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A resource about dairy-based nutrition
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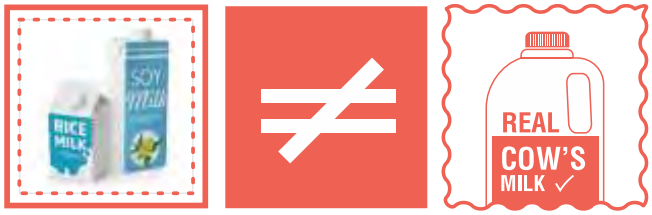
This review describes the nutritional differences between cow's milk and plant-based milk alternatives and summarises arguments for and against the use of these non-dairy milk alternatives, given current scientific evidence.

A publication for health professionals

Dairy as part of a plant-based diet



INTRODUCTION

Why do we drink milk? Explaining the history of milk and milk sources.

Milk can come from any mammal, but dairy products used for human consumption are usually produced from milk provided by cattle, sheep, goats, horses, camels and buffaloes, with milk from cattle being most common (in 2016, cow's milk accounted for 83% of global production). Milk is used to produce various dairy products, such as milk for drinking (available as fresh milk or in powdered form), cheese, yoghurt, butter, and whey proteins used as a food ingredient.

The consumption of milk from domesticated animals can be traced back 9 000 years to Anatolia, the modern-day Turkey or Middle East. From there the practice spread to Greece and the Balkans, and lactase persistence – the ability to digest milk in adulthood – emerged in central Europe. Dairy farming practices spread as part of the Neolithic transition from hunting and gathering to structured agriculture. Since then, the consumption of milk and its use as a food ingredient have proliferated worldwide, and now play a crucial role in the nutrition of humans of all ages.

Today, the beneficial role of milk and other dairy products in the diet is well established and confirmed by the Food and Agriculture Organization (FAO) and other reputable government and academic groups in countries around the world.

THE BIGGER PICTURE:

Sustainable nutrition: The role of plant- and animal-based foods in a sustainable food system

Considerations for a sustainable food system are becoming increasingly present in the international and national arena, with both health professionals and food policymakers around the world debating the topic.

According to the United Nations, a sustainable food system is one that 'delivers food and nutrition security for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised'.

A food system therefore includes:

- the food supply system, i.e. production, manufacturing, transport and food provision;
- the food environment, i.e. food availability, price, nutrient quality, labelling and promotion of food;
- the consumer's preferences, knowledge and purchasing power, and
- diet quality.

The debate about sustainable food systems has generated a push to consume a diet that is mostly plant-based, with recommendations to eat seasonal and local produce and to reduce food waste. Some research groups have concluded that current dietary guidelines can be adjusted to achieve more sustainable dietary patterns. For example:

- the EAT-Lancet report recommends that only 250 g of dairy foods need to be consumed per day;
- the Food Climate Research Network recommends dairy foods to be eaten in moderation;
- other researchers recommend mostly vegan diets as the mechanism for reducing greenhouse gas (GHG) emissions.

These recommendations are generally based on hypothetical dietary scenarios, which lack the appropriate contextualisation and consideration of the long-term consumption and health outcomes associated with such nutrition strategies. As such, the recommendations lead to confusion among health professionals, food manufacturers and, ultimately, consumers.

The purpose of this forum is to discuss how dairy – as an animal protein – can fit into a plant-based diet aimed at achieving a more sustainable nutrition future.

Does sustainable nutrition need to focus on plant-based foods at the expense of animal-based foods? What are the future implications of focusing on sustainable diets?

Malnutrition in all its forms (hunger, obesity and micronutrient deficiency) affects about a third of the world's population, while non-communicable diseases are responsible for almost 70% of all deaths worldwide. Globally it is recognised that current food systems are failing to deliver healthy diets for all. The current approach to food systems is considered to be a major driver of negative environmental impacts, given that it is responsible for approximately a quarter of anthropogenic GHG emissions and is seen as a leading cause of deforestation, biodiversity loss, freshwater use and water pollution. Food systems are currently insufficient at feeding people all around the world adequately. Researchers are therefore leaning towards a more plant-based system to help save the planet.

Moving towards sustainable nutrition involves more than reducing the environmental impacts of the food system, and is thus more complex than focusing just on shifting from animal products to plant-based foods. The approach to food needs to be multidimensional, as plants and animals work best as an

integrated system for providing a more sustainable nutritional future.

Food is essential for human survival and an important part of a healthy lifestyle, but it is also at the heart of the debate about achieving a sustainable society. What people eat naturally affects what is produced and evidence increasingly points to the need for more sustainable food systems and diets. This will require profound changes in the food we produce and consume and how we do it.

A sustainable diet is an integral part of food systems, as it affects all aspects of sustainability, either directly or indirectly. A clear distinction between sustainable diets, individual foods and other components of the food system is not always possible.

Expert discussions have put forward several definitions and frameworks for the terms 'sustainability' and 'sustainable diets'. Although the wording differs, they all acknowledge the multifaceted nature of sustainability, which spans social, economic and environmental aspects. Some definitions also raise the issue of animal welfare, practicality of diets and the aspect of good-quality food. As an authoritative voice, the FAO brings these diverse aspects together as follows: 'Sustainable diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimising natural and human resources.'

