drinks, infant formula and follow-on formula, processed foods with milk as the main ingredient

[4] Sweetened milk products: mainly sweetened yoghurt and quark

[5] Fresh milk products: drinking milk (whole milk, semi-skimmed milk, skimmed milk and other drinking milk), milk produced and used on farms, buttermilk products, sour milk, kefir, yoghurt and mixed milk products, mixed milk drinks and cream products

[6] Production + Import – Export

[7] The European Commission has recently clarified in its FAQ that *Lithothamnium calcareumis* cannot be used in all organic processed food, as its primary function is the addition of calcium (https://agriculture.ec.europa.eu/farming/organic-farming/organics-glance_en; version dated 06.05.2025).

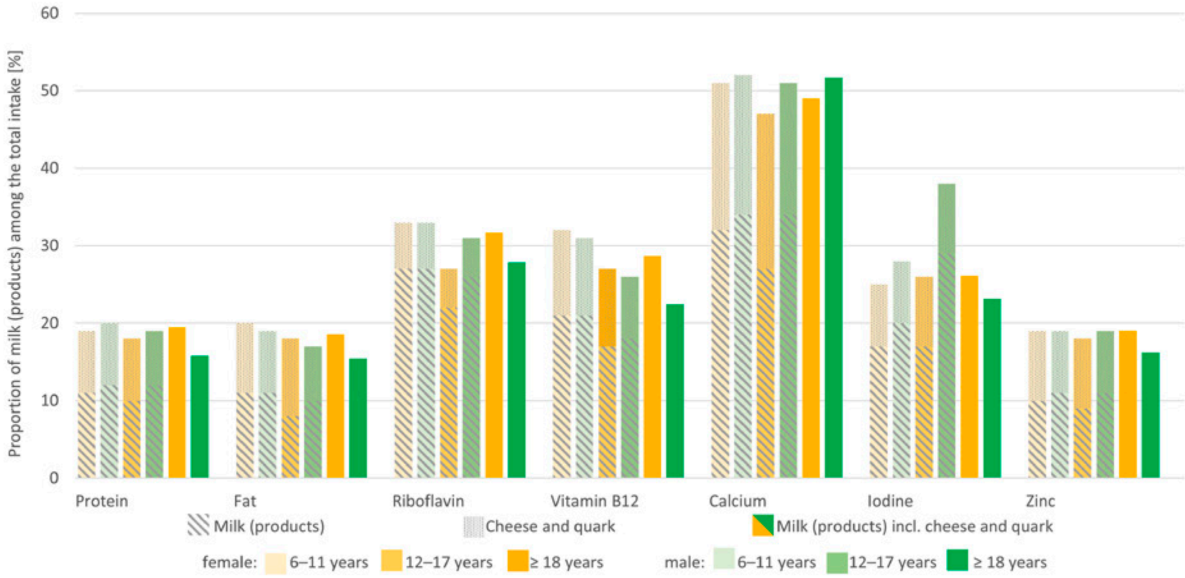

Fig. 1: **Proportion of milk (products) among the total intake of selected nutrients in Germany**
Data for children: EsKiMo II; milk and milk products (e.g., yoghurt, buttermilk, kefir, soured milk, whey, condensed milk and cream), cheese and quark; n = 2644 [1]
Data for adults: NVS II; women and men aged 15–80 years; milk and milk products including yoghurt, cream, sour cream, buttermilk, kefir, whey, cheese and quark, but excluding butter; n = 13,753 [2]

PBMA can be based on grains such as oats and rice, legumes such as soy and peas, nuts and seeds such as almonds or pseudo-grains such as quinoa [24]. In some cases, mixtures of different ingredients are used. The proportion of raw materials in PBMA varies considerably between products. An analysis of 115 products in Australia found percentages ranging from 2 to 20% [28].
PBMA are available as sweetened and unsweetened varieties or with different flavours. Depending on the raw material, additional ingredients such as oil, emulsifiers, inorganic phosphates, thickeners and enzymes may be required to achieve the desired consistency [24, 26, 29]. The wide range of e.g. different raw materials and fortification and the constant development of products make it difficult to compare cow's milk and plant-based alternatives in terms of both nutritional and environmental factors.

Health

Nutrients

Cow's milk contains many essential nutrients, including indispensable amino acids, riboflavin and vitamin B_{12} as well as calcium, iodine and zinc (◆ Table 1; for detailed information see [30]).
Data from the NVS II and EsKiMo II study show that milk (products) account for a significant proportion of nutrient intakes in Germany (◆ Fig. 1). For children, adolescents and adults, milk (products) are the primary food source of riboflavin and calcium and contribute to intake of vitamin B_{12}, iodine and zinc [1, 18, 31]. Around 10% of daily energy intake comes from milk (products) [1-3]. Milk products tend to have a higher nutrient and energy density than milk, especially cheese, whose production requires a large amount of milk relative to the weight of the final product.

◆ Table 1 shows the results of a UK market survey on the nutrient contents of cow's milk and various PBMA summarised by source (grains, legumes, nuts and seeds) for selected nutrients [32]. The comparison clearly shows that the various PBMA differ, in some cases remarkably, from cow's milk and from each other in terms of nutrient content. The amount of energy and saturated fatty acid in the listed product groups of PBMA are lower than those of cow's milk, although the energy content of grain drinks is not significantly different from that of cow's milk. The carbohydrate and sugar contents of PBMA made from legumes, nuts and seeds are lower than those of cow's milk. PBMA made from grains have a significantly higher carbohydrate content than cow's milk. PBMA contain less protein than cow's milk; however, unlike cow's milk, they contain fibre. There are also significant differences between cow's milk and PBMA in terms of vitamins and minerals [32].

