

THIS ISSUE	PAGES
Summary points .....	1
Introduction .....	2
Nutritional composition .....	2
Consumer perceptions and drivers of choice .....	5
Health impact .....	5
The vegan trend, plant-based diets and sustainability .....	5
Alternative choices within the dairy category .....	6
Conclusions .....	7
Contact us .....	8

## Dairy alternatives - how do they compare?



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**This review provides a comprehensive nutritional comparison of cow's milk and plant-based alternatives, and examines the scientific research regarding their impact on health.**

### Summary points

- Despite fortification with calcium and some other nutrients, plant-based dairy alternatives lack many of the important nutrients naturally and uniquely provided by milk. Therefore, cow's milk and plant-based dairy alternatives are not nutritionally equivalent.
- In cases where plant-based beverages offset the consumption of cow's milk, it is important not to overlook the nutritional differences and potential health impact.
- A wealth of research supports the role of dairy as an important component of a healthy diet. Research is still needed to explore if plant-based alternatives can contribute to population health.
- Whole milk is generally higher in calories and fat compared to plant-based beverages but semi-skimmed and skimmed milk have comparable levels to most of the alternatives.
- Cow's milk is higher in protein compared to plant-based alternatives. However, soya beverages have comparable levels but the protein in cow's milk is of higher nutritional quality.
- The carbohydrate component of cow's milk is composed of the naturally occurring milk-sugar, lactose. Many plant-based dairy alternatives contain added sugar or sweeteners.
- Cow's milk is a rich source of bioavailable calcium and iodine but the calcium bioavailability of plant-based beverages depends on the type of fortificant used and most are devoid of iodine.
- Many plant-based alternatives contain additives such as stabilisers, emulsifiers, flavourings, sweeteners and salt. Fresh cow's milk does not contain these additives.
- Perceived health benefits and ethical factors such as animal and environmental welfare are key motivators in choosing plant-based dairy alternatives. However, with its grass-based dairy production, Ireland is one of the most carbon-efficient milk producers globally. In addition, high standards of animal welfare are mandatory and are monitored through the Sustainable Dairy Assurance Scheme.

## Introduction

A few decades ago, the word 'milk' had a similar meaning for most people. It was a trusted and unquestioned staple in the Irish diet, with everyone generally consuming the same variety: cow's milk. It was recognised as part of a healthy diet and one of the aims of implementing school milk schemes across the EU was to provide children with important nutrients to support growth and development. In today's world, 'milk' has many guises and the range of consumption choices have spiralled, while consumer attitudes to cow's milk have become more diverse and, for some, emotive. Many consumers are now reducing or replacing their milk consumption, with a trend towards plant-based dairy alternatives gathering pace.

The visibility of various new plant-based dairy alternatives on our supermarket shelves is evidence of consumer demand. Euromonitor figures indicate that their sales more than doubled between 2009 and 2015 and current market share figures from Nielsen predict a continuing annual growth rate of 8-12% over the next four years.

Increased food choice is largely positive as it offers more variety, particularly for those with unique taste preferences or for those on restrictive diets. However, in cases where plant-based beverages offset the consumption of milk or where they completely replace it as part of a dairy-exclusion diet, it is important not to overlook the nutritional differences and potential health impact. As food choice

is increasingly being influenced by popular trends, food blogs and social media, scientific-based advice on the best choices for healthy eating often lose authority among the noise. Understandably, with such diverse sources of nutritional information now available to consumers, some lack accuracy and lead to widespread confusion regarding which choices are best.

The Department of Health Guidelines for Healthy Eating advise individuals who choose dairy alternatives to "choose those with added calcium"<sup>1</sup>. This is due to the fact that calcium is not naturally present in most dairy alternatives and dairy foods are the main provider of calcium in the Irish diet. However, despite fortification with calcium and some other nutrients, plant-based beverages still lack many of the important nutrients naturally provided by milk. As a result, the Food Administration Authority in Denmark recently advised that "plant based drinks from soya, rice, oat and almond cannot be recommended as valid alternatives to cow's milk". Therefore, for those that are unable or unwilling to consume cow's milk, it is imperative that they are informed regarding the dietary sources that can provide the shortfall of nutrients not being met by dairy alternatives.