Current literature on healthy and sustainable diets generally seems to focus on sustainability metrics that evaluate GHG emissions and land use. This focus resulted in recommendations that favour diets consisting of plant-based foods as the answer to achieving sustainable, healthy diets. However, these two metrics, GHG emisions and land use, focus on limited aspects of sustainability, and may fail to capture the important synergies of sustainable nutrition.

Moving towards food systems that focus on plant-based foods alone may very well not save the planet. Rather, shifting systems towards a diet rich in plant-based foods while including the most efficient and environmentally sustainable form of animal-source foods seems to be the answer to a complex matter. Milk and dairy foods can help make plant-packed plates even better by adding nutrients, health benefits, flavour, texture and satisfaction. Dairy and plant-based foods work better together.

Multidisciplinary research has yielded valuable insights into the complex nature of sustainable diets and most experts agree that healthy eating involves:

- consuming a diet rich in plant-based foods (i.e. vegetables, whole grains, pulses and legumes, and fruit);
- limiting the intake of salt, sugars and red- and processed meat;
- consuming more unsaturated fats; and
- consuming low-fat dairy.

Across the world, food-based dietary guidelines (FBDGs) take these recommendations into account and so support diets that include a variety of food, of both plant and animal origin.

Milk and dairy are valuable components of a sustainable diet, as they represent a nutrient-dense source of animal protein, are regarded as enjoyable, are well accepted in many countries as a common component of the general diet, and are consumed regularly. According to the FAO database, 94 countries have dietary guidelines and all of them recommend the consumption of dairy. This is in response to the overwhelming evidence that the consumption of milk, cheese and yoghurt as part of healthy dietary patterns are associated with positive health outcomes and can contribute to alleviating malnutrition.

Can animal foods fit into a plant-based diet?

Around the world, large proportions of populations consume adequate amounts of animal-based foods such as meat, poultry and eggs, but often fall short when it comes to vegetables, dairy foods, fruits and whole grains.

Fruits, vegetables, whole grains, nuts, seeds and legumes are key components of healthy eating patterns and thus it is important to include these foods in the daily diet. Throughout the world, healthy eating plans are described with the help of FBDGs, each applicable to a country's specific needs. FDBGs are a good example of a food-based approach to balance. For example, the Dietary Approaches to Stop Hypertension (DASH) diet refers to food choices that embrace foods from plant and animal sources, including dairy foods such as milk, yoghurt and cheese.

What does 'balance' refer to in context of a dietary pattern? Balance refers to the relative contribution of food groups in a diet while supporting variety and moderation. Variety refers to the diversity of food items within a food group, while moderation refers to the proportion of the food group in a healthy diet.

A balanced diet is more about what you include than what you exclude. When diets exclude certain foods or food groups, the chances of consuming a diet that lacks some vital nutrients is increased. A diet containing only plant-based foods generally contains inadequate amounts of calcium and vitamins A, D and B_{12}.

Milk and dairy foods are naturally nutrient-rich, providing an abundant supply of high-quality protein, calcium, potassium, magnesium, phosphorus, zinc and vitamins A, B_2 and B_{12} as well as vitamin D when fortified. The unique package of essential nutrients in dairy products contributes to the prevention of all forms of malnutrition, and is associated with better growth in children, and better micronutrient status, cognitive performance and motor function development. With regard to the association of dairy consumption and non-communicable diseases, a growing evidence base also supports no or an inverse association between dairy consumption and the incidence of obesity, type 2 diabetes, stroke, certain cancers and cardiovascular disease.

In view of this, the thinking about sustainable healthy diets as an issue of plant food versus animal foods does not represent a comprehensive mindset. Animal foods contribute important nutritional value to healthy, plant-based eating patterns. Including milk and other dairy foods in the diet can help South Africans to reach the recommended intake of three of the four nutrients generally lacking in their diet (calcium, potassium and vitamin A), as well as contributing high-quality protein. Well-balanced, healthy eating as part of a kilojoule-controlled diet (which prevents overeating) should contain a mix of plant- and animal-based foods, including dairy foods, to help reduce the nutrient gaps and lower the risks of developing non-communicable diseases.

LOOKING AT SPECIFIC QUESTIONS:

1. Why do some people choose to exclude milk or dairy from their diet?

Today's consumer is showing an increased interest in and preference for buying food products that promise nutritional and health benefits. In response, the food industry constantly introduces new products to the market to satisfy the consumer's pursuit of well-being.

Therefore, the consumer is constantly exposed to new products on the shelf and wider choices for improving their diet and health. The availability of these products, coupled with a wealth of health and nutrition information freely available on the internet – of which some is scientifically sound and some not at all – can overwhelm and confuse the consumer who has so many options to choose from.

Consumers often cite cow's milk protein allergy or lactose intolerance, cultural preferences or beliefs, or a specific dietary preference (such as vegan, flexitarian and so-called paleo diet) as reasons for excluding milk and other dairy products from their diet. Recent research also found that consumers who exclusively chose plant-based dairy alternatives did so based on the belief that animal mistreatment is reduced by lower consumption of animal products or because of the perceived environmental benefits, while others are concerned with the saturated fat and hormone content of milk or the use of antibiotics in dairy cattle.