Other publications also indicate significant discrepancies in the nutritional profiles of PBMA derived from different raw materials, both in comparison to one another and to cow's milk [6, 8, 11, 23, 28, 33–43]. A comprehensive and up-to-date review of the diverse range of PBMA commercially available in Germany

Parameter	Unit	Cow's milk[a]	Plant-based milk alternatives made from		
			Grains[b]	Legumes[c]	Nuts and seeds[d]
Energy	kcal	50.27 ± 1.783	48.32 ± 2.010	41.23 ± 2.275	30.20 ± 2.196
Fat	g	1.91 ± 0.207	1.35 ± 0.129	2.11 ± 0.145	1.83 ± 0.126
Saturated fatty acids	g	1.23 ± 0.136	0.20 ± 0.019	0.31 ± 0.018	0.20 ± 0.019
Carbohydrates	g	4.77 ± 0.025	8.21 ± 0.417	2.19 ± 0.406	2.61 ± 0.444
Sugar	g	4.75 ± 0.034	4.74 ± 0.450	1.42 ± 0.219	1.56 ± 0.286
Dietary fibre	g	0.00 ± 0.000	0.56 ± 0.090	0.52 ± 0.067	0.27 ± 0.046
Protein	g	3.49 ± 0.017	0.56 ± 0.067	3.08 ± 0.142	0.74 ± 0.077
Vitamin D	µg	n/a	1.03 ± 0.094	0.91 ± 0.067	0.83 ± 0.054
Vitamin B_{12}	µg	0.79 ± 0.053	0.38 ± 0.000	0.44 ± 0.043	0.38 ± 0.000
Riboflavin	mg	0.24 ± 0.005	0.21 ± 0.000	0.21 ± 0.000	0.21 ± 0.000
Calcium	mg	124.40 ± 0.571	120.00 ± 0.000	111.20 ± 9.587	114.50 ± 7.069
Iron	mg	n/a	n/a	1.38 ± 0.441	0.20 ± 0.000
Iodine	µg	31.25 ± 0.250	n/a	26.28 ± 2.027	n/a

Tab. 1: **Average energy and nutrient contents of cow's milk and plant-based milk alternatives made from varying raw materials** (some with nutrient enrichment) per 100 mL [32]
n/a: not available
Of the 136 plant-based milk alternatives, 60 contained added sugar and 77 were fortified with nutrients (all of them with calcium, 68 with vitamin D, 44 with riboflavin, 6 with iodine and 6 with potassium)
[a] Whole milk, semi-skimmed cow's milk and skimmed cow's milk
[b] Plant-based milk alternatives made of oats, rice or rice/quinoa
[c] Plant-based milk alternatives made of soy or peas
[d] Plant-based milk alternatives made of almonds, hazelnuts, cashews, tiger nuts, walnuts or almonds/hazelnuts

is currently lacking. Additionally, the selection is constantly expanding due to ongoing product development and changes. The Max Rubner-Institut (MRI) analysed 36 unsweetened, non-fortified and organic PBMA produced from soy, almonds and oats, with a focus on quality and safety aspects (composition, digestibility, microbiology, residues and contaminants). In comparison to cow's milk, the plant-based drinks contained higher levels of unsaturated fatty acids, vitamin E and iron, but lower levels of calcium, iodine and vitamins [44].
A number of FBDGs (see "Plant-based milk alternatives in food-based dietary guidelines") and other publications have highlighted that the nutrient profiles of PBMA produced from soy are most similar to that of cow's milk, especially in terms of the protein content [11, 34, 35, 37, 40, 44]. However, the nutrient contents of PBMA produced from the same raw material by different manufacturers can vary considerably [45]. Jeske et al. [36] examined 17 PBMA, including four almond drinks. The protein content of the almond drinks (n = 4) ranged between 0.41 ± 0.02 to 2.4 ± 0.24 g/100 g, while their fat content ranged from 1.18 ± 0.05 to 4.40 ± 0.11 g/100 g. These differences in nutrient content can be attributed to variations in the proportions of the raw material and other ingredients, such as oils, sugars and water, used in the production process.

> **Therefore, it is not feasible to provide a generalised statement regarding the nutritional content of plant-based milk alternatives produced from a specific raw material.**

Moreover, the varying international food fortification strategies mean that statements on the nutrient contents of products from other countries cannot be transferred to products from Germany. A comparison from North America shows a higher vitamin D content for both cow's milk (120 IU/240 mL) and plant-based alternatives (100–150 IU/240 mL) [35] than the value stated in the German Nutrient Database (*Bundeslebensmittelschlüssel*, BLS) for cow's milk (0.1 µg/100 mL) [46]. This discrepancy is attributable to the practice of fortifying cow's milk with vitamin D in North America.
Calcium: In Germany, milk and milk products are the primary source of calcium intake (◆ Figure 1). Non-fortified PBMA contain only small amounts of calcium. Therefore, calcium is in some cases added to such products, e.g., by adding calcium carbonate, tricalcium phosphate salts or algae. The quantity of calcium added is usually based on the calcium content of cow's milk (120 mg/100 mL) [27, 45, 47]. However, not all fortified products contain this amount of calcium [28]. The bioavailability of the added calcium is determined by its chemical form and the presence of absorp-

tion-inhibiting substances in PBMA [26, 27, 47–49]. The absorption rate of calcium from PBMA made from soy and fortified with calcium carbonate is comparable with that of calcium from cow's milk; however, the absorption rate is lower with tricalcium phosphate [47–49]. The added minerals can settle; therefore, it is important to shake plant drinks before intake [50].

Many organically produced PBMA do not contain any added calcium. Only addition of nutrients directly prescribed by law is permitted in organically produced foods; thus, calcium carbonate and tricalcium phosphate salts cannot be used. The EU Organic Regulation 834/2007 from 2018, which came into force in 2022, has been interpreted as permission to add the red alga *Lithothamnium calcareum* as a calcium rich ingredient to PBMA [25].

Iodine: Intake of milk (products) accounts for approximately one-third of the iodine intake of children, adolescents and adults (◆ Figure 1). However, dietary survey methods do not allow exact quantification of iodine intake because use of iodised table salt, especially in processed foods, is recorded with insufficient precision, and databases do not adequately reflect variations of the iodine content within food groups [51]. The iodine content of cow's milk varies considerably. It is mainly determined by feeding (pasture or stall rearing, proportion and type of concentrated feed, provision of iodised salt) and the iodine content of iodine-enriched feed [52–54] (maximum 5 mg/kg [55]). The proportion of concentrated feed is often higher during winter, resulting in higher iodine levels in milk. Due to differences in feeding practices, organically produced cow's milk often contains less iodine than conventionally produced cow's milk. Additionally, use of iodine-containing agents for disinfection of udder or equipment can increase the iodine content of cow's milk [52, 54]. The bioavailability of iodine from cow's milk is high (absorption rate 72–98%) [52].

