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Accepted Version

Clegg, M. E., Tarrado Ribes, A., Reynolds, R., Kliem, K. ORCID: https://orcid.org/0000-0002-0058-8225 and Stergiadis, S. ORCID: https://orcid.org/0000-0002-7293-182X (2021) A comparative assessment of the nutritional composition of dairy and plant-based dairy alternatives available for sale in the UK and the implications for consumers' dietary intakes. Food Research International, 148. 110586. ISSN 0963-9969 doi: https://doi.org/10.1016/j.foodres.2021.110586 Available at https://centaur.reading.ac.uk/99002/

To link to this article DOI: http://dx.doi.org/10.1016/j.foodres.2021.110586

Publisher: Elsevier

A comparative assessment of the nutritional composition of dairy and plant-based dairy alternatives available for sale in the UK and the implications for consumers' dietary intakes

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Abstract

The popularity of plant-based dairy alternatives (PBDAs) products has grown exponentially in recent years creating a new market of PBDA. The aim of this study was to compare the nutritional content of plant-based alternatives of milk, yogurt and cheese with dairy equivalents and the impact on nutritional intake across the lifespan when they are substituted into UK diets. Nutritional information from cow's milk, yogurt, cheese and PBDAs available on the UK market was collected via manufacturers information. The products were categorised according to primary plant-based ingredient/s and compared with the equivalent dairy product. The National Diet and Nutrition Survey data was used to calculate the intake of milk, yogurt and cheese across all age groups and the energy and nutrient intake was calculated. Plant-based milk, cheese and yogurt alternative categories were then substituted for dairy intakes, and energy and nutrient intakes were calculated and compared to UK Dietary Reference Values. A total of 299 PBDA products were identified consisting of 136 milk alternatives, 55 yogurt alternatives and 109 cheese alternatives. All PBDAs were more expensive than dairy products. Milk contained more energy, saturated fat, carbohydrates, protein, vitamin B_2, vitamin B_{12} and iodine, and less fibre and free sugars, than plant-based milk alternatives ($P<0.05$). There were significant differences between yogurt and cheese and their corresponding PBDAs for energy, fat, saturated fat, carbohydrate, sugars, fibre protein, salt, and calcium ($P<0.05$). These differences were reflected in the nutrient intakes of different age groups and the results demonstrated that PBDA may be useful as practical replacements of dairy products but cannot be considered nutritional replacements.

Keywords: milk; yogurt; cheese; dairy-free; soya; oat

Abbreviations:

PBDAs: Plant-based dairy alternatives

UK DRV: United Kingdom Dietary Reference Values

NDNS: National Diet and Nutrition Survey,

EAR: Estimated Average Requirement

RNI: Reference Nutrient Intake

ESPEN: European Society for Clinical Nutrition and Metabolism

CVD: Cardiovascular disease

CHD: Coronary Heart Disease

1. Introduction

Cows' milk is one of the most complete foods available, making it an important source of protein and micronutrients such as calcium, vitamin B12 and iodine, amongst others (Haug, Hostmark, & Harstad, 2007). Yet, there are several reasons why people may choose not to consume it. Cows' milk is the most common allergen in early childhood, with between 2.2 and 3.5% of infants reported to be allergic to it (Gray et al., 2014; Sicherer & Sampson, 2014; Villa, Costa, Oliveira, & Mafra, 2018). However, the majority of children will outgrow their allergenicity by the time the reach their late teens (Gray et al., 2014; Santos, Dias, & Pinheiro, 2010; Skripak, Matsui, Mudd, & Wood, 2007). Lactose intolerance, a deficiency or absence of the enzyme lactase in the digestive tract, is found in 5% of the British population and in 17% of the population in Finland and northern France. In South America, Africa and Asia, over 50% of the population has lactase non-persistence and in some Asian countries this rate is almost 100% (Lomer, Parkes, & Sanderson, 2008). In these populations the avoidance of cows' milk is required to prevent complications from lactose intolerance and allergy.

For many more consumers, excluding cows' milk is a personal choice. Recently, environmental consciousness has been a major contributing factor in peoples' choice to reject animal-based foods and consume plant-based food products. Almost a quarter (23%) of people in Britain used plant-based dairy alternatives (PBDAs) in the three months to February 2019, up from 19% in 2018 (Mintel, 2019a) and 48% of British consumers view reducing consumption of animal products as a good way to lessen humans' impact on the environment (Mintel, 2020). This opinion is encouraged by recent studies indicating that dairy milk requires more land and water usage and produces more environmental emissions compared to PBDAs (Poore & Nemecek, 2018). However, environmental performances in the latter study do not acknowledge differences in nutrient density between these products and a true comparison of products needs to acknowledge the interaction between health and environment (McAuliffe, Takahashi, & Lee, 2020).

The perceived opportunity for improved health is another potential explanation for the increased purchasing of PBDAs (Miki, Livingston, Karlsen, Folta, & McKeown, 2020). The purchase of whole and reduced-fat cows' milk has been decreasing over the decade 2008-2018, whilst the purchase of PBDAs has significantly increased (DEFRA., 2020). The popularity of PBDAs has grown exponentially, with the UK taking the global lead for the number of vegan products launched in 2018 (Mintel, 2019b). However the belief that PBDAs are healthier primarily originates from media information and the consumers' negative perception of milk, rather than fact (Makinen, Wanhalinna, Zannini, & Arendt, 2016). Households are therefore viewing plant-based products as a healthier alternative to dairy products with little evidence to reinforce their choices (Graca, Truninger, Junqueira, & Schmidt, 2019).