It has been shown that consumers' deliberate replacement of cow's milk with a plant-based beverage could be influenced by the term 'milk' being used on packaging of various plant-based beverages. Consumers may interpret the product name to mean that it is similar to cow's milk or that it is an appropriate nutritional replacement for cow's milk.

To ensure that consumers are protected from false claims or to prevent them from being deceived by false information on packaging, specific regulations regarding labelling have been put in place by both international and local legislation (see info under question number 13).

2. Which products are typically chosen as alternatives to dairy when milk is excluded from the diet?

Consumers are experimenting with the use of plant-based alternatives to milk such as almond, rice, oats and coconut milk. There seems to be an assumption that if a product is called 'milk' or looks like milk it has the same nutritional properties as cow's milk. However, as the nutritional composition of these plant-based 'milks' depend on the plant source, processing methods and fortification, they do not have a consistent nutritional profile and contain varying levels of macro- and micronutrients.

Plant-based beverages used as assumed alternatives to cow's milk are fluids made from the breakdown (size reduction) of plant material such as cereal or pseudo-cereal grains (products that resemble grains), legumes, oil seeds and nuts. These products are then mixed with water. Further homogenisation results in particles of 5–20 µm being evenly suspended in the mixture, which yields a product that imitates the appearance and consistency of cow's milk.

Although literature does not offer any formal definition or classification of such plant-based beverages (so-called milk alternatives), the following five categories of these products are generally described:

- cereal-based products, such as oat milk, rice milk, corn milk and spelt milk;
- legume-based products, such as soya milk, peanut milk, lupin milk and cowpea milk;
- nut-based products, such as almond milk, coconut milk, hazelnut milk, pistachio milk and walnut milk;
- seed-based products, such as sesame milk, flaxseed milk, hemp milk and sunflower milk; and
- products derived from pseudo-cereals, such as quinoa milk, teff milk and amaranth milk.

Although these products are not all currently available in the South African retail market, history has taught us that international trends often emerge in South Africa fairly soon after products' first introduction elsewhere in the world, either being imported or manufactured locally.

3. How does the nutrient profile of plant-based beverages compare with that of cow's milk?

It is hard to match or mimic the nutritional profile of cow's milk. Plant-based beverages are formulated and highly processed products that are fortified (with macro- and micronutrients) to mimic the composition of milk. Even so, they are not nutritionally equivalent to cow's milk.

Milk is naturally nutrient-rich and a good source of several essential nutrients, such as high-quality protein and a unique mix of slow- and fast-digesting proteins, minerals and vitamins. Milk contains many natural bioactive components (e.g. specific fatty acids and peptides) and has a uniquely high internal biodiversity in its composition with e.g. more than 400 different fatty acids and more than 400 different proteins.

Milk is not considered a 'high-fat' product and a range of lower-fat options are available to suit different consumer preferences. When comparing the nutritional value of milk and plant-based beverages, it is important to take the food matrix into consideration. In the context of milk, the matrix concept refers to the unique combination of nutrients and bioactive factors in milk, and how they interact with one another and the physical food structure to produce the overall effect on health. Although milk contains some saturated fat, there is no evidence to support a harmful effect on cardiovascular health; the matrix effect of milk is different from what would be expected based on single nutrients.

The nutrients in milk contribute to good health during all stages of life (from childhood to advanced age), and with options ranging from whole milk to fat-free and lactose-free milk, diverse dietary preferences and needs can be accommodated.

The analysis of the composition of formulated plant-based beverages shows that it varies considerably, both between and within types. Plant-based beverages generally:

- are low in protein (except for beverages derived from soya and peas, and some oat milks);
- have a lower protein quality than milk (except for soya beverages, which have a similar protein quality to milk, especially in the case of crops, that are genetically modified for increased protein content and an improved amino acid profile);
- contain added sugar (whereas plain cow's milk contains no added sugar);
- contain several added ingredients (e.g. additives such as emulsifiers, stabilisers, etc.); and
- do not naturally contain the vitamins or minerals found in milk, and therefore are often fortified; however, this practice is not standardised (e.g. many of the added vitamins or minerals are not permitted in organic products) and hence there is a wide variation in micronutrient composition of plant-based beverages.

Furthermore, formulation differences between brands result in a high degree of variability in the nutrient composition of plant-based milk alternatives, even among beverages derived from the same plant base.

A comparison of the nutritional composition of cow's milk and plant-based substitutes is given in Table 1. For a representative quantity, values for milk alternatives are given as an average across four products available on the South African market.

To avoid potentially severe nutritional deficiencies, consumers who choose to use plant-based beverages instead of cow's milk should familiarise themselves with the nutritional profile of the product and be able to make dietary adjustments to replace lost nutrients. This is particularly important in the case of infants and children. Young children often eat what is provided and do not yet have the autonomy to choose foods to achieve a balanced intake of macronutrients. Furthermore, their bodies are not yet able to self-regulate energy intake and the amount of food until satiety is reached. Their stomach capacity is still too small to handle the higher volume of a plant-based beverage needed to fulfil their nutrient needs. This could lead to young children developing severe nutrient deficiencies that may lead to serious illnesses.

It is important that dietitians teach their clients how to differentiate between real milk and plant-based beverages, that public education initiatives be conducted and that labelling requirements are enforced to prevent consumers from mistakenly considering plant alternatives to milk as a direct nutritional alternative to cow's milk.