The objective of this edition of *DN Forum* is to provide a comprehensive nutritional comparison of cow's milk and plant-based alternatives, and to examine the scientific research regarding their impact on health.

## Nutritional composition

Given that many plant-based beverages are commonly packaged and referred to as 'milk', consumers could easily presume that they are purchasing a nutritionally equivalent product. However, as shown in Table 1 (A-C), there are differences in the nutritional compositions of cow's milk compared to five of the most commonly consumed plant-based beverages on the market. Dairy alternatives are generally derived from plant-based ingredients such as soya, rice, almond, oat, coconut, hazelnut or hemp. The main difference is that the dairy alternatives have a higher water content and are often fortified with calcium and some vitamins to improve their nutritional value, whereas cow's milk is a natural source of calcium, protein and a wide matrix of micronutrients, including B vitamins, iodine, potassium and phosphorus.

Being of biological origin, the composition of cow's milk is naturally variable but, given that milk collections are pooled and the varying fat contents are standardised, the nutritional composition of commercially available cow's milk is relatively consistent and composed of a single natural ingredient: milk. Plant-based dairy alternatives, however, are more variable in composition due to the fact that they are manufactured products, composed of several ingredients in varying proportions, depending on the brand recipe<sup>2</sup>. Therefore, the nutritional comparisons presented in this publication are based on the original version of each product and on the most representative reference source available, rather than on individual data from branded products. The nutritional compositions were obtained from *Nutritics Professional Nutrition Analysis Software* ([www.nutritics.com](http://www.nutritics.com)), which is based on existing food databases (such as McCance and Widdowson), manufacturer data and published research papers.

### Macronutrients

**Energy and fat:** Whole milk is generally higher in calories and fat compared to plant-based beverages but semi-skimmed and skimmed milk have comparable levels to most of the alternatives. The energy content of plant-based beverages tends to vary depending on the addition of ingredients such as oil or sugar. Coconut versions tend to have the highest fat content among the plant-based beverages and, like cow's milk, the fat component is predominantly composed of saturated fatty acids. Given that the popular term 'full-fat' is often used to describe whole cow's milk, it is not surprising that some consumers

perceive the fat content to be much higher than the actual value of approximately 3.6%. In an effort to reduce population saturated fat intake, the Department of Health recommend low-fat varieties of milk to be consumed<sup>1</sup>. Currently, milk contributes just 10% to saturated fat intakes in Ireland, despite over half of consumers choosing whole milk<sup>3</sup>. Research also indicates that not all saturated fats behave the same way and that the saturated fat in whole dairy products is not associated with cardiovascular risks due to the overall effect of its nutrient matrix<sup>4,5</sup>. While much focus has been on the saturated fat component of cow's milk, dairy fat is composed of a wide range of about 400 different types of fatty acids with varying properties<sup>6</sup>. It is this unique composition that contributes to the distinctive 'mouth-feel' and texture of dairy products.

**Protein:** With the exception of soya beverages, cow's milk is higher in protein compared to plant-based alternatives, containing about 3.4%. This is over six times the amount present in almond, rice or coconut beverages. Cow's milk and soya beverage have similar amounts of protein and both are classified as 'complete proteins', which makes soya beverage the favourable alternative for those that are trying to maintain their protein intake. However, from a nutritional perspective, the protein in cow's milk is considered to be of higher quality than that of soya, which is limited by lower levels of the amino acids methionine and cysteine<sup>7,8</sup>. Protein quality is rated according to its digestible indispensable amino acid score (DIAAS) and the DIASS for milk protein concentrate is higher at 1.18 compared to soya at 0.91<sup>8</sup>. In addition, this is demonstrated by research which indicates that the amino acid composition of cow's milk is more favourable than soya beverage for promotion of muscle synthesis and recovery after exercise<sup>9,10</sup>.