Older studies of the iodine content of cow's milk from Germany reported an average iodine concentration (mean ± standard deviation) of 122.0 ± 36.8 μg/L (n = 135; samples collected in 2007–2011) [56], 105.0 ± 31.0 μg/L (n = 77; samples collected in 2012–2013) [53] and 98 ± 34 μg/L (n = 112; samples collected in 2004–2010) [57]. The iodine content of organically produced cow's milk was on average approximately 50 μg/L lower than that of conventionally produced cow's milk [56, 57]. More recent studies from Great Britain and Switzerland demonstrated considerable variations of the iodine content, with values ranging from 111 ± 26 μg/L to 438 μg/kg in conventionally produced cow's milk [58-60] and from 71 ± 25 μg/L to 324 μg/kg in organically produced cow's milk [58, 59]. The mean iodine concentration of non-fortified PBMA ranged from 2.1 μg/L to 16 ± 5 μg/kg. Iodine-fortified products contained 266–287 μg iodine/kg [59-61]. In various surveys, only 2–20% of the PBMA examined [60–62] and 5% of the yoghurt alternatives and none of the cheese alternatives were fortified with iodine [62].

Addition of algae can also enhance the iodine concentration in PBMA. Nevertheless, red algae, which are used to increase the calcium content, only have a minor effect on the iodine content [59].

In Germany, iodine is regarded as a critical nutrient for the general population (◆ Box 2). Comparative studies from Germany indicate that iodine intake of vegan children, adolescents [63, 64] and adults [65–67] who do not consume any dairy or fish is often lower than that of individuals who consume an omnivorous diet. In a study of 36 vegan and 36 omnivorous adults in Germany, mean daily iodine intake was 80 μg (25th percentile–75th percentile (P25–P75): 50–100 μg) and 120 μg (P25-P75: 80–170 μg), respectively. Furthermore, mean iodine excretion in urine was lower in the vegan diet than in the omnivorous diet (28 μg/L [P25–P75: 18–42 μg/L] vs. 74 μg/L [P25–P75: 42–102 μg/L] [67]. In both groups, mean iodine excretion fell within the range defined as iodine deficiency by the World Health Organization (WHO) (◆ Box 2) [68]. These results are consistent with data from other countries [69-75].

In a study conducted in the UK (2014–2017), iodine intake and iodine excretion in spontaneous urine of children aged 4 years and older and adults who consumed cow's milk or PBMA were compared. Of the total 3,976 participants, 185 (4.6%) drank PBMA, 88 of those consumed these products exclusively. Both iodine intake (94 vs. 129 μg/day, $p < 0.001$) and iodine excretion (79 vs. 132 μg/L, $p < 0.001$) were significantly lower in individuals who solely consumed PBMA than in those who exclusively drank cow's milk [76]. Iodine excretion fell within the range of iodine deficiency defined by the WHO in individuals who exclusively consumed PBMA [68].

Other vitamins and minerals: In addition to its role in providing the essential minerals calcium and iodine, milk (products) are a primary food source of riboflavin and vitamin B_{12}. This is particularly the case for vitamin B_{12} in a vegetarian diet. Furthermore, milk (products) also contribute to the supply of zinc (◆ Figure 1) and vitamin A in Germany (approximately 5–10% of retinol equivalents come from milk [products] [1, 2]). These nutrients are not naturally present in PBMA or are only present in smaller quantities. Zinc is present in some PBMA, e.g., products made from cashew or soy (◆ Table 1), in quantities similar to those in cow's milk. However, these products also contain phytates, which can reduce absorption of divalent cations such as zinc [37].

An analysis conducted as part of the National Health and Nutrition Examination Survey (NHANES) in the USA found that intake

Box 2: Iodine deficiency

Analyses of the nationally representative "German Health Interview and Examination Survey for Adults" (DEGS) and the "German Health Interview and Examination Survey for Children and Adolescents" (KiGGS) indicate that, based on data on iodine excretion in urine, approximately 30% and 44% of the population, respectively, have an iodine intake below the estimated average requirement [77, 78]. Median urinary iodine excretion less than 100 µg/L is classified as iodine deficiency by the WHO [68].
Dairy is an important source of iodine in Germany. Consumption of a diet that excludes dairy carries an increased risk of developing iodine deficiency. This can result in the manifestation of deficiency symptoms and the emergence of developmental disorders, particularly in children or during pregnancy in the mother and foetus. One method to improve the iodine intake of individuals who predominantly or exclusively replace dairy with plant-based alternatives is to use iodine-fortified products. As an alternative, targeted supplementation with iodine should be considered in consultation with the treating physician, particularly during childhood and adolescence. During pregnancy and lactation, in addition to consuming iodine-rich foods and iodised table salt, daily intake of a dietary supplement containing 100–150 µg iodine is recommended. Women with thyroid disorders must consult their physician before supplementation [79, 80].