4. How does the protein quality of cow's milk and plant-based dairy alternatives compare?

Cow's milk and plant-based dairy alternatives differ considerably with regard to the amount and quality of protein present per 100 ml. Protein quality has a notable effect on the nutritional quality of a dietary protein source.

Currently, the most widely used method for rating protein quality is the Protein Digestibility-Corrected Amino Acid Score (PDCAAS), which rates proteins on a scale of 0 to1 (1 represents the highest score).

Cow's milk has a score of 1, whereas the PDCAAS score for wheat is 0.50, 0.69 for oats, 0.79 for peas, and 0.93 for soya (protein isolate).

However, the FAO recently recommended using the Digestible Indispensable Amino Acid Score (DIAAS) method to determine protein quality, because it measures protein quality more accurately and also takes into account the body's ability to absorb essential/indispensable amino acids. The DIAAS measures the digestibility of individual amino acids rather than the crude protein levels measured by PDCAAS. Using the DIAAS method, the score for wheat is 0.45, 0.67 for oats, 0.65 for peas and 0.84 for soya (protein isolate), whereas cow's milk has a score of 1.16. Cow's milk can therefore be considered an excellent protein source, based on the FAO recommendations for food items with a DIAAS $\geq$ 100%.

Proteins from animal sources are generally of higher quality than those from plant sources. According to both the PDCAAS and DIAAS classifications, milk is a source of high-quality protein and constitutes one of the best natural sources of proteins.

Cow's milk contains both whey and casein, which both have a high biological value. Cow's milk typically contains approximately 3.4% protein, whereas plant-based milk substitutes generally contain around 0.5% protein (this excludes soya milk, which has a protein content of approximately 3%).

The high protein quality and content of cow's milk is due to the presence of enzymes, immunoglobulins, bactericides, mediators and growth factors – all related to the physiological role of milk. These components are not present in plant-based beverages.

The quality of protein depends to a large extent on the amino acid composition of the product and particularly its relative content of essential amino acids and their digestibility. The FAO (2013) defines a high-quality or complete protein as one that contains all the essential amino acids in the quantities and proportions required to maintain good health and avoid deficiencies (i.e. in line with human requirements), while offering excellent bioavailability and rapid digestibility.

Cow's milk is also naturally high in 'complete' protein (providing all essential amino acids), whereas plant-based milk substitutes contain mostly 'incomplete' protein. Owing to the ratio of essential amino acids in animal-derived protein, the protein in cow's milk has a higher bioavailability than that of plant-based milk substitutes. For example, the nutritive value of soya protein is limited by its lower content of methionine and cysteine. Therefore, when plant-based protein is used, more total protein must be consumed for the body to get enough of the amino acids it needs.

A major drawback of beverages derived from nuts such as almonds is that the protein content is strained out along with the pulp; hence, it contains very little protein – usually only 1 g per cup, compared to 8 g in a cup of cow's milk.

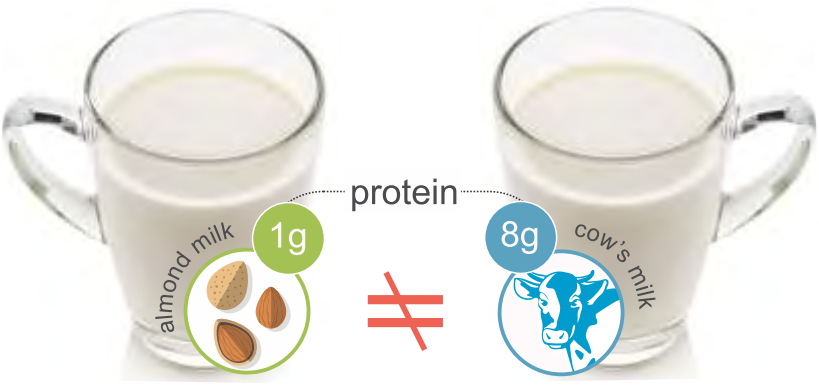


Table 1

Comparison of the nutritional composition of cow's milk and plant-based alternatives to milk*

Product type/source per cup (250ml)	Energy (kJ)	Protein (g)	Total carbohydrates (g)	Of which added sugar (g)	Fat (g)	Calcium (mg)	Sodium (mg)	Fortifications
Cow's milk (full-cream)	645	8.3	11.8	0	8.3	298	123	None
Cow's milk (fat-free)	365	8.3	12.00	0	0.3	308	130	None
Soya beverage (sweetened)	496	7.8	8.3	6	5.4	139	168	Vitamins (B_2, B_{12} & D) Calcium (tricalcium phosphate, or calcium carbonate), Phosphorus, Magnesium
Soya beverage (usweetened)	394	7.7	5.5	1.6	5.0	230	97	Vitamins (B_2, B_{12} & D) Calcium (tricalcium phosphate, or calcium carbonate), Phosphorus, Magnesium
Oat beverage (sweetened)	591	2.8	19.4	9.8	6.0	238	94	Potassium phosphates Calcium (calcium carbonate), Phosphorus
Oat beverage (unsweetened)	398	2.0	12.5	2.3	3.8	265	133	Calcium (calcium carbonate)
Almond beverage (sweetened)	298	1.3	9.2	9.3	3.1	321	135	Vitamins (A, B_2, B_{12}, D, E) Calcium (tricalcium phosphate, or calcium carbonate)
Almond beverage (unsweetened)	258	1.4	4.6	1.4	4.7	286	91	Calcium (tricalcium phosphate, or calcium carbonate)
Coconut beverage (sweetened)	934	1.7	11.8	8.2	19.2	316	71	Vitamins (B_{12} & D_2) Calcium (tricalcium phosphate)
Coconut beverage (unsweetened)	1134	2.3	7.4	3.8	25.8	323	64	Vitamins (not specified) Calcium (tricalcium phosphate, or calcium phosphate)
Rice beverage (unsweetened)	570	0.4	28	13.6	3.0	280	71	Calcium (tricalcium phosphate, or calcium carbonate), Vitamins (B_2 & B_{12})