**Carbohydrate/sugar:** The carbohydrate component of cow's milk, like most mammalian milks, is composed of the naturally occurring disaccharide lactose. Lactose is a low glycaemic-index sugar, which does not fall under the same classification as 'free' or 'added' sugars. Many plant-based dairy alternatives, including the original versions, contain added sugar, fruit juice or other sweeteners. The Scientific Advisory Committee on Nutrition recommends that the consumption of sugar-sweetened beverages should be minimised by both children and adults<sup>11</sup>. This includes sugars that are added as an ingredient or those naturally present in honey, syrups and fruit juices, but excludes the lactose in plain milk and dairy products. Therefore, for those opting to choose an alternative, the

**Table 1:** Nutritional composition per 100g of typical cow's milk and dairy alternatives\*

A - Macronutrient Composition							
	Whole Cow's Milk (un-fortified)	Low-fat Cow's Milk (un-fortified)	Soya Original (fortified)	Almond Original (fortified)	Coconut Original (fortified)	Rice Original (fortified)	Oat Original (fortified)
Energy (kcal)	63	46	43	24	27	50	45
Protein (g)	3.4	3.5	3.1	0.5	0.2	0.3	1
Total fat (g)	3.6	1.7	2.4	0.1	2	1	1.5
Saturated fat (g)	2.3	1.1	0.4	0.1	1.9	0	0.2
Carbohydrate (g)	4.4	4.5	2.2	3	1.9	10.1	6.3
Sugars (g)	4.4 <sup>†</sup>	4.5 <sup>†</sup>	2.2	3	1.6	4.6	3.8
Fibre (g)	0	0	0.5	1.6	0.1	–	0.9

  

B - Mineral Composition							
	Whole Cow's Milk (un-fortified)	Low-fat Cow's Milk (un-fortified)	Soya Original (fortified)	Almond Original (fortified)	Coconut Original (fortified)	Rice Original (fortified)	Oat Original (fortified)
Calcium (mg)	120	120	130	120	120	88	120
Iron (mg)	0.02	0.02	0.3	0.2	0.1	0.3	0.3
Iodine (µg)	31	30	1	0.1	0.04	–	0.1
Magnesium (mg)	11	11	18	10	2.3	–	9.2
Phosphorus (mg)	96	94	89	28	73	34.4	31.3
Potassium (mg)	157	156	119	59	26	–	30.6
Sodium (mg)	42	43	56	50	40	33.3	49

  

C- Vitamin Composition							
	Whole Cow's Milk (un-fortified)	Low-fat Cow's Milk (un-fortified)	Soya Original (fortified)	Almond Original (fortified)	Coconut Original (fortified)	Rice Original (fortified)	Oat Original (fortified)
Vitamin A (µg)	38	20	–	–	–	25	–
Riboflavin (mg)	0.2	0.2	0.2	0.2	–	–	0.2
Vitamin B5 (mg)	0.6	0.7	–	0.5	0.02	–	0.1
Vitamin B12 (µg)	0.9	0.9	0.4	0.4	0.4	0.1	0.4
Folic Acid (µg)	8	9	9	3.4	1.3	–	30
Vitamin D (µg)	–	–	0.8	0.8	0.8	0.3	0.8
Vitamin E (mg)	0.1	0.04	0.3	1.8	0.03	–	0.1

\*Source: Nutritics Professional Nutrition Analysis Software

<sup>†</sup>Lactose is a naturally occurring milk sugar

– Data not available

'unsweetened' varieties will help to limit the intake of added sugars. Grain-based dairy alternatives, such as rice and oat beverages, generally contain additional carbohydrate in the form of starch.

### Micronutrients, fortification and bioavailability

**Fortification:** Although Table 1 presents the nutritional composition of plain, unfortified cow's milk, there are also many versions available that have been fortified with additional nutrients. The nutrients that are added are often based on population insufficiencies or are tailored to specific consumer categories e.g. additional B vitamins such as folic acid; iron, vitamin C, vitamin D, vitamin E and additional protein. In general, most plant-based alternatives are fortified with calcium, vitamin B2, B12, vitamin D and occasionally, with vitamin E.