of milk (products) was positively correlated with serum vitamin B_{12} concentration and was associated with a reduced risk of vitamin B_{12} deficiency. Additionally, the evaluation demonstrated that higher intake of milk (products) was associated with higher serum concentrations of folate, vitamin B_6 and vitamin B_{12}, as well as a reduced risk of a deficiency of these vitamins [81].
An analysis conducted by the MRI found higher levels of folate and magnesium in soy drinks than in cow's milk, and higher levels of iron and vitamin E in all plant drinks analysed. The latter is attributed to the added sunflower oil. As with zinc, the bioavailability of iron must be considered (see "Other ingredients") [44].
Protein: Most PBMA contain, in some cases remarkably, less protein than cow's milk (◆ Table 1). Additionally, the protein quality (amino acid composition and bioavailability) of PBMA is usually lower than that of cow's milk [36–38, 42, 44]. However, the protein content and quality of products made from legumes, particularly soy, are comparable with those of cow's milk [37, 42, 44]. The mean protein intake in Germany is considerably higher than the recommended intake, indicating that protein is not a critical nutrient for the general population. However, protein supply can become critical if energy intake is not aligned with requirements. In such cases, the consumed protein is used for energy supply and is not available for endogenous protein synthesis. Young women and older people are particularly susceptible to this phenomenon [82].
A suitable combination of different protein-containing foods can compensate for possible limitations in the protein quality of individual foods through the supplementary effect of amino acids [83, 84].
Carbohydrates: The carbohydrate content of PBMA varies significantly (◆ Table 1). PBMA made from grains, such as oats and rice, typically contain more carbohydrates than those made from nuts, seeds and legumes. If starch within the grain is hydrolysed during processing, the content of low-molecular sugars will increase. Furthermore, glucose and other sugars are added to some PBMA, which increases their carbohydrate content. PBMA lack lactose and oligosaccharides, which are naturally present in cow's milk [36, 37, 42, 44] (for fibre, see "Other ingredients").
The glycaemic index (GI) is directly correlated with the concentration of glucose in food. Nevertheless, other components of PBMA such as β-glucans in oats have the potential to mitigate this effect. A study of the GI values of cow's milk and various PBMA revealed that cow's milk and products made from cashew, macadamia nuts and quinoa had low GI values (< 55), while products made from hazelnuts, hemp and oats had medium GI values (56–69). Drinks made from soy and almonds had low and medium GI values. On the other hand, products made from coconut and rice had high GI values (> 70). The glycaemic load (GL), which is determined by the amount of usable carbohydrates in a food, was highest in products made from rice (> 15), followed by a product made from oats (8) and a product made from almonds (6). All other plant drinks and cow's milk had GL values lower than 5 [36]. It is generally recommended to follow diets with a lower GI or GL [85, 86].
Fat: The fat content of PBMA varies greatly (◆ Table 1). Vegetable oil is added to some products in order to improve their stabilities, resulting in significantly higher fat contents than PBMA without oil and, in some cases, also cow's milk [7, 34].
The fatty acid composition of PBMA depends on the raw material used. With the exception of coconut-based products, PBMA contain less saturated fatty acids and more polyunsaturated fatty acids than cow's milk [34, 42, 44]. Cow's milk fat contains about 70% saturated fatty acids. About 8% of the fatty acids are short- and medium-chain saturated fatty acids (C4:0–C10:0) [30, 87].

The fatty acid composition of cow's milk is influenced by how the cows are fed. Milk from pasture-fed cows has a more favourable ratio of linoleic acid to α-linolenic acid, which are essential fatty acids, than milk from silage-fed cows [87, 88]. Organically produced cow's milk contains e.g., more eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) than conventionally produced cow's milk [88, 89]. Of the PBMA (including almond, cashew, coconut, hemp, oat, rice, soy and spelt), only soy has a significant proportion of n-3 fatty acids. Low levels of n-3 fatty acids result in high n-6 to n-3 ratios in other PBMA [37, 42].
The fat present in lipid droplets in cow's milk is surrounded by a membrane called the milk fat globule membrane, which mainly consists of fat and protein. There is evidence that this membrane in human's and cow's milk has beneficial effects on the immune system, the gastrointestinal tract, serum lipids, brain development and cognitive function in both infants and adults [90, 91]. Such milk-specific fat and protein globules are not found in PBMA.

Other ingredients: PBMA can also contain other ingredients such as dietary fibre, e.g., β-glucans from oats, and phytochemicals, e.g., isoflavones from soy [26, 27]. In a study conducted by the MRI, soy drinks had the highest fibre content at 1.76 g/100 g. Most of this fibre was insoluble. The average total fibre content of oat drinks was 0.45 g/100 g, consisting of 0.31 g/100 g insoluble fibre and 0.15 g/100 g water-soluble fibre. Almond drinks had a lower total fibre content of 0.13 g/100 g. The total content of isoflavones in soy drinks was 11.90 ± 3.08 mg/100 g [44]. Depending on how the cows are fed, cow's milk may also contain phytochemicals such as carotenoids and isoflavones [89, 92].
Some of the ingredients in PBMA contain phytochemicals such as polyphenols and phytates, which reduce absorption of divalent cations. For example, phytates and oxalates found in sesame, oats, soy and cashews form insoluble complexes with calcium, zinc, magnesium and iron in the small intestine, which limits their absorption [24, 27]. The MRI calculated the ratios of phytates to various minerals in non-fortified soy, oat and almond drinks . The results suggest that absorption of magnesium is not affected by phytate present in plant drinks, but the absorption of zinc and iron is greatly reduced and of calcium is only negatively affected in soy drinks [44]. Thermal treatment of PBMA for preservation can dissolve absorption-inhibiting complexes. This can increase the bioavailability of nutrients, as can fermentation [24, 27].
In addition, undesirable substances from the surrounding environment have the potential to accumulate in both plants and animals. For example, in PBMA, arsenic from rice and mycotoxins from oats were detectable [36, 37, 43, 93]. An examination of PBMA by the MRI revealed unremarkable results with regard to heavy metal contamination. Furthermore, the total bacterial count was very low and no pathogenic bacteria were detected. Two samples contained quantities of a pesticide that were not deemed to be critical, and no pesticide residues were detected in the other products [44]. With regard to the mycotoxin content of PBMA in the MRI study, the German Federal Institute for Risk Assessment (*Bundesinstitut für Risikobewertung*, BfR) concluded that regular intake of almond drinks containing aflatoxin at the levels determined in the study may negatively affect health in children aged from 0.5 years to younger than 6 years with a moderate likelihood of occurrence [94]. When cows are fed mycotoxin-containing feed, mycotoxins can also pass into cow's milk [95-97].