**Source of the composition of plant-based beverages: Milk SA report on sales of plant-based imitation dairy beverages in the South African retail market. September 2020.*
Note: The table above shows the fortified ingredients that were mentioned on the labels of the products per category. Not all the sampled plant-based beverages, within a specific category were fortified with the all the ingredients or micronutrients mentioned. However, all categories of plant-based beverages contained stabilisers. It is advisable to read the labels of each brand to determine the specific fortification that is applicable. At present there is no regulation stipulating the nutritional requirement for plant-based imitation dairy beverages

5. Is the calcium in plant-based milks comparable to that found in cow's milk?

According to the Institute of Medicine, adults need 1 000 mg of calcium per day (this increases to 1 200 mg per day during pregnancy, as well as for women over 50 and men over 70 years of age).

It is important to note that it is not only the amount of calcium present in foods but also the bioavailability (amount that can be absorbed by the digestive system) that determine how much is available to the body. Dairy foods are excellent sources of a number of macro- and micronutrients, including calcium. In addition to calcium, dairy foods also contain lactose and casein phosphopeptides, which promote calcium absorption.

Although it is possible to meet calcium requirements without consuming dairy foods, it can be challenging. Plant foods that contain notable amounts of calcium may also contain components that inhibit calcium absorption, such as oxalates (found in spinach, nuts, cabbage, sweet potatoes, rhubarb and beans) and phytates (found in wheat bran, beans, seeds, nuts, soya isolates and fibre-containing wholegrain products), which bind to calcium and form insoluble salt complexes, thus decreasing calcium absorption. About 30–35% of the calcium in cow's milk is bioavailable, while only about 5% of the calcium in plant foods is absorbed. It is thus much easier to meet calcium requirements when milk and milk products are included in the diet than when relying only on plant foods.

One glass of cow's milk (250 ml), two small tubs of yoghurt (2 x 100 ml) and two tablespoons of grated cheese (40 g) provide 300 mg of calcium each, almost a third of daily calcium needs.

Other foods, such as sardines (if you leave the bones in), tofu (fortified with calcium), beans (red, white), certain fruit (e.g. figs) and vegetables (e.g. spinach, sweet potato and broccoli), and almonds also contain calcium. However, it is hard to meet calcium needs from these foods. For example, to get the same amount of calcium as found in 1 glass of milk (250 ml), a person will need to consume either 7 sardines, 25 almonds, 2 cups of cooked spinach, 3 cups of beans or 7 cups of cooked broccoli.

The most noticeable difference between the calcium found in cow's milk and that in plant-based beverages is that the mineral is not naturally found in these milk alternatives. Manufacturers have to fortify plant-based beverages with calcium to provide comparable amounts to that found naturally in cow's or goat milk. The most common forms used for fortification are calcium carbonate and calcium triphosphates. However, the bioavailability of fortified calcium does not compare well with that of calcium occurring naturally in foods, possibly owing to the presence of isoflavones and phytates, which generally decrease calcium absorption.

A review by Chalupa-Krebzdak et al. (2018) refers to various studies that compared the bioavailability of calcium fortificants in soya milk which found that the use of tricalcium phosphate and a combination of sequestering and stabilising agents resulted in a calcium–phosphate ratio of 1.3:1. Soya milk fortified with calcium carbonate showed less calcium stability and a less ideal calcium–phosphate ratio at 2.6:1, but exhibited a higher calcium availability than when fortified with tricalcium phosphate. As calcium bioavailability is the critical factor in choosing calcium salts for use as a fortifying agent, calcium carbonate should be considered as the preferred option in plant-based beverages used as milk alternatives.

Consumers should note that in beverages that are fortified with the water-soluble mineral calcium-triphosphate, the calcium tends to settle out at the bottom of the container. Consumers should therefore make sure that they shake the container well before use to allow the calcium to mix with the liquid.

6. How does the sugar content of cow's milk and plant-based beverages differ?

Milk is an excellent source of a number of macro- and micronutrients. The main source of carbohydrates in milk is lactose, also called milk sugar. Lactose is naturally present in all mammalian milk and is generally defined as intrinsic sugar.

Lactose consists of two monosaccharides, namely glucose and galactose, bound together. During normal digestion, the body produces an enzyme called lactase to separate these two sugar components, so that they can be absorbed into the blood. Milk naturally contains approximately 4.7% lactose (i.e. 4.7 g lactose per 100 g).