**Calcium:** As shown in Table 1B and C, cow's milk is naturally rich in a wide range of micronutrients. However, it is perhaps best recognised as a key source of bioavailable calcium, which has several established roles in the body, including bone health<sup>12</sup>. Indeed, it is the calcium content of dairy that forms the basis of the Department of Health's recommendations to consume three servings from the 'milk, yogurt and cheese' food group each day and to increase this to five servings if aged between nine and 18 years, due to increased requirements at this critical stage of bone development. As most dairy alternatives are innately devoid of or low in calcium, the majority are fortified, generally to the level of 120mg per 100g, which is equivalent to that naturally present in cow's milk.

Research indicates that calcium contents on a nutritional label do not guarantee equivalent nutritional value, as different food matrices and different nutrient forms impact how well the calcium can be absorbed and used by the body<sup>13</sup>. The naturally occurring calcium present in cow's milk is in the form of colloidal calcium phosphate, which is held in suspension by the casein protein micelles<sup>14</sup>. Combined with other components present in milk, the breakdown of this complex during digestion enables an efficient release of the calcium phosphate and hence a high bioavailability of dairy calcium<sup>15</sup>. It has also been suggested that the lactose component of cow's milk may play a role in enhancing calcium absorption<sup>16</sup>.



▲ **Figure 1:** Naturally occurring micronutrients and common added ingredients: cow's milk compared to a dairy alternative.

Calcium bioavailability in plant-based beverages however, depends on the type of fortificant used. Various calcium salts can be used but the most common forms employed in plant-based alternatives are calcium carbonate (CC) or tricalcium phosphate (TCP). The calcium absorption from a TCP-fortified soya beverage has been shown to be significantly lower than both a CC-fortified soya beverage and cow's milk but no difference was observed between the CC-fortified soya beverage and cow's milk<sup>17</sup>. In another study, the calcium absorption from a TCP-fortified soya beverage was found to be only 75% the efficiency of calcium absorption from cow's milk<sup>18</sup>. Therefore, for those that opt for plant-based alternatives, care should be taken to check the type of calcium fortificant listed under the ingredients.

**Iodine:** Iodine is an important micronutrient, which contributes to normal cognitive function, growth in children, thyroid function and the maintenance of normal skin<sup>12</sup>. Poor iodine intake during pregnancy has been associated with a lower IQ in offspring<sup>19,20</sup> and mild deficiency has been shown to impair cognition in children<sup>21</sup>. In Ireland, cow's milk is a rich source of iodine<sup>12</sup>, with consumption attributing to 45% of total intake in the population<sup>22</sup>. With the exception of one fortified product identified on the market in Ireland, the majority of plant-based dairy alternatives do not contain iodine and are not fortified with this important micronutrient. As 77% of Irish women of childbearing age are not meeting the recommended average requirement set for iodine during pregnancy, it is imperative that those choosing to switch from cow's milk to plant-based alternatives are informed regarding the potential nutritional consequences and other dietary sources, should they become pregnant<sup>22</sup>.

**Vitamin D:** The vitamin D content of cow's milk naturally varies but in general, plain milk is not considered a good source. As vitamin D contributes to the normal absorption of calcium, it has been recognised that vitamin D can be a beneficial addition to milk. On that basis, some countries (such as the US) choose to fortify all milk with vitamin D. This is not the case in Ireland, where the consumer can choose to purchase either plain or a vitamin D-fortified milk. The same is the case for plant-based beverages, although many of the leading brands are now fortified with vitamin D.

**Vitamin B12:** Vitamin B12 (cobalamin) is available from a range of animal products, with milk, yogurt and cheese contributing to approximately 36% of intake in the Irish population<sup>3</sup>. With the exception of fortified products, plant foods do not contain vitamin B12. Therefore, for vegans that do not consume supplements, it is important that they select plant-based alternatives that have been fortified with vitamin B12.