Whilst PBDAs are known for their inclusion of dietary fibre, vitamins and antioxidants, they contain much lower proportions of essential nutrients such as vitamin B_{12}, calcium and iodine, compared with dairy products, which are also often less bioavailable (Aydara, Tutuncua, & Ozcelik, 2020; Vanga & Raghavan, 2018). Removing dairy products from the diet could cause deficiencies in these nutrients. This means that plant-based products need to be fortified to recreate a similar nutritional composition of dairy products. The quality of protein in dairy products is also higher than that of plant protein due to the presence of all essential amino acids (Gorissen et al., 2018). Foods with lower biological value such as plant proteins need to be consumed in combination to ensure all of the essential amino acids are obtained from the diet, which requires considerable planning and knowledge. Vanga and Raghavan (2018) found soya-based liquid products to be the nutritionally best alternative to dairy products, when compared with other PBDAs, due to their higher and more complete protein content. However, soya's 'beany flavour' and potential allergens can deter consumers. Despite being marketed as alternatives to dairy, these findings indicate that the like-for-like substitution of dairy with plant-based products will not provide the same nutritional benefits.

There is concern that the variation in the nutritional profile of PBDAs (Scholz-Ahrens, Ahrens, & Barth, 2020) may affect the most vulnerable groups in society, including infants and children and the elderly, who rely on the nutrients in dairy products, such as calcium, iodine and vitamin B_{12} (Haug et al., 2007). Studies have shown that the consumption of dairy products contributes to greater growth in children compared to PBDAs (Morency et al., 2017), while the use of PBDAs in infants resulted in severe nutritional deficiencies, which could be preventable (Le Louer et al., 2014). As many as 30% of British parents believe their child has a food allergy when the correct figure is around 6%. This self- diagnosis of allergies is a problem with parents removing whole food groups from their children's diet without proper knowledge (Savage & Johns, 2015). It has previously been identified that there are significant differences across the nutritional composition of plant-based milk alternatives and dairy products and it is essential that parents only convert their children to PBDAs for the correct reason as the elimination of food groups can cause nutritional deficiencies (Villa et al., 2018). The elderly population are also at a higher risk of osteoporosis and require adequate amounts of calcium in their diet to mitigate this issue (Sambrook & Cooper, 2006). Additionally, the elderly are more prone to vitamin B_{12} deficiency, so are well advised to regularly consume sources of vitamin B_{12} such as dairy milk to achieve their reference nutrient intakes, but this is harder to achieve through PBDAs (Dhonukshe-Rutten et al., 2005). The consumption of PBDAs may differentially impact people across the lifespan depending on their current consumption patterns and nutritional requirements.

The current study had two objectives: (1) examine the label nutrient composition of PBDAs (milk, yogurt and cheese alternatives) available in the UK market and compare these to equivalent dairy products, and (2) model the comparative impact on nutrient intake from the consumption of dairy products or their substitution with PBDAs with reference to UK Dietary Reference Values (DRV) for each age group. This is the first study to conduct a comprehensive assessment of the labelled nutrient composition of PBDAs sold in major UK retailers, which could serve to help consumers make informed decisions about their purchases.

2. Method

2.1 Product identification

The data for dairy products as well as for plant-based milk, yogurt and cheese alternatives was collected in July 2020 via the websites of six major supermarkets in the UK (collectively covering ~73% of grocery market share in 2020 (Kantar, 2020)) including; Tesco, Asda, Sainsbury's, Morrisons, Waitrose and Ocado; and niche supermarkets Planet Organic and The Vegan Kind Supermarkets. The nutritional information was collected via the retailers' or manufacturers' website where possible, to ensure the most up-to-date data was obtained.

2.2 Milk and plant-based milk alternatives nutrient data collection

A database containing milk, cheese and yogurt and PBDAs was created. Database information included primary ingredient/s, retailer, brand, price (£, GBP), description, product listing URL, package size (g) and serving size (g). The nutritional data collated were: energy (kcal), fat (g), saturated fat (g), carbohydrate (g), sugar (g), fibre (g), protein (g), salt (g), vitamin D (µg), vitamin B_{12} (µg), vitamin B_2 (µg), calcium (mg), iron (mg), iodine (µg) and potassium (mg). For milk these values were expressed per 100ml and for yogurt and cheese per 100g. Due to a lack or limited records in the data for vitamin B_2, iron, iodine and potassium in yogurt category, and vitamin B_2, iron and iodine in the cheese category, these nutrients were not included in the corresponding categories.

2.3 Data categorisation

2.3.1 Milk

Milks and PBDAs were categorised into 6 different groupings, based on their primary ingredient/s (cow's milk, coconut, grains, legumes, nuts and seeds, and mixed where a mixture of primary ingredients was used). Each category was split into sub-categories; the cow's milk category included skimmed (% fat: 0.05-0.3%), semi-skimmed (% fat: 1.6-1.8%) and whole milk (% fat: 3.5-4.0%). The coconut included coconut-based milk alternatives. The grains category included oat, rice and rice and quinoa -based milk alternatives. The legumes category included soya and pea -based milk alternatives. The nuts and seeds category included almond, hazelnut, cashew, tiger nut, walnut and almond and hazelnut -based milk alternatives. The mixed category included alternatives that had more than one main plant source, such as coconut and almond, almond and oat, coconut and rice, and rice and almond.