Further positive and negative effects of milk (products) and plant-based milk alternatives on health

Milk and products produced from it are among the 14 most common triggers of **allergies or intolerances**. Furthermore, legumes such as peanuts, soy and lupins as well as nuts such as hazelnuts, walnuts, cashews, macadamia nuts and almonds, from which PBMA are made, are among the major allergens. The use of such food ingredients must be indicated on the product packaging or in menus as part of allergen labelling [98].
Despite the presence of saturated fatty acids, milk fat has a low cholesterol-increasing effect, which is influenced by other milk ingredients. Trans fatty acids naturally present in milk fat also do not appear to elevate the risk of **cardiovascular disease**, in contrast to trans fatty acids produced during the partial hardening of vegetable fats [30, 99].
Epidemiological data indicate that intake of milk (products) is associated with a lower risk of various diseases compared with low or no consumption [30, 99-101]. In observational studies, intake of milk products was associated with e.g. a lower risk of **high blood pressure, cardiovascular disease and stroke** [101-106], **obesity** [106, 107] and **type 2 diabetes** [101, 106, 108]. In analyses of individual food items, intake of yoghurt or fermented milk (products) was associated with improved cardiovascular health [101, 105, 109] and a lower risk of obesity [106] and type 2 diabetes [101, 106, 109]. However, the results concerning the associations between milk consumption and cardiovascular disease, obesity and blood pressure were inconsistent [101–103, 105, 107, 110–112]. Furthermore, intake of milk products, including milk and fermented milk products, was associated with improved **bone mineral density** [101, 109, 113, 114]. However, studies examining the relationship between consumption of milk products and the occurrence of bone fractures yielded inconclusive results [113, 115, 116]. Consumption of milk products as a gen-

eral category as well as milk and yoghurt, but not cheese, was associated with a lower risk of developing non-alcoholic fatty liver disease (new nomenclature: **metabolic dysfunction-associated steatotic liver disease**, MASLD) [117, 118].

Results regarding the association between intake of milk (products) and **cancer** risk are inconsistent due to the high heterogeneity and low quality of the reviews [119, 120]. Intake of both milk and milk products was associated with a reduced risk of colorectal cancer [101, 109, 121, 122]. Additionally, there is evidence that intake of yoghurt or fermented milk products is associated with a reduced risk of breast cancer [101, 109] and liver cancer [123]. Evidence regarding the relationship between intake of milk (products) and ovarian and bladder cancer is inconclusive. Consumption of low-fat milk [124] or milk (products) in general as well as fermented milk products [119] was associated with a reduced risk of these diseases. Conversely, higher intake of whole milk compared with lower consumption was associated with a higher risk of these diseases [119, 124].

An increased risk of prostate cancer was observed with high intake of milk (products) [101, 109, 125–127]. A systematic review revealed a relative risk of prostate cancer of 1.08 (95% confidence interval: 1.00–1.16) when comparing the highest and lowest intakes of milk proteins. A positive association was identified for intake of 30 g milk protein or more per day. Furthermore, a dose-response analysis indicated a 10% increase in risk for every 20 g increase in milk protein intake [128]. An elevated risk of prostate cancer was observed with a calcium intake of 1200 mg/day [129], which is equivalent to intake of approximately 1 L of milk or 110 g of hard cheese [99]. However, it remains unclear which components of milk are responsible for this association [126].

In a systematic review of 29 clinical studies, the health effects of PBMA compared with cow's milk were analysed. In 27 of the included studies, the effect of consuming soy drinks was compared with that of consuming cow's milk. One of these studies also examined almond drinks, while two other publications examined the effect of rice drinks. Although some evidence suggests that PBMA may have a beneficial impact, e.g., on lipid profiles, it is not possible to draw any definitive conclusions due to the contradictory results [130].

> **There is a lack of evidence from observational studies investigating the long-term influence of intake of plant-based milk alternatives on human health. Furthermore, the food and nutrient databases typically contain none or only a limited number of these products.**

PBMA are frequently classified as ultra-processed foods [131]. Intake of ultra-processed foods is associated with a higher risk of nutrition-related diseases. However, nutritional quality is not adequately considered in the assessment, and not all foods categorised as ultra-processed necessarily have a detrimental effect on health [132–135]. Further detailed analyses are necessary to ascertain the extent to which the processed grade of PBMA may contribute to an increased disease risk.

Environment

To assess the impact of food on the environment or the ecological dimension of sustainability, it is necessary to consider a number of different indicators. The selection of indicators varies between different publications. If possible, at least the following indicators should be considered:

- Greenhouse gas emissions (carbon dioxide, nitrous oxide and methane).
- Land use.
- Eutrophication potential.
- Water pollution and water use [136, 137].
- Biodiversity loss [121].

Furthermore, additional indicators permit a more nuanced perspective such as the acidification potential [138]. In addition, by-products generated during food production warrant consideration, e.g., the connection between beef and cow's milk production [139]. Another example is the management of by-products from the manufacture of plant-based alternatives. Depending on the source material, these are rich in antioxidants and fibre. If these are employed further, for instance in animal feed, other raw materials can be saved [24].

The environmental impact of the food system is substantially influenced by animal-source foods. The adverse effects include the considerable contribution to global greenhouse gas emissions, land requirements for feed cultivation, loss of biodiversity, deterioration of soil quality (e.g., nutrient surpluses and over-fertilisation of pastures) and air and water pollution [24, 34, 137, 140–142]. PBMA made from almonds are also subject of criticism due to the significant amount of water required for their production, and the fact that almond trees are cultivated in areas where water is scarce [143].