Owing to the nature of processing used in producing plant-based beverages, they often do not have a palatable taste or texture and therefore are generally sweetened with added sucrose sugar. The added sugar is used to improve the general sensory profile of the product. Plant-based beverages typically contain 3–11 g added sugar per 100 g, in the form of evaporated cane juice, cane sugar or cane syrup.

7. How do the health effects of cow's milk compare with those of plant-based beverages?

When considering the role of milk and dairy in health and health promotion, one could consider:

- dairy as a food group,
- or the effects of different dairy products,
- or else focus on dairy at a component level.

At a component level, health effects can be viewed with reference to nutrients (e.g. calcium, nutrients, fats) or non-nutrient substances (e.g. bioactive peptides). However, the matrix concept allows for the health effects of milk to be evaluated in terms of a whole food, extending beyond the effects of its individual nutrients.

For the purpose of this question we will consider the effect of milk and plant-based beverages only on health and health promotion.

Evidence-based literature offers a wealth of data to support the beneficial association between the consumption of cow's milk and conditions such as colorectal cancer, hypertension and metabolic syndrome, weight loss with energy restriction, bone and dental health, and growth and development [https://www.rediscoverdairy.co.za/nutrition-health-wellness/]. Neutral associations have been found between the consumption of dairy milk and cardiovascular disease, stroke, type 2 diabetes and overweight.

There is currently limited research and a lack of evidence on the health effects of commercially available plant-based beverages. For example, although it is acknowledged that enriched soya milk has a similar composition to milk with reference to protein, vitamins and minerals, the nutritional similarity does not imply that the health effects will be the same.

Unlike the research on milk, there is little or no evidence supporting the beneficial effects of plant-based beverages on disease endpoints (e.g. cardiovascular disease, type 2 diabetes). Information about these products generally focuses on the beneficial effects of their constituents (e.g. soya protein, unsaturated fat) on disease markers (e.g. cholesterol) and extrapolate these to product effects.

A serving of a plant-based beverage (e.g. an almond-based or oats-based drink) is not nutritionally equivalent

to a serving of that specific plant food as a whole (e.g. almonds or oats). The plant-based beverage marketing information shifts its focus to the health benefits of 'plant-based diets' as such, thus creating a halo effect by implying that these plant-based beverages are healthy because a plant-based diet is considered healthy.

8. Do plant-based beverages offer nutritional benefits?

The best way to explain the nutrient benefit of plant-based beverages is to refer to the product's original source (i.e. the raw product). In raw, or whole form, the foods from which these beverages are produced (for example, almonds, soya, oats or cashews) are nutrient-rich and may contribute to a healthy eating pattern if used as part of a varied diet.
However, the 'milks' produced from nuts such as almonds and cashews tend to be highly diluted with water (e.g. 1 L of almond milk contains the equivalent of only 7 almonds). While the dilution makes them relatively low in energy (kilojoules), it also means that they supply minimal amounts of the nutrients typically found in nuts, including protein, manganese, magnesium and copper.

Unsweetened almond-based beverages used as milk alternatives generally have an energy content of less than 210 kJ per cup. However, to improve the sensory profile, most almond drinks are sweetened with sugar and a cup may contain up to 16 g of sugar, which increases the energy content to 378 kJ.

Soya milk is likely the 'least processed' of all the plant-based milk alternatives. Soya is one of the top three genetically modified crops(GMOs) in the US, with 94% of all soya beans in the country being genetically engineered. In South Africa, according to the National Science and Technology Department, 90% of all soya crops are genetically modified. Most mainstream soya milk brands include certified GMO ingredients.

Oat milk has a low overall energy value and is also low in cholesterol and saturated fat. It offers more fibre than other milk alternatives and may contain up to 2 g per cup (sometimes more, depending on whether oat bran has been added). It also contains iron, vitamin E and folic acid. In addition, oat milk offers 4 g of protein per cup (1.6%), which is higher than most other plant-based milk alternatives. Naturally occurring sugars contribute to a higher carbohydrate content than other comparable plant-based beverages. Depending on the brand, oat milk may be a viable option for people with nut and seed allergies, but it cannot be considered a nutritional replacement for cow's milk.

9. Are plant-based beverages used as milk alternatives suitable for use as a complete milk replacement?

- Generally, plant-based milk alternatives do not have the same nutritional composition as cow's milk and cannot replace cow's milk in the diet, especially in growing children. Cow's milk is a natural source of well-absorbable and highly bioavailable protein, calcium and micronutrients. In contrast, plant-based dairy alternatives are not naturally rich in nutrients and therefore have to be fortified, specifically with calcium and vitamin B12.

The nutritional composition of plant-based beverages depends on:

- the source of the product;
- the processing methods used to extract the liquid; as well as
- the fortification used to mimic the nutrients in milk.

Different plant-based beverages have different nutritional properties, and also differ in their levels of macro- and micronutrients compared with cow's milk (or any other bovine milk). Consumers' perception that plant-based beverages are as nutritious as milk could lead to nutritional deficiencies, particularly in young children. It is important to note that milk and water are the recommended beverages for children of 12 months to 5 years of age. Plant-based beverages are not recommended as milk equivalents for children between the ages of 12 and 24 months owing to nutrient inadequacies. Thus, their consumption is not advised in children between the ages of 2 and 5 years (unless medically indicated, as in the case of cow's milk protein allergy).