2.3.2 Yogurt

The yogurt data was again grouped by their primary ingredient, including cows' milk, coconut, nuts and soya -based yogurt alternative categories. Sub-categories for cows' milk included plain full-fat, plain low-fat, plain fat-free, Greek full-fat, Greek low-fat, Greek fat-free, fruit and vanilla. Sub-categories for coconut included plain, fruit and vanilla. The soya category included plain, Greek, fruit and vanilla. The nuts category included cashew and almond nuts and had plain, fruit and vanilla.

2.3.3 Cheese

Cheeses were categorised into ingredient group; cows' milk, nuts and seeds, and oils. Sub-categories for cows' milk cheese included mature cheddar, soft cheese and mozzarella. These three specific cheeses were selected because there were several plant-based cheese alternative imitations of these. The nuts and seeds category included almond, sunflower and cashew, and had just soft cheeses. The oils category included coconut oil, soybean oil and palm fruit oil and had soft cheeses, cheddars, hard cheeses and mozzarella.

Within each sub-category, nutritional information per unit of mass or volume was averaged, so that mean values were calculated for nutrients.

2.4 Nutritional intake and cost from cow's milk, yogurt and cheese

National Diet and Nutrition Survey (NDNS) data years 7 to 8 (conducted in 2014/15-2015/16) was used to identify the daily intake from milk, yogurt, cheddar and other cheeses (Public Health England., 2018). Intake data in the NDNS is broken down into different age categories (1.5-3 years; 4-10 years; 11-18 years; 19-64 years; 65+ years; 75-74 years; 75+ years) and these categories were used throughout our analysis. Intakes for the different product categories (milk, yogurt, cheddar and other cheese) from NDNS data were given as a percentage of total energy intake per age group. To convert the NDNS intake data from a percentage of energy intake to absolute intake in g/mg/µg, food composition data from McCance and Widdowson food tables (Public Health England., 2019) were used. Following this, the nutrient content per unit of mass/volume (as found in product label) was multiplied by the mass of product consumed (as calculated from the NDNS) in order to calculate the specific intake of energy and nutrients per product category (milk, yogurt, cheddar and other cheese) and per age group. In order to explore a scenario whereby cow-based dairy products in the diets were entirely replaced by corresponding PBDAs, the nutrient intakes from PBDAs were calculated by using the same intakes (of the equivalent milk/dairy product) for each age group but multiplied with the label information from the plant-based alternative. The data for cows' milk within NDNS was broken down into whole, semi-skimmed and skimmed milk intake, these were combined to create one milk intake category to compensate for the lack of milk types within each milk PBDA. Cheese intake was divided into cheddar cheese and other cheese within the NDNS, and this division was also followed within our database for accuracy. The nutrient intakes from the consumption of the different product types where then compared to the UK DRV. Estimated Average Requirements (EAR) for energy intake were based on the average of male and female intake and for middle age groups for children (e.g in the 1.5-3 year age group, 2 year old EAR data was used; in children aged 4-10 years, 7 year old EAR data was used) (Scientific Advisory Committee on Nutrition., 2011). Fat was based on 35% of daily food energy based on recommendations and saturated fat was based on no more than 11% of daily food energy for population aged 5 years and above (Committee on Medical Aspects of Food Policy, 1991). Protein was based on the Reference Nutrient Intake (RNI) for adults and children, and for older adults the higher recommendation by European Society for Clinical Nutrition and Metabolism (ESPEN) of 1.1g/kg (Deutz et al., 2014) was used. DRVs for carbohydrate were set at 50% of daily food energy based on the Scientific Advisory Committee on Nutrition report on Carbohydrate (Scientific Advisory Committee on Nutrition, 2015). Currently UK sugar guidance is based on free sugars, and as milk sugar is not classified as free sugar this comparison was not completed. Vitamin and mineral intakes were based on RNIs, and where male and female requirements differed, these were averaged (Committee on Medical Aspects of Food Policy, 1991; Scientific Advisory Committee on Nutrition., 2016). The cost of consumption of dairy products milk, cheese and yogurt per year was calculated for each age group and the corresponding cost was calculated when these dairy products were substituted for equal quantities of corresponding PBDAs.

2.5 Data Analysis

The difference between dairy food products and PBDAs, as well as the impact of substituting dairy products with PBDAs on nutrient intake of different age groups, was assessed by conducting an Analysis of Variance, using a linear model (residual maximum likelihood analysis; REML; (Gilmour, Thompson, & Cullis, 1995) in GenStat (VSN International, 18th Edition, Hempstead, UK), with type of product being the fixed effect. When the fixed effect was significant, pairwise comparisons of means ($p < 0.05$) were performed using Fisher's Least Significant Difference test.

3. Results

A total of 299 PBDA products were identified consisting of 136 milk alternatives, 55 yogurt alternatives and 109 cheese alternatives. A total of 167 dairy products were identified including 51 milks, 78 yogurts and 38 cheeses. Out of the 136 plant-based milk alternatives, 60 contained additional sugar as sweetener and 77 were fortified. Of the fortified products, 77 were fortified with calcium, 68 with vitamin D, 44 with vitamin B_2, 68 with vitamin B_{12}, 6 with iodine and 6 with potassium. In the plant-based yogurt alternatives there were 43 sweetened. Of the 55 plant-based yogurt alternatives, 35 products were fortified. Of the fortified products, 35 were fortified with calcium, 32 with vitamin D, 15 with vitamin B_2 and 31 with vitamin B_{12}. In the plant-based cheese alternatives, 50 products were fortified. Of the fortified products, 14 were fortified with calcium, 2 with vitamin D and 40 with vitamin B_{12}.