**Organic:** It is important to note that organic varieties of both cow's milk and plant-based alternatives are typically not fortified. As plant-based alternatives are not naturally rich in nutrients, consumers of organic varieties should take extra care to ensure they are meeting their nutrient requirements (particularly calcium) from elsewhere.

### Additives

Fresh cow's milk is a natural dairy product, composed of the single ingredient, milk. Although milk is pasteurised for food-safety purposes, no colours, preservatives, sweeteners or other ingredients are added, with the exception of the nutrients that are added to fortified milks. Plant-based dairy alternatives are produced by the blending and extraction of plant products such as soya, nuts or grains in water, with the plant ingredient generally ranging from 2.3-12%. To improve shelf-life, taste, texture and the suspension of these plant particles in the water solution, additives such as oils, stabilisers, emulsifiers, flavourings, sweeteners and salt are commonly added.

Stabilisers that are used in plant-based beverages include locust bean gum, xanthan gum, carrageenan, guar gum or gellan gum. These are polysaccharides that are commonly used in the food industry. They act as thickening agents and also help to prevent

ingredients from separating. Maltodextrin is another thickening agent that can help to give a smoother and creamier texture. Dipotassium phosphate is an additive that helps to prevent coagulation and it also acts as a source of both potassium and phosphorus in some of these plant products. Lecithin is a commonly used emulsifier, which also helps to make these beverages more homogeneous and smooth in consistency. These ingredients are all approved for use in the EU.

## Consumer perceptions and drivers of choice

There are few absolutes in consumer behaviour and the drivers of food choice are complex. Motivation to switch from milk to plant-based dairy alternatives has not been explored in great depth and appears contradictory at times. Consumer research suggests that the key drivers in switching to dairy alternatives include perceived health benefits associated with 'lactose-free' or 'clean-eating', a trend towards veganism and a pursuit of improved animal or environmental welfare<sup>23</sup>.

In a report, conducted by Ireland's leading independent market research agency, Behaviours & Attitudes in 2017, attitudes to dairy across the Irish population were explored. The sample included 1,001 individuals and was based on census quotas representing gender, age, religion, social class and location. Milk avoidance, but not total exclusion, was observed among 21% of those surveyed (25% of women and 16% of men), while 10% of the sample believed that milk is 'not good for you'. Many individuals consumed more than one type of 'milk', with the consumption of plant-based alternatives relatively low overall, at 5-7%. However, this was skewed towards females under the age of 24 years, living in the Dublin and Leinster region. Negative perceptions towards dairy were associated with a belief that it provokes allergies and is high in fat. Among the sample, 20% of women and 13% of men reported having a food allergy or intolerance and 85% believed that food hypersensitivities have become more common in recent years (commissioned report; un-published).

Plant-based beverages are often marketed as a healthier choice and their higher price may give the impression of a more nutritious or premium product. The cost of plant-based beverages is often up to 100% more expensive per litre compared to cow's milk, yet as shown above, the nutrient density per litre is much lower (price comparisons were obtained from five leading supermarkets). This indicates that the motivational factors among these consumers is strong enough to override price and that there is an added value associated with plant-based beverages. It also suggests that there may be a lack of awareness regarding the nutritional aspects.

In Ireland, fresh milk is pasteurised and requires refrigerated storage but most plant-based beverages are UHT (ultra-high temperature) sterilised, which means they do not require refrigeration until after opening and they have a shelf life of six months or longer. Despite this, many of these products are now positioned in the chilled cabinets which may give the impression of a fresh, natural product. Due to factors such as product placement, marketing, packaging and appearance, it is understandable that many consumers see plant-based alternatives as an attractive alternative to cow's milk. In recognition of potential confusion regarding the nutritional value of plant-based dairy alternatives, and in an attempt to prevent consumers from being misled, the European Court of Justice recently granted legislation that reserves the term 'milk' only for milk of animal origin. This helps to create awareness regarding product differentiation but more work is needed to inform consumers about the appropriate replacement of essential nutrients when excluding cow's milk. Also, the promotion of trusted information sources is important in instances where consumers are motivated by misconceptions regarding the health or ethical impacts of cow's milk.