However, when used as part of a well-designed dietary plan, specific plant-based beverages can be part of a healthy diet for individuals who choose to avoid animal products. Given its nutritional composition, soya milk is the one product that could serve as an alternative to cow's milk when an individual chooses to use plant-based foods exclusively.

The first use of soya milk was reported in China about 2000 years ago and it was the first plant-based 'milk' used to provide nutrients to a population who did not have ready access to cow's milk or who were allergic to milk proteins. Soya milk is a good source of essential monounsaturated and polyunsaturated fatty acids and has a protein content close to that of cow's milk (approximately 3% vs 3.4% in cow's milk).

As most soya crops are genetically modified to increase the protein content and improve the amino acid profile, soya milk can be considered a possible alternative to cow's milk in terms of protein content.

However, despite containing a similar amount of protein as cow's milk, soya milk still offers limited amounts of the amino acids methionine, cysteine and lysine; does not naturally contain vitamin B_{12}; and contains very little calcium. Most commercially available soya milks are therefore fortified with both vitamin B_{12} and calcium.

In general, the lower protein content, calcium availability, higher GI values, and potential presence of anti-nutritional factors, make plant-based milk alternatives nutritionally inferior to cow's milk.

Plant-based beverages may have a place in the diet, however, owing to the fact that plant-based beverages are generally considered not to be nutritionally equivalent to cow's milk (with reference to their respective nutrient profiles), they cannot be included as part of the milk and dairy group in food-based dietary guidelines. Plant-based beverages should not replace milk in a healthy, balanced diet.

10. Considering that consumers are advised to use less processed foods, how does processing differ in the production of plant-based beverages compared to cow's milk?

Milk is a natural product, which requires minimal processing, whereas plant-based beverages are formulated products, in other words, highly processed foods.

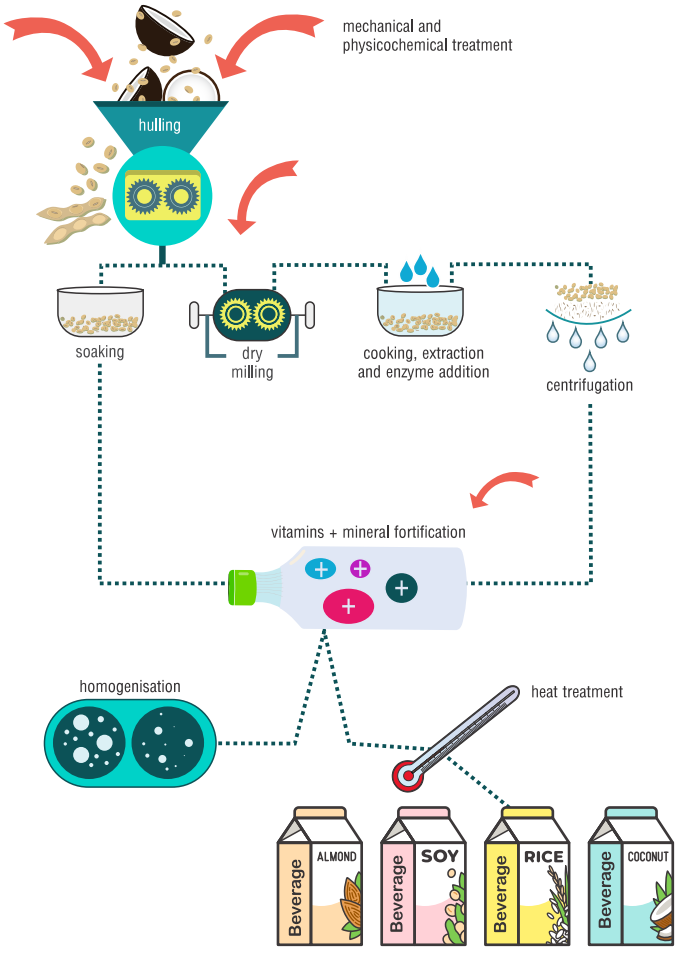
The processing of plant-based beverages involves many technical interventions and may include one or more of the following unit operations:

- mechanical and physicochemical treatment of seeds, such as hulling, soaking, mechanical cooking, extraction, filtration and centrifugation;
- enzyme addition;
- preparation of a beverage base prior to further processing;
- formulation by the addition of selected functional ingredients;
- harsh heat treatments to remove compounds causing undesirable flavours;
- treatments with acids or bases (e.g. $NaHCO_3$, HCl);
- oxidation processes, which could lead to undesirable flavours; and/or
- production of large amounts of waste and by-products that are difficult to dispose of.

The production of plant-based beverages often requires the addition of food additives such as preservatives, stabilisers, thickeners and flavouring to improve palatability (see associated ingredients list). Additives such as salt, lecithin and gellan, guar, Acacia and xanthan gums are often added to give plant-based beverages a smooth, creamy mouth feel.

Comparing the packaging label of plain milk with a typical plant-based milk alternative, it is clear by just looking at the ingredients list, that cow's milk is minimally processed. The typical processes involved in plain cow's milk are fat standardisation, homogenisation or pasteurisation (heat treatment). Cow's milk also contains no added ingredients.

PLANT-BASED BEVERAGES ARE HIGHLY PROCESSED



11. How do the greenhouse gas emissions from dairy production compare with those for producing plant-based milk alternatives?