3.1 Milk and milk alternatives

There were differences ($P < 0.05$) between milk and milk alternatives in price, and declared energy, saturated fat, carbohydrates, sugars, fibre, protein, vitamin B_{12}, and iodine content (Table 1). Cows' milk was substantially cheaper (by 44-50%; $P < 0.05$) than all PBDAs. Coconut and nuts & seeds PBDAs had the lowest declared energy content (30-33 kcal/100ml) whilst cow's milk was the highest (50 kcal/100ml; $P < 0.05$). Grains, legumes and mixed PBDAs contained intermediate concentrations. Coconut PBDA was highest in declared saturated fat content (1.63 g/100ml; $P < 0.05$) followed by cow's milk (1.23 g/100ml), while grains, legumes, nuts & seeds and mixed PBDAs contained less (<0.3 g/100ml milk). Label carbohydrate content was highest in grains and mixed PBDAs (7.7-8.2 g/100ml; $P < 0.05$) and lowest in legumes and nuts and seeds PBDAs (2.2-2.6 g/100ml; $P < 0.05$). Declared sugar content was highest in cows' milk and grains and mixed PBDAs (< 4.7 g/100ml; $P < 0.05$), and lower in coconut, legumes and nuts & seeds PBDAs (<2.3 g/100ml). Fibre is not found in cows' milk; among the PBDAs, grains and legumes had higher label concentrations ($P < 0.05$) than coconut, nuts and seeds and mixed. Declared protein content was highest in cows' milk (3.49 g/100ml; $P < 0.05$), had intermediate values in legumes (3.08g/ml) and was <1 g/100ml for all other PBDAs. The highest declared content of vitamin B_2 was observed in coconut PBDA with only one sample in this group (0.50 mg/100ml; $P < 0.05$), followed by cows' milk (0.24 mg/100ml) while grains, legumes, nuts and seeds and mixed PBDAs had slightly lower (0.21 mg/100ml). Cow's milk had a higher (+80-108 %; $P < 0.05$) declared content of vitamin B_{12} compared with PBDAs. Legumes and cows' milk had similar contents of iodine, and more than twice the amounts found in the single coconut PBDA that contained iodine. The other PBDAs did not report iodine contents.

These differences between declared nutrient contents were reflected in individual nutrient intakes from milk and PBDAs, when these were calculated for each consumer age group, using NDNS data, resulting in changes in their contribution to nutritional requirements for energy, saturated fat, carbohydrates, sugars, fibre, protein, vitamin B_{12}, and iodine (Table 2).

3.2 Yogurt and yogurt alternatives

There were differences ($P < 0.01$) between cows' milk yogurt and PBDAs in price and declared energy, fat, saturated fat, carbohydrates, sugars, fibre, protein, salt, and calcium content (Table 3). Cow's milk yogurt was substantially cheaper (by 43-66%; $P < 0.05$) than PBDAs based on coconut, nuts and soya. Declared energy content was highest ($P < 0.05$) in coconut PBDA (112 Kcal/100g), lowest in soya PBDA (68 Kcal/100g) and showed intermediate values in nuts PBDA and cows' milk yogurt. Labels on coconut and nuts PBDAs suggested these products contained more fat ($P < 0.05$) than cows' milk yogurt and soya PBDA. Declared saturated fat was nearly three times greater ($P < 0.05$) in coconut PBDA than cows' milk yogurt, while nuts and soya PBDA contained the lowest amounts (<1.2 g/100g). Declared carbohydrate contents were 1.4-1.8 times higher ($P < 0.05$) in coconut PBDA than any other product. For label sugar contents, there was no difference ($P > 0.05$) between cows' milk, coconut and soya but the nuts category had 2.5-2.9 times less sugar ($P < 0.05$) than these. Declared fibre content was highest ($P < 0.05$) in soya PBDA (1.03 g/100g), lowest in cows' milk yogurt (0.10 g/100g) and showed intermediate values in coconut and nuts PBDA. Cows' milk yogurt had more (P < 0.05) declared protein than PBDAs, while soya had more than twice the amount (P < 0.05) of protein than the nuts and coconut PBDAs. Cows' milk yogurt contained 20-33% less salt (P < 0.05) than PBDAs. There was no information on calcium content for the nuts PBDA, but cows' milk yogurt declared 39% more calcium than soya PBDA; while coconut PBDA was not different to any of the other products. As with liquid milk, these differences in declared nutrient composition also affected the individual nutrient intakes from yogurt and PBDAs when these were calculated for each consumer age group, according to NDNS, this resulted in difference in the yogurt and PBDA yogurt contribution to nutritional requirements for energy, fat, saturated fat, carbohydrates, sugars, fibre, protein, salt, and calcium in each age group (Table 4).