## Health impact

Given that dairy products have been part of the European diet for thousands of years, a wealth of research exists, which has examined their impact on health<sup>24,25,26</sup>. Dairy has been associated with many health benefits, particularly in the areas of bone health<sup>27</sup> and cardiometabolic health<sup>25,26,28</sup>. A recent comprehensive review of the scientific evidence suggests that the intake of milk and dairy products may help to protect against the most prevalent chronic diseases, whereas very few adverse effects have been reported<sup>24</sup>. This review also indicated that no such evidence exists for plant-based beverages and that their value to health requires more study.

Considering that 'maintaining a healthy lifestyle' is a motivational driver in choosing plant-based alternatives<sup>23</sup>, there is little evidence to support any health benefits beyond cases where the exclusion of dairy is necessary as part of a medical diagnosis. In these specific cases, plant-based dairy alternatives can be a useful substitution in combination with tailored dietary advice from a registered health practitioner, such as a dietitian<sup>29</sup>. Research shows that inappropriate substitution of cow's milk with plant-based beverages can lead to nutritional deficiencies<sup>29,30</sup>.

Earlier this year, at the launch of 'A Message to My Younger Self', a bone health campaign by the National Osteoporosis Society in the UK, the Society expressed concerns about a 'clean-eating' trend among young adults, referring to it as "a ticking-time bomb for their bones". Diet is among the important factors that influence bone health and bone mass accretion is at its maximum from puberty until about 20 years<sup>27</sup>. The consequences of failing to achieve it during this period may only become apparent in later life, with the onset of osteoporosis<sup>27</sup>. The campaign was launched by the Society following a survey that showed that 20% of 18-24 year olds in the UK, had cut out or significantly reduced dairy in their diet<sup>31</sup>. In the absence of dairy, the Society highlighted the importance of obtaining bone-friendly nutrients from a range of alternative sources in the diet.

It is concerning that misconceptions regarding the health benefits of dairy exclusion could impact the future health of our younger population, particularly if those who are not yet able to make their own dietary choices are affected. In a recent study of over 5,000 children in Canada, researchers found that children aged three years who consumed three cups of plant-based beverages daily were on average 1.5cm shorter in height compared to those consuming the same amount of cow's milk<sup>32</sup>. In another study, which explored the acidogenic potential of beverages in relation to tooth decay, soy beverages showed significantly greater cariogenic potential compared to cow's milk, indicating that plant-based beverages are less appropriate for supporting dental health<sup>33</sup>. In addition, a meta-analysis which explored childhood obesity found that children with the highest dairy intake were 38% less likely to be overweight or obese compared to those in the lowest dairy intake group<sup>34</sup>.

The role of dairy in the maintenance of a healthy body weight has also been observed in adults<sup>26,35</sup>. In a weight-loss study of premenopausal women assigned to diets including either low-fat milk or calcium-fortified soya beverage, significantly greater weight loss was observed among the milk consumers<sup>35</sup>. Also, in a study of 1,500 Irish adults, individuals in the highest tertile of dairy consumption had significantly lower BMI, percentage body fat, waist circumference and blood pressure<sup>26</sup>.

## The vegan trend, plant-based diets and sustainability

A trend towards 'plant-based' diets or veganism has taken a leap in recent years, with an estimated 500,000 vegans now living in the UK<sup>36</sup>. This is a 360% increase over the last decade, with similar growth trends across Europe. In an assessment of the vegan



consumer market, HRA Food and Drink reported that switching to veganism has now become more achievable with the launch and labelling of more 'vegan-friendly' products, and through a widening of the market with cheaper, own-brand products by large retailers<sup>36</sup>.