All food production – whether of plant-based or animal-based foods – has an impact on the environment. Reducing the environmental impacts of the food system is a lot more complex than just plant versus animal products. The food system needs a multidimensional approach, as plants and animals work best as an integrated system.

The nutritional profiles of dairy- and plant-based beverages are fundamentally different, which complicates the direct comparison of the relative contribution of their production to greenhouse gas (GHG) emissions. Extensive research has been conducted regarding both the contribution of dairy to human health and its impact on environmental sustainability, compared with fairly little research around the production, consumption and integrated health effects of plant-based beverages used as milk alternatives. In addition, it is not yet clear how GHG emissions associated with the production of plant-based beverages compare with those of dairy production when figures are adjusted for nutritional and economic factors.

The exact quantification of GHG emissions is complicated, as evidenced by the initial figures provided by the FAO in 2006 being retracted owing to calculation errors. At present, the FAO estimates that dairy production at the farm amounts to 2.7% of global anthropogenic GHG emissions. Most available data compare the GHG emissions per kilogram of food produced at the farm, without taking into account the nutrient density or the industrial processes involved in producing the product in the form it is consumed.

As most plant foods have a lower carbon footprint than most animal foods, there is a common perception that plant-based beverages are a more environmentally responsible option than milk. This idea is often used in the marketing of plant-based beverages. Although GHG emissions from milk would appear to be higher than those from plant-based beverages when expressed per kilogram, this is not true, as one would have to drink a larger amount of a plant-based beverage for the equivalent nutritional value offered by cow's milk. The production and processing to deliver these higher volumes of plant-based beverages has a direct impact on various environmental factors, increasing the environmental sustainability of plant-based beverages. Furthermore, producing plant-based beverages involves intensive heat and mechanical processes, as well as several additives (e.g. stabilisers, emulsifiers and fortified supplements) having to be added to the raw material to produce a fluid alternative to milk; while the same extent of processing is not required in the production of dairy milk. In fact, milk is wholly edible, whereas a large portion of the plant materials used in producing a plant-based milk alternative is not and contributes significantly to the waste stream (flow of specific waste, from its source through to recovery, recycling or disposal).

12. What is the relationship between production efficiency and resource use of producing animal-based foods?

The dairy sector has steadily improved its carbon footprint: globally the sector has seen a reduction of 11% in GHG emissions per litre of milk produced between 2005 and 2015. The inverse relationship between

production efficiency and resource use or GHG emissions is well known. Dairy farmers are constantly using innovative farming practices to produce the same amount of food, with a comparable nutrient profile, while using fewer natural resources. This implies that efficiency has improved, and GHG emissions, waste and water use per unit product have declined. In South Africa, the number of cows has declined since 1990 by 24% while total milk production has increased by 56%. With increasingly modern and innovative farming methods, the US dairy industry has succeeded in reducing their carbon footprint and improving the environmental impact of producing 3.8 L (1 gallon) of milk by 19% from 2005 to 2015. This translates to 30% less water consumption, 21% less land use and 21% less manure production. This was as a result of implementing key changes in agricultural practices, such as improvements in reproduction or fertility, vaccinations and veterinary care, improved breeding, and improved feeds. The dairy sector has improved its available grazing land by means of effective pasture management, manure management, better crop–livestock integration and waste reduction. Furthermore, it is essential to take into account that grazing animals contribute to maintaining grasslands that otherwise cannot be used for crop farming. For example, in the South African context, the World Wide Fund for Nature (WWF) estimates that only 12% of available land can sustain crop production, whereas 69% of land is suitable for grazing. The contribution of grazing animals to grassland conservation is also another example of animal- and plant-based food systems working better together.

13. What is the position of international authorities on plant-based milk alternatives?

Although the Food and Drug Administration (FDA) has not released a formal definition for the terms 'natural' and 'clean' or any of their derivatives, several members of Congress have signed a letter urging the FDA to ban the use of the word 'milk' for anything but liquid derived from a cow's udder. The group claims that nut and grain milks are an imitation and therefore should be labelled similarly to imitation cheese or non-dairy creamer.

In June 2017, the European Union (EU) Court of Justice stated in a press release that the terms 'milk', 'cream', 'butter', 'cheese' and 'yoghurt' are reserved for animal products under EU laws and cannot be used for purely plant-based products.

In South Africa there are still no regulatory definitions that differentiate between the use of the word 'milk' on packaging of plant-based beverages and cow's milk. The South African milk industry is investigating the matter.

Conclusion

Several plant-based milk alternatives are commercially available. Although they look like cow's milk, they differ significantly from cow's milk with regard to nutritional composition and bioavailability of nutrients.

Replacing cow's milk with plant-based milk alternatives may result in unintended nutritional consequences owing to the lack of nutritional balance compared with cow's milk. It is important that plant-based dairy alternatives should not be considered to be nutritional substitutes for cow's milk until nutritional quality and bioavailability of nutrients have been established.

Current evidence indicates that the sum of the dairy nutrients in the dairy food structure (referred to as the dairy matrix) has specific effects on health as seen in the metabolic effects of whole dairy on body weight, cardiometabolic risk and bone health compared with that of single nutrients. This important feature further distinguishes cow's milk from plant-based beverages.

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