The Institute for Energy and Environmental Research Heidelberg (*Institut für Energie- und Umweltforschung Heidelberg*, ifeu) compiled the ecological footprints of foods and dishes in Germany in 2020. The greenhouse gas emissions in CO_2 equivalents are provided for 188 food items. The entire value chain, encompassing cultivation, processing, packaging, distribution, transport and sale, was included in the calculation. The greenhouse gas emissions for cow's milk ranged from 1.1 kg CO_2 equivalents per kilogram of food for skimmed milk to 1.7 kg CO_2 equivalents per kilogram

	Greenhouse gas emissions [kg CO_2 equivalents/kg]	Phosphate footprint [g phosphate rock equivalent/kg]	Area footprint [m^2 * a natural area occupancy/kg]	Water footprint [L water equivalent/kg]	Energy requirement [kWh primary energy equivalent/kg]
Cow's milk	1.1–1.7	n/a	n/a	n/a	n/a
ESL whole milk	1.4	20	0.5	2000	2
Soy drink	0.4	8	0.3	3000	1.5
Oat drink	0.3	8	0.2	300	3
Spelt drink	0.3	n/a	n/a	n/a	n/a
Almond drink	0.3	n/a	n/a	n/a	n/a

Tab. 2: **Environmental impact of cow's milk and plant-based milk alternatives per kilogram of food [144]**
a: years; ESL: extended shelf-life; these products have a longer shelf-life than fresh milk; n/a: not available;.

of food for organic extended shelf-life (ESL)[8] whole milk in composite board packaging, respectively. The greenhouse gas emissions of the considered PBMA ranged from 0.3 to 0.4 kg CO_2 equivalents per kilogram of food [144].
For 35 selected foods, including cow's milk, soy and oat drinks, the phosphate, land and water footprints as well as the energy requirement[9] were also specified. The conditions prevailing in the country of production, such as water scarcity, were taken into account in the calculation. In a comparison of cow's milk, soy and oat drinks, the phosphate and land footprints were highest for cow's milk. The soy drink had the highest water footprint and the oat drink had the highest energy requirement (◆ Table 2) [144].
Data on cow's milk and PBMA are also presented in other databases. For example, the SHARP Indicators Database provides European data on greenhouse gas emissions and land use per kilogram for cow's milk and PBMA produced from soy and rice. Both PBMA exhibited lower values than cow's milk for both parameters. For instance, the greenhouse gas emissions for soy drinks were one-third of those for cow's milk, while land use for rice drinks was found to be half of that for cow's milk [145, 146].

This comparison demonstrates that a single parameter is inadequate to comprehensively assess the environmental impact of food items. When several parameters are considered together, it becomes evident that PBMA have a lower overall environmental impact than cow's milk [137, 147]. The differences between milk and PBMA are minor in comparison to the environmental impact, e.g., of cheese and meat [137].
The values provided in the various surveys for individual environmental indicators exhibit considerable discrepancies in certain instances [34, 39]. In an evaluation of 18 studies, a comparative analysis was conducted of the environmental impact of cow's milk and PBMA derived from oats, almonds, rice and soy. The environmental indicators examined included greenhouse gas emissions, energy requirements, water use, ozone depletion potential, marine and freshwater eutrophication, acidification potential and land use. Cow's milk exhibited significantly higher maximum values for greenhouse gas emissions, eutrophication potential and land use. In this evaluation, land use for the production of 1 L of cow's milk was 1.18–54 m^2, while that for 1 L of PBMA was a maximum of 0.76 m^2. However, the ranges of the different environmental parameters exhibited considerable variations and overlap. Greenhouse gas emissions per litre of milk ranged from 0.089 to 72.70 kg CO_2 equivalents, while those per litre of PBMA ranged from 0.02 to 3.85 kg CO_2 equivalents. Variation in water use was also considerable; production of 1 L of almond drink required 59–6,100 L of water, while production of 1 L of cow's milk required 11.7–1,030 L of water. By contrast, production of 1 L of the other PBMA required a maximum of 376 L of water [34].
The discrepancy in values can be attributed to both, production of milk or PBMA and the method used to quantify the environmental impact. In the context of milk production, the number of animals on the farm, the husbandry conditions (organic vs. conventional, grazing vs. arable feed-based systems and differences in feed) and milk yield are pivotal determinants [34, 148]. For example, the greenhouse gas emissions per litre of milk in Europe are approximately only one-fifth of those in parts of Asia and Africa, partly due to the high milk yield of cows in Europe [149, 150]. For PBMA, the most significant influencing factor is production of the raw material. However, processing procedures and the technologies used also have an impact on the indicators analysed [34]. A further reason for the differing results may be the varying scopes of analysis. Therefore, it is essential to ascertain

[8] ESL is an abbreviation of 'extended shelf-life'; these products have a longer shelf-life than fresh milk
[9] Cumulative expenditure on primary energy that is not covered by renewable resources

whether the environmental impacts under consideration relate solely to the production site or to the entire lifecycle [143]. When evaluating the environmental sustainability of cow's milk and PBMA, it is essential to consider not only the production method but also the underlying calculation method [39].
The considerations in this chapter apply to the environmental impact of cow's milk or PBMA, expressed in terms of volume (per litre) or mass (per kilogram). An alternative approach is to consider energy or nutrient density, e.g., protein, calcium or iodine. In certain cases, the environmental impact of PBMA can be significantly higher than that of cow's milk, depending on the underlying raw material and whether the PBMA are fortified with nutrients [143, 147, 151].

Social dimension

The national Scientific Advisory Board on Agricultural Policy, Food and Consumer Health Protection (*Wissenschaftlicher Beirat für Agrarpolitik, Ernährung und gesundheitlichen Verbraucherschutz*, WBAE) of the BMEL characterises the conditions under which food is produced and provided as the social dimension of nutrition. Income and working conditions depend on the type of work on which production is based (e.g., self-employed agricultural work or dependent employees in agriculture). Low wages and unfavourable working conditions are also social problems in other areas of the agricultural and food sector. Import of food or animal feed from abroad can lead to social problems in these countries [152].

> **The conditions under which foods or animal feed is grown are the decisive factor for the social dimension of food production.**

The social dimension also has an impact on consumers because it allows them to freely choose which products they wish to purchase. However, PBMA are often more expensive than cow's milk [24], which can act as a barrier to purchasing for low-income households. The costs for foods are determined by the expenses incurred during production of raw materials (raw milk, soy, oats, etc.), costs for transport, processing, packaging and storage, disposal, trade margins and value added tax (VAT). Part of the price discrepancy can be attributed to variations in taxation. A VAT rate of 19% applies to PBMA, whereas the reduced rate of 7% applies to milk (products) [153].