3.3 Cheese and cheese alternatives

There were differences (P < 0.05) between cows' milk cheese and PBDAs in price and declared energy, fat, saturated fat, carbohydrates, sugars, fibre, protein, salt, and calcium contents (Table 5). Cows' milk cheese was 1.7 times cheaper than oil PBDA and 3.5 times cheaper than nuts and seeds PBDA (P < 0.05). The label energy content was highest for cows' milk cheese, followed by oils, and then nuts and seeds (P < 0.05). Cows' milk cheese had 14-24% more (P < 0.05) declared fat content than PBDAs. However, declared saturated fat was higher (P < 0.05) for oils PBDA compared with cows' milk, while nuts and seeds contained 8.2-9.0 times less saturated fat compared with both other sub-categories. The oil PBDA sub-category also had 3.2-9.8 times more (P < 0.05) declared carbohydrate, but 2.5-4.0 times less (P < 0.05) declared sugar, compared with the other two product categories. Cows' milk cheese had less (P < 0.05) fibre than the other two product categories, but the protein content of cows' milk cheese was higher (P < 0.05) compared with the nuts and seeds, and oils PBDAs, respectively. Oils PBDA had a higher salt content than cows' milk cheese. Cows' milk cheese had higher (P < 0.05) amounts or calcium (+85%) than oils PBDA. There was insufficient data on vitamin D, vitamin B_{12} and potassium to make statistical comparisons but means for oils PBDA (the only one reporting these values in label) are presented in Table 5. These differences affected the individual nutrient intakes from cheese and PBDAs when these were calculated for each consumer age group, according to NDNS resulting in changes in their contribution to nutritional requirements (Table 6).

3.4 Cost of dairy products and alternatives

The cost of consumption of dairy milk, cheese and yogurt varied across different age groups, ranging from £48.00-£88.07/ year for cows' milk; £24.37- £47.74/ year for dairy yogurt; and £12.31-£20.06/ year for dairy cheese (Table 7). These costs almost double across all plant-based milk alternatives with the nuts and seeds group being the most expensive (£95.99-£176.07/ year). In the yogurt category, the plant-based yogurt alternatives were almost three times more expensive than dairy yogurt. In 1.5-3 year olds, this represented an increased cost from £47.74 /year for dairy yogurt up to £138.44 /year in the plant-based yogurt alternatives in the nuts category. In the cheeses, the plant-based cheese alternatives were up to 2.6 times the price. For people aged 70+ years this represented an increased cost from £20.06 /year for dairy cheese up to £52.47 /year in the PBDA cheeses for the nuts and seeds cheese.

4. Discussion

Limited research has explored the nutritional differences in plant-based liquid milk alternatives compared with dairy milks (Vanga & Raghavan, 2018), but to date these comparisons have not included plant-based yogurt and cheese alternatives. This is the first study to conduct a comprehensive assessment of plant-based milk, yogurt and cheese alternatives sold in major UK retailers and to examine the impact of differences in declared nutrient content on nutrient intakes across different societal age groups, using national intake data. Results from this study have highlighted that there are major differences in the nutrient composition between PBDAs and dairy products. Many people consume dairy products for their nutritional benefits (Litwin, Bradley, & Miller, 2015), it is therefore essential that consumers are aware of the differences between the products and the potential implications of their food choice on their nutrient intakes before purchasing these alternatives.

4.1 Implications for consumers' energy intake

There were significant differences in the energy content within all of the milks, cheese and yogurt groups which was reflected in the corresponding changes in energy intake across the lifespan. Replacing cows' milk with milk from nuts/seeds would decrease energy intake. For many age groups in the UK, obesity is an issue and a reduction in energy intake would be beneficial (NHS Digital, 2019). However, in the 1.5-3-year-old age group where milk intake reflects a significant proportion of their daily energy intake, replacing cows' milk in the diet with nut/seed-based milk would account for a 5.01% drop in their EAR for energy. In contrast, the declared energy content of yogurt was both higher and lower depending on the alternative type, and all of the cheese alternatives had less energy than cows' milk cheese. In England in 2019/20, obesity prevalence in children aged 4-5 years was at 9.9% in 2019/20 increasing to 21% by age 10-11 years (NHS Digital., 2020). This also reflects an increase in obesity prevalence in both groups compared to data from the previous year (NHS Digital., 2019). With growing levels of obesity across the population, reductions in energy intake through the substitution of milk from alternative sources may seem of benefit. However, with milk, cheese and yogurt accounting for a cumulative of 17.9% of the energy intake in the diet of 1.5-3 years and 8.4% in children aged 4-10 years, the overall nutrient density of each product line needs to be considered to ensure there are no nutritional consequences (De Matteis et al., 2017).

4.2 Implications for consumers' protein intake

One notable difference across all the categories of plant-based dairy alternatives was the difference in protein content, with PBDAs generally lacking protein. Protein is essential for healthy growth and development, with many people relying on dairy milk (3.49g protein/100ml) as an essential protein source (Graham et al., 1996). All the plant-based milk alternatives had lower declared protein content compared with cows' milk, apart from soya and pea milk in the legumes category with 3.08g/100ml. When focusing on protein intake by age group, replacing dairy milk with plant-based milk alternatives such as coconut resulted in a protein intake of less than 1 g/day for all age groups, while the protein intake with dairy milk is between 4.1g and 8.4g depending on the age group. The protein content of yogurts demonstrated a similar difference between yogurt sources as liquid milk, with soya being the only plant source to come close to matching dairy milk's protein content. Consumers may rightly consider cheese a high protein food source and consequently assume plant-based cheese alternatives will have a similar nutritional value. However, this study demonstrated that plant-based cheese alternatives only contained between 1.05 and 6.45 g/100 g protein (oil and nuts and seeds PBDAs, respectively). This compared poorly with cheese made from cow milk, which had a declared content of 16.57g/100g of protein.