The report also examined the driving factors behind rising numbers of individuals choosing a vegan lifestyle and while the drivers are diverse, ethical reasons were a principal factor. Concerns about animal welfare have been amplified through social media, images used by animal rights activists and short films about the food industry<sup>36</sup>. Awareness and regulation of animal welfare is undoubtedly vital, but it should be recognised that milking systems vary across the world and that much of the provocative or emotive footage used to highlight poor animal welfare is not a fair representation of general practice in many countries, such as Ireland. In the Irish dairy system, cows spend up to 300 days a year grazing freely on a grass-based diet with indoor housing confined to periods of inclement weather. Irish farmers are legally and ethically obliged to provide a good standard of welfare for livestock in their care with animal health and wellbeing being a key pillar of the Irish Sustainable Dairy Assurance Scheme audit<sup>37</sup>. There are requirements throughout this standard that facilitate a thorough assessment of animal welfare at farm level.

Information regarding livestock as a source of global pollution is another motivational driver of plant-based eating<sup>36</sup>. It is generally well-accepted that farming is among the many contributing factors to pollution globally and that food production carries a significant carbon footprint<sup>38</sup>. It is estimated that the dairy sector contributes an average of 2.7% to the international registered greenhouse gas emissions<sup>39</sup>. The global population is also expanding and it is expected that the world will have to produce enough food to feed 9.1 billion people by the year 2050<sup>40</sup>. In order to meet these growing demands, upscaling food production must be both nutritious and environmentally sustainable.

Global initiatives to limit climate change, such as the Paris Agreement, have resulted in political commitments and major publicity about the need to decrease greenhouse gas emissions. In addition, consumer demand for more sustainably produced products is encouraging the food industry to evolve accordingly, with the help of technology. Population awareness regarding the

environment means that many citizens also want to make their own individual contribution, with plant-based diets seen as one route to reducing the carbon footprint of their diet.

It must be acknowledged however, that many factors contribute to diet sustainability and the concept of directly replacing animal-based foods with plant-based alternatives is overly simplistic as a strategy. Research suggests that diets higher in plant-based foods, locally produced and lower in energy have less environmental impact<sup>41</sup>. Factors such as nutritional adequacy, food processing and air-miles also need to be considered<sup>42</sup>. Most milk in Ireland is locally sourced, whereas the plant-based alternatives on the market contain a number of ingredients from different countries.

In a Dutch study, which explored acceptable options for mitigating the environmental impact of various diets, the removal of dairy was not shown to be an effective solution<sup>42</sup>. As Ireland has a grass-based dairy system, it is one of the most carbon-efficient milk producers globally. Bord Bia's Origin Green is a national sustainability programme that promotes the reduction of greenhouse gas emissions throughout the Irish food and drink sector<sup>43</sup>.

## Alternative choices within the dairy category

Although concerns for animal welfare and the environment are key drivers in switching from dairy to plant-based alternatives, a desire to improve health is another motivational factor<sup>36</sup>. This sector of consumers includes 'flexiarians' who do not fully identify as vegan, but who want to reduce their use of animal products; people who perceive plant-based products as 'better for them'; and people suffering from milk allergies or intolerances<sup>36</sup>.

**Allergy:** In developed countries, the incidence of cow's milk allergy is about 2-3% in early childhood but the prognosis is good, with a remission rate of 85-90% by the age of three<sup>44</sup>. Therefore, it is predominantly a paediatric condition with much lower prevalence in adulthood. For those with a cow's milk allergy, management includes the removal of all dairy products from the diet while ensuring nutritional adequacy of any alternative through dietetic support<sup>44</sup>.

**Lactose intolerance:** Commonly known as lactose intolerance, primary lactase deficiency is caused by natural deregulation of the lactase gene expression. This results in a reduced ability to digest the natural milk sugar, lactose. Not all individuals are symptomatic however and malabsorption of lactose is associated with gastrointestinal distress including cramps, bloating or diarrhoea<sup>45</sup>. While relatively common worldwide, in Ireland and other northern European countries, the prevalence is about 4-5% of the population<sup>46</sup>, and research indicates that in most instances, individuals can tolerate daily doses of 12-15g lactose (a 200ml glass of milk contains about 9-10g lactose)<sup>47,48</sup>. Therefore, current management strategies include the limitation of dairy intake to match the tolerance of individual patients. The use of lactase enzyme supplementation or lactose-free milk can also be employed to negate the need for dairy avoidance<sup>47</sup>.