Animal welfare

The avoidance of animal suffering is a significant motivation for reduction or elimination of food of animal origin from the diet and utilisation of PBMA [154]. In the position statement on a more sustainable diet, the DGE states "Another aspect of a more sustainable diet is livestock husbandry that supports better animal welfare, and therefore meets the changing ethical demands of (western) societies" [13]. Consequently, animal welfare is also an important factor for more sustainable consumption of dairy.
The foundation for integrating animal welfare considerations into dairy selection is the availability of transparent information regarding production conditions. Dairy cows are kept in different husbandry systems, which vary in their level of ensured optimal animal welfare. According to the Federal Centre for Nutrition (*Bundeszentrum für Ernährung*, BZfE), Germany is the largest milk producer within the EU, with a dairy cow population of 3.8 million. Around 87% of all dairy cows in Germany are kept in open pen and around 31% have access to pasture for just under half of the year on average. Conversely, the practice of tethering is declining [155]. In its 2020 report, the national Competence Network Lifestock Husbandry *(Kompetenznetzwerk Nutztierhaltung)* stated that "the husbandry systems in dairy cattle husbandry have developed positively in recent years in terms of animal welfare" [156].
Nevertheless, this approach to husbandry does not inherently ensure adequate animal welfare. Additionally, the Competence Network Lifestock Husbandry has highlighted the association between high milk yield and adverse health outcomes for the animals, including fertility disorders, udder inflammation and lameness [156]. Further information on animal health and behavioural parameters in the form of comprehensive and valid labelling is necessary to make informed purchasing decisions [13]. The national Act on Animal Husbandry Labelling *(Tierhaltungskennzeichnungsgesetz)* regulates the mandatory labelling of animal husbandry. The law initially regulated the fattening of pigs and is to be expanded to other animal species and other areas within the utilisation chain [157]. The terms 'species-appropriate' and 'animal welfare' are not legally protected and consequently may be used without any special requirements for animal husbandry [158].

Plant-based milk alternatives in food-based dietary guidelines

The recommendation to consume milk (products) is part of the FBDGs of many countries. Plant-based alternatives are mentioned less frequently [159–161]. Herforth et al. [160] analysed the key messages and graphical representations of the FBDGs of 90 countries. The majority of FBDGs (75%) included recommendations regarding consumption of milk (products), while 11% contained statements on PBMA, e.g., those made from soy [160]. In a more recent evaluation, PBMA were mentioned in 36 of 90 (40%) FBDGs analysed [161].

Some examples of statements in FBDGs are listed in ◆ Box 3. While the statements may appear similar, they have distinct characteristics. The FBDGs from the Netherlands, Canada and the USA exclusively refer to PBMA derived from soy, while the Swedish FBDG mentions soy and oats, and the British FBDG cites soy as an example. The British and Dutch FBDGs explicitly highlight unsweetened variants. Nutrient enrichment of products is mentioned in all cases, with the selection of fortified products being recommended as follows: generally (Canada, Nordic Nutrition Recommendations), generally with vitamins and minerals (Sweden), with calcium (UK) and with calcium, vitamin A and vitamin D (USA). In the Netherlands, reference is made to PBMA enriched with B vitamins and calcium. No statement is made about the level of fortification. None of the examples mention iodine fortification.

Summary

The intake data show the significance of dairy in the diet of the German population. In recent years, the supply and sales of PBMA have grown steadily. Only limited data on intake of PBMA is available from observational studies. With this position statement, the DGE provides a contextual framework for the comparison of PBMA with cow's milk in regard to the dimensions of a more sustainable diet, primarily health and environmental impact.

Dairy contributes significantly to intake of e.g. calcium, iodine, riboflavin and vitamin B_{12} in Germany. In addition to providing essential nutrients, intake of dairy is associated with other beneficial effects on human health. The nutrient content and nutrient fortification strategies of PBMA are very heterogeneous. The exact nutrient composition, beyond the legally prescribed information, is often unknown, so generalised statements on this cannot be made. In the absence of fortification, the nutrient profiles of PBMA exhibit significant disparities in comparison to those of cow's milk; the nutrients usually supplied via dairy are present at considerably lower levels in PBMA. Whether the bioavailability of added nutrients in PBMA is comparable to nutrients in cow's milk depends on the raw material used in their production, the chemical form of the added nutrient and the presence of absorption-inhibiting substances. Depending on the raw material, PBMA contain other health-promoting ingredients, such as phytochemicals and fibre, which are lacking in cow's milk or only present in small quantities. Furthermore, they contain no cholesterol and less saturated fatty acids and, especially in the case of plant-based alternatives made from seeds and nuts, more unsaturated fatty acids than cow's milk (see "Health").

Box 3: **Examples of statements on plant-based milk alternatives in FBDGs**

United Kingdom "Unsweetened calcium-fortified dairy alternatives like soy milks, soy yoghurts and soy cheeses also count as part of this food group. These can make good alternatives to dairy products."
→ www.nhs.uk/live-well/eat-well/food-types/milk-and-dairy-nutrition/

Netherlands "If you don't like dairy or have an intolerance, an unsweetened soy drink enriched with calcium and B vitamins makes for the most wholesome alternative."
→ https://mobiel.voedingscentrum.nl/Assets/Uploads/voedingscentrum/Documents/Service/English/Wheel-of-five.pdf

Sweden "Drinks made of oats and soya are eco-friendly. Choose the ones enriched with vitamins and minerals – you'll see this information on the packaging."
→ www.livsmedelsverket.se/en/food-habits-health-and-environment/dietary-guidelines/adults/dairy-products-advice/

Canada "Protein foods: include legumes, nuts, seeds, tofu, fortified soy beverage, fish, shellfish, eggs, poultry, lean red meat including wild game, lower fat milk, lower fat yogurts, lower fat kefir, and cheeses lower in fat and sodium."
→ https://food-guide.canada.ca/sites/default/files/artifact-pdf/CDG-EN-2018.pdf

USA "Healthy dietary patterns feature dairy, including fat-free and low-fat (1%) milk, yogurt, and cheese. Individuals who are lactose intolerant can choose low-lactose and lactose-free dairy products. For individuals who choose dairy alternatives, fortified soy beverages (commonly known as "soy milk") and soy yogurt – which are fortified with calcium, vitamin A, and vitamin D – are included as part of the dairy group because they are similar to milk and yogurt based on nutrient composition and in their use in meals."
→ www.dietaryguidelines.gov/sites/default/files/2021-03/Dietary_Guidelines_for_Americans-2020-2025.pdf

Nordic Nutrition Recommendations "If consumption of milk and dairy is lower than 350 gram/day, products may be replaced with fortified plant-based alternatives or other foods."
→ www.norden.org/en/publication/nordic-nutrition-recommendations-2023

> **Given the usual consumption habits in Germany, complete or partial replacement of dairy by plant-based alternatives without ensuring adequate nutrient substitution can lead to nutrient deficiencies. However, the overall quality of an individual's diet is important.**

Values concerning the environmental impact of cow's milk and PBMA vary greatly. To comprehensively assess the environmental impact of food, it is important to include indicators of various environmental aspects. However, there is often a lack of data, which means that products cannot be compared with each other in terms of all environmental indicators (see "Environment").