Due to anabolic resistance that limits muscle maintenance and accretion, adults over the age of 65 years of age are recommended to increase their protein intake to 1.0–1.2g protein/kg body weight/day for a healthy older adult (over 60 years), and to 1.2–1.5g protein/kg body weight/day for older people who are malnourished or at risk of malnutrition (Bauer et al., 2013; Deutz et al., 2014). UK dietary reference nutrient intake values indicate that protein requirements for adults are 0.75g/kg body weight per day (Department of Health., 1991). From the NDNS data set, adults over 75 years of age obtain 12.1% of their protein requirements from dairy sources (cumulative data from milk, yogurt and cheese). This has the potential to reduce to as little as 1.9% of requirements if the PBDAs are chosen. These cheese alternatives are therefore not nutritionally similar; this huge difference in protein content can cause issues for people who have recently switched to a plant-based diet and rely on cheese as a valuable protein source.

Although not measured in this study the quality and bioavailability of the protein source needs to be considered when purchasing PBDA products. Dairy milk contains a complete amino acid profile (Payne-Botha & Bigwood, 1959) and bioavailability of the amino acids available in dairy milk proteins is higher than that of plant proteins (Scholz-Ahrens et al., 2020). Amino acids are the fundamental components of proteins and are required for the synthesis of hormones and neurotransmitters (Wu, 2009) and in older adults are essential for the maintenance of muscle mass (Bauer et al., 2013; Deutz et al., 2014) whereas children require adequate amount of proteins for growth, maintenance and repair of the body (Graham et al., 1996). Many plant sources do not contain all the essential amino acids making them incomplete protein sources. Soya and pea protein contain the highest concentration of essential amino acids making them the most complete plant protein sources (Gorissen et al., 2018). Nuts and seeds are relatively good sources of plant protein, however the biological value of nuts is not very high; they are limiting in some essential amino acids depending on the type of nut and on the different cultivars (Brufau, Boatella, & Rafecas, 2006; Gorissen et al., 2018). Even though nuts may be a reasonable source of plant protein, this is not the case for the PBDA that are produced from them due to the processing required during production (Gorissen et al., 2018). By combining plant protein sources together, there is potential to produce a higher quality of product. Manufacturers already provide various blended plant-based milk alternatives coming from combination of different plant sources but the protein content of these products at present still remains low.

4.4 Implications for consumers' total and saturated fat intake

Dairy products are often associated with a high fat and saturated fat content which is an incentive for people converting to a plant-based diet (Vanga & Raghavan, 2018), due to the links between dietary saturated fat intake and increased risk of cardiovascular disease (CVD) (Mensink, Zock, Kester, & Katan, 2003). In the current study, we averaged the whole, semi and skimmed milks into one milk category which may have provided different results if compared individually. There was no difference between milk sources for fat content, but coconut milk, yogurt and cheese was much higher in saturated fat. Coconut oil is widely used in the PBDAs as it has desirable properties, which include enhanced flavour and sensory properties. However, these improved properties result in an increased fat and saturated fat content, particularly lauric acid (12:0) (Lal, Sreeranjit Kumar, & Indira, 2003). Despite dairy fat being relatively high in saturated fatty acids, a recent meta-analysis concluded that dairy milk intake was not associated with an increased risk of mortality, CHD or CVD (Guo et al., 2017). The consumption of fermented dairy products was even marginally associated with a lower mortality risk, coronary heart disease (CHD) and CVD risk, with cheese outperforming yogurt (Guo et al., 2017). However, another meta-analysis highlighted that the consumption of coconut oil significantly increased low density lipoprotein cholesterol (Neelakantan, Seah, & van Dam, 2020), which is a risk factor for CVD. This difference in response between dairy milk and coconut oil could be due to differences in fatty acid profile, with dairy milk fat containing a range of different saturated fatty acids (C4:0 – C18:0) as well as unsaturated fatty acids (particularly *cis*-9 C18:1) which may help to mitigate increases in LDL-cholesterol. However it is more likely that other nutrients within dairy products, and the matrix of products themselves (particularly cheese) are possible mechanisms for the lack of effect on CVD risk factors when consuming dairy products (Feeney & McKinley, 2020). These findings emphasise the importance of the whole food matrix when exploring different high saturated fat products which may include the presence of micronutrients.

4.5 Implications to consumers' carbohydrate, sugar and fibre intakes

In cows' milk, lactose is the primary source of carbohydrate and sugar, with lactose intolerance being one of the primary reasons for people to avoid consuming cows' milk and related products (Vanga & Raghavan, 2018). There were no consistent patterns when comparing carbohydrate content of plant-based milk and yogurt alternatives with cows' milk and yogurt. However, in plant-based cheese alternatives there was a consistently higher carbohydrate content across all product categories compared with dairy cheese, primarily due to the addition of starch.

Current UK public health policy focuses on reducing sugar in the diet (Scientific Advisory Committee on Nutrition, 2015) and several of the plant-based milk alternatives had a lower sugar content. However, UK public health guidance acknowledges the benefits of milk in the diet and hence the guidance only includes the free sugars (all monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and unsweetened fruit juices). Under this definition, lactose when naturally present in milk and milk products is excluded (Scientific Advisory Committee on Nutrition, 2015). So, although cow's milk may contribute 11.5g/day of sugar to children aged 1-3 years diet it does not contribute to free sugars (which are the sugars that should be restricted according to the nutritional recommendations).