**Lactose-free milk:** The natural milk-sugar lactose, is a disaccharide composed of glucose and galactose. Lactose-free milk is cow's milk that has its lactose content already broken down into these simple sugars, meaning there is no lactose remaining in the milk. This is achieved through the addition of the enzyme lactase during production. Lactose-free milk is a suitable dairy alternative for those suffering from lactose-intolerance.

**A2 milk:** A2 milk is a relatively new development, which has not yet been produced or available for purchase in the Republic of Ireland. Cow's milk protein is composed of approximately 80% casein and 20% whey fractions, with the casein fraction typically containing both the A1 and A2 variants of  $\beta$ -casein. Gastrointestinal digestion of the A1  $\beta$ -casein, but not the A2 variant, results in the release of  $\beta$ -casomorphin-7, an opioid peptide<sup>49</sup>. It has been speculated that this peptide can cause inflammation or milk intolerance in some individuals<sup>50</sup>. This form of milk-intolerance is distinct from lactose intolerance (described above) and more research is needed to confirm the existence of the condition<sup>50</sup>. As some cows produce only A2 forms of the  $\beta$ -casein, genetic selection enables the production of A2 only milk<sup>49</sup>. Some emerging research has shown positive findings for a reduction of gastrointestinal symptoms in those consuming A2 milk<sup>50</sup>.

**Goat and sheep milks:** In some countries camel and buffalo milks are commonly consumed but, in Ireland, the predominant choice is cow's milk with a smaller number of individuals opting for goat or sheep milks. These are often more popular for consumption in the form of cheese as opposed to liquid milk. Although they taste different, mainly due to variation in their diet, the nutritional composition of cow, sheep and goats' milk is largely similar<sup>14</sup>. The water content in sheep milk is slightly lower at about 81% compared to cow and goat milk, which are both around 87%. This means that per volume, sheep milk is slightly higher in fat, protein and some vitamins and minerals. However, the variability within each species can be as much as between them<sup>14</sup>.

## Conclusions

Cow's milk and plant-based dairy alternatives are not nutritionally equivalent. The composition of the milk-matrix, with its nutrient interactions, gives cow's milk its unique nutritional value. Given that the bioavailability of nutrients used in fortification does not always match that of cow's milk, plant-based alternatives alone should not be promoted as a sufficient substitution.

The rise in consumers switching from dairy to plant-based alternatives raises some public health challenges. Currently, dairy is the main provider of calcium and iodine in the Irish diet and research shows that significant segments of the population have sub-optimal intakes of these nutrients<sup>3,22</sup>. There is a risk that population intakes may worsen if consumers continue to move away from dairy consumption.

As this evolving landscape progresses, research is ongoing to improve the nutritional completeness of plant-based dairy alternatives<sup>51</sup> but legislation for product labelling that is more reflective of nutrient bioavailability could help consumers make more informed choices.

Health professionals working in the area of nutrition have a role to play in guiding these dietary choices, whether it be in choosing the best plant-based alternative to suit an individual's specific requirements, in providing information on additional dietary sources of nutrients, or in clarifying the facts in cases where misconceptions are motivating an unnecessary avoidance of dairy in the diet. In addition, more regulation is needed in the area of accurate diagnostic testing of food allergies and intolerances.

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Mission: To deliver real and unique value to Irish dairy farmers by protecting and promoting the image, quality, taste and nutritional credentials of Irish dairy produce to a wide variety of audiences in a clearly defined, focused and effective manner.

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Food for Health Ireland

Mission: To leverage the world-class capabilities of the Irish academic partners, with the market expertise of the industry partners, into a pipeline of innovative, nutritional functional ingredients/products for the global food industry.