> **On average, plant-based milk alternatives have lower values for greenhouse gas emissions, and water and land use than cow's milk. However, when multiple environmental indicators are taken into account, the differences between cow's milk and plant-based milk alternatives are minor in comparison to the environmental impact of e.g., cheese and meat.**

In addition to positive effects on the environment, the avoidance of animal suffering is a significant motivation for consuming PBMA instead of cow's milk. Farming livestock with the aim of maximising milk yield is associated with negative health consequences for the animals. One measure to support animal welfare when consuming food of animal origin is to make an informed choice. This requires comprehensive and valid labelling, taking into account parameters relating to animal health and behaviour (see "Animal welfare").
For the social dimension of a more sustainable diet, the working conditions during the production of raw materials, among other things, must be taken into account. The social dimension also has an impact on consumers. For example, PBMA are often more expensive than cow's milk, which can act as a barrier to purchasing for low-income households (see "Social dimension").
When comparing cow's milk with PBMA in terms of the different dimensions of a more sustainable diet, it is almost impossible to make generalised statements. In particular, the nutritional quality of PBMA is very heterogeneous, meaning that only one specific product can be evaluated in comparison to cow's milk.

Conclusion and recommendations for action

Cow's milk and PBMA differ in terms of their nutrient compositions and their effects on humans and the environment. PBMA are not nutritionally equivalent to milk, especially if they are not fortified with specific nutrients. However, they increase the range of foods of plant origin and can thus help to implement a plant-based diet. For nutritional evaluation of the use of PBMA, it is crucial to consider whether cow's milk is partially or completely replaced and whether only cow's milk or all dairy is avoided. When assessing plant-based alternatives to dairy products such as yoghurt or cheese, contribution to nutrient supply and impact on the environment must be considered separately. The characteristics of the specific plant-based alternative product should be taken into account, e.g., the respective fortification practice, which may differ from those of PBMA [33, 62].

> **Given the beneficial effects of dairy on human health, the DGE recommends their daily intake. According to the approximate values of the German FBDG of the DGE for adults, which provide a guide for intake amounts, two servings of dairy can be consumed per day, e.g., one serving of milk and one slice of cheese [5]. This amount contributes to an adequate supply of calcium, iodine, riboflavin and vitamin B_{12}.**

It is not necessary to consume more than the recommended amount of dairy in a balanced diet to ensure a sufficient supply of nutrients. For other population groups such as children and adolescents or for diets other than an omnivorous mixed diet, e.g., an ovo-lacto-vegetarian diet, the number of servings of dairy recommended to cover the requirements may differ.

> **For individuals who consume smaller amounts or no dairy, or who exceed the recommended intake, the DGE advocates the use of plant-based milk alternatives. This contributes to reduce the diet-induced environmental impact.**

The recommendations of the German Healthy Start Network (*Netzwerk Gesund ins Leben*) apply to infants and young children: "If infants are not or not exclusively breastfed, they should be given infant formula produced in accordance with the statutory regulations" [80]. The recommendations for infants recommend that parents who wish to feed their children a vegetarian or vegan diet should also be given advice on plant-based products. Possible contents of this advice include the nutritional and physiological differences compared with foods of animal origin as well as the wide variety of products. The Healthy Start Network concludes that not all products are equally suitable as substitutes [163]. In accordance with the recommendation of the DGE, the Nutrition Commission of the German Society for Paediatrics and Adolescent Medicine (*Deutsche Gesellschaft für Kinder- und Jugendmedizin*, DGKJ) recommends in a statement on the use of PBMA in children to ensure an adequate intake of important nutrients from other foods or, if necessary, from supplements if milk (products) are excluded from a child's diet [164].

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The following recommendations for action summarise recommendations for the selection of PBMA, in particular for people who replace cow's milk entirely or partially with PBMA. Plant-based alternatives to dairy products were not in the scope of this position statement. However, many of the following recommendations can also be helpful when choosing plant-based alternatives to dairy products.

Recommendations for choosing plant-based milk alternatives as part of a healthier and more sustainable diet

- For supply of calcium and iodine and, especially in the case of a vegetarian or vegan diet, riboflavin and vitamin B_{12}, products that are fortified with these nutrients should be selected. However, organic products are not fortified with nutrients for legal reasons.
- When using products that are not fortified at all or only with some of these nutrients, it is important to ensure that the remaining nutrients are obtained from other sources (food or nutrient supplements). The total diet and nutrient intake should be considered. Qualified nutritionists can provide support in this regard.
- As part of a healthier and more sustainable diet, products without added sugar should always be favoured. If sweetened products are used, this should be taken into account in the total sugar intake. The intake of free sugars should be less than 10% of the total energy intake [162].
- For individuals with pre-existing health conditions for whom the ingredients of PBMA can lead to negative health aspects, such as allergenic ingredients for individuals with food allergies, these aspects must be taken into account when selecting plant-based alternatives.
- For a more detailed overview, it is advisable to look at the lists of ingredients. They show the proportion of the name-giving ingredient(s), the added vitamins and minerals, and any other ingredients such as sweeteners, emulsifiers, flavourings and thickeners.
- PBMA taste different. If individuals wish to use PBMA, they might, try different products. To get used to the flavour of PBMA, it can help to mix them with cow's milk and gradually adjust the mixing ratio.

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