Dietary fibre is known to have many health benefits including potential reduction in CVD, type 2 diabetes and cancer (Scientific Advisory Committee on Nutrition, 2015). Increases in fibre were seen following theoretical substitution of milk and dairy products with some of the PBDA. In the 1.5-3-year-old age group, the substitution of cow's milk with grain-based milk resulted in an increase of 1.32g of fibre per day consisting of 8.8% of the requirements for fibre in this age group. The PBDA are likely to contain soluble dietary fibres. The physicochemical properties of different dietary fibres (including the solubility, viscosity and fermentability) can vary greatly depending on the origin and processing which can impact their functional characteristics and clinical utility (Gill, Rossi, Bajka, & Whelan, 2021). Further work is required to better understand the role that fibre in PBDA can play in human health, which should consider both the type and processing it has undertaken.

4.6 Implications to consumers micronutrient intakes

The amount of calcium provided by all milk and consequently the differences in theoretical intake of calcium if milk was substituted with plant-based milk alternatives were not significant. This was due to plant-based milk alternatives being fortified with calcium more often than other PBDA products, resulting in significant decreases in calcium in the plant-based cheese and yogurt alternatives compared to dairy products. This provides a clear example of why fortification of plant-based products is essential in order to match the micronutrients present in dairy (Sethi, Tyagi, & Anurag, 2016). The Codex Alimentarius Commission (1994) has indicated that where a substitute food is intended to replace another food which has been identified as a significant source of either energy or essential nutrients in the diet, and particularly where there is a demonstrated public health need, nutritional equivalence is strongly recommended. Dairy products are a vital source of many vitamins and minerals; in this research nutritional information from vitamin D, B_2, B_{12}, calcium, iron, iodine and potassium was collected when available. In the present work, fortification varied significantly across PBDA and categories with some manufacturers exceeding expectations with fortification. These products were fortified with a variety of nutrients which were not recorded in this analysis, including vitamin C, omega-3 fatty acids and folic acid. These products were a very small minority. It is also important to highlight that several of the PBDAs were labelled as 'organic', and inline with organic regulations cannot contain any fortification despite consumers associating 'organic' with a more premium and healthful product (Vukasovič, 2016).

Calcium is needed for bone mineralisation which is especially important for young children, and the adverse effects of consumption of PBDA in children has been well documented (Merritt et al., 2020). In the current study, 43.4% of plant-based milks and 36.4% of plant-based yogurts contained no calcium at all while none of the plant-based yogurt alternatives in the nuts category were fortified with calcium. Although cheese is a valuable source of calcium for humans (Pampaloni, Bartolini, & Brandi, 2011), 87% of all plant-based cheese alternatives were not fortified with calcium. Additionally, grains, nuts and legumes are high in the absorption inhibitor phytate and evidence suggests that the bioavailability of calcium from these plant-based milk alternatives is therefore still lower than that of dairy milk (Gibson, Bailey, Gibbs, & Ferguson, 2010). Children and breastfeeding mothers are age groups that require higher amounts of calcium, with children aged 1.5-3 years obtaining 85.8% of the RNI for calcium from cows' milk. In these demographic groups cow's milk or fortified alternative products should always be recommended.

Vitamin B_{12} is an essential nutrient that helps keep the body's brain, nerve and blood cells healthy in addition to synthesising DNA (Vogel, Dali-Youcef, Kaltenbach, & Andres, 2009). Although milk alternatives were also fortified with vitamin B_{12}, cows' milk was higher compared to all other plant-based milk alternatives. From the data collected, 50% of plant-based milk alternatives, 56% of plant-based yogurt alternatives and 80% of plant-based cheese alternatives were fortified with vitamin B_{12}. As observed previously with calcium, none of the plant-based yogurt alternatives made with nuts or plant-based cheese alternatives made with nuts and seeds were fortified with vitamin B_{12}. If fortified products were consumed the ability to meet the RNI for vitamin B_{12} was not an issue. However, the lack of fortification of products means that consumers need to be aware of their requirements for these key nutrients and make informed decisions when choosing PBDAs.

Iodine is an essential nutrient, required in the body to make thyroid hormones, which are used to control the body's metabolism. Iodine is of particular importance for pregnant women and young children as iodine deficiency has been shown to slow mental development in young children (Bougma, Aboud, Harding, & Marquis, 2013). Previous studies in the UK reported iodine deficiencies in the population; including 68% of schoolgirls in nine UK centres (Vanderpump et al., 2011), and 22% of women 11-18 years of age and 10% of women 19-64 years of age (Miller, Spiro,

& Stanner, 2016). Despite milk and dairy products being the main source of iodine in human diets, only 6 plant-based milk alternatives out of the 136 collected were fortified with iodine, while iodine fortification was completely absent within the plant-based cheese and yogurt alternatives. As demonstrated in the results, children aged 1.5-3 years are reliant on cows' milk and dairy products as their primary source of iodine in the diet, and insufficient intake can have implications for healthy brain development.

4.7 Implications to household expenditure

The cost of PBDA alternatives is considerably higher than their equivalent dairy products. The average annual food cost for a typical UK household was around £4,805 in 2019 (based on the average 2.4 people per household), including £276 spent on non-alcoholic drinks (Office for National Statistics., 2020). If we consider a family of 2 adults (19-64 years) and one child (4-10 years) the cost of consuming dairy products to this household is £310.89 / year, representing 6.47% of their total food expenditure. This has the potential to increase to £856.70 / year, representing 17.89% of total expenditure if switches were made to PBDAs. Many of the PBDA were fortified as highlighted above, however the cost of both production and fortification results in these products being high cost for the consumer.

5. Conclusion

Despite PBDA products costing almost three times the price of cows' milk and dairy products, which can have a considerable impact on total household expenditure, the plant-based market is continuously expanding and is expected to continue to further attract consumers. This study revealed that nutritional considerations should be made when making food substitutions such as milk/dairy with plant-based alternatives, or excluding milk/dairy from the diet, because there is a risk of nutrient deficiencies; in particular protein, calcium, iodine and vitamin B_{12}. This may affect the population as a whole but would be even more impactful to consumer groups that milk is a major contributor to their nutrient intakes (e.g. toddlers, children) or others that have higher requirement for nutrients that milk is a good source for (e.g. pregnant women, nursing mothers). Fortification provides a potential route for improving the nutritional composition and consequently impact on nutritional intake of PBDAs. However, there was considerable variability in the fortification of PBDAs, with some products fortifying across many micronutrients whilst a large number of others are not. This is particularly true of organic PBDA products which consumers may not realise are not fortified. Consumers need to be informed that PBDA products can act as a practical replacement for dairy products, however they cannot act as a nutritional replacement due to their large differences in nutrient composition.

Funding: ATR was in receipt of funding by an Undergraduate Research Opportunities Programme (UROP) grant from the University of Reading, to assist with the collection of data and writing up parts of the manuscript.

Author contribution: MEC and SS conceptualised the idea, ATR and RR collated the data, ATR, SS, MEC and KK undertook the analysis and all authors contributed to the writing of the manuscript.

Declarations of interest:

The authors have no conflicts of interest to declare.

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List of tables:

Table 1: Price and energy and nutritional content of cows' milk and coconut, grain, legumes, nuts and seed and mixed plant-based milk alternatives available on the UK market.

Variable	Cows[1]		Coconut[2]		Grains[3]		Legumes[4]		Nuts and Seeds[5]		Mixed[6]		
	n	Mean	n	Mean	n	Mean	n	Mean	n	Mean	n	Mean	P-value[7]
Price (GBP/100ml)	50	0.10±0.002[c]	19	0.19±0.011[ab]	34	0.18±0.006	26	0.18±0.011[b]	43	0.20±0.012[a]	10	0.19±0.015[ab]	<0.001
Energy (kcal/100ml)	51	50.27±1.783[a]	21	33.67±3.899[cd]	34	48.32±2.010[ab]	26	41.23±2.275[bc]	44	30.20±2.196[d]	11	45.00±5.962[ab]	<0.001
Fat (g/100ml)	51	1.91±0.207	21	1.88±0.255	34	1.35±0.129	26	2.11±0.145	44	1.83±0.126	11	1.39±0.158	0.062
Saturated fat (g/100ml)	50	1.23±0.136[b]	21	1.63±0.201[a]	34	0.20±0.019[d]	26	0.31±0.018[cd]	44	0.20±0.019[d]	11	0.68±0.124[c]	<0.001
Carbohydrates (g/100ml)	51	4.77±0.025[b]	21	3.70±0.683[bc]	34	8.21±0.417[a]	26	2.19±0.406[d]	44	2.61±0.444[cd]	11	7.72±1.362[a]	<0.001
Sugars (g/100ml)	50	4.75±0.034[a]	21	2.28±0.351[b]	34	4.74±0.450[a]	26	1.42±0.219[b]	44	1.56±0.286[b]	11	5.00±0.735[a]	<0.001
Fibre (g/100ml)	33	0.00±0.000[c]	21	0.16±0.056[bc]	33	0.56±0.090[a]	26	0.52±0.067[a]	43	0.27±0.046[b]	10	0.09±.050[bc]	<0.001
Protein (g/100ml)	51	3.49±0.017[a]	21	0.28±0.068[e]	34	0.56±0.067[cd]	26	3.08±0.142[b]	44	0.74±0.077[c]	11	0.29±0.081[de]	<0.001
Salt (g/100ml)	50	0.11±0.002	21	0.12±0.019	34	0.10±0.004	26	0.13±0.017	44	0.11±0.007	11	0.10±0.011	0.459
Vitamin D (µg/100ml)	0	*	10	0.75±0.075	16	1.03±0.094	18	0.91±0.067	19	0.83±0.054	5	0.90±0.150	0.150
Vitamin B_2 (mg/100ml)	4	0.24±0.005[b]	1	0.50±0.000[a]	11	0.21±0.000[c]	16	0.21±0.000[c]	13	0.21±0.000[c]	3	0.21±0.000[c]	<0.001
Vitamin B_{12} (µg/100ml)	15	0.79±0.053[a]	10	0.39±0.033[b]	16	0.38±0.000[b]	18	0.44±0.043[b]	19	0.38±0.000[b]	5	0.38±0.000[b]	<0.001
Calcium (mg/100ml)	30	124.40±0.571	13	108.10±13.860	18	120.00±0.000	22	111.20±9.587	23	114.50±7.069	5	120.00±0.000	0.547
Iron (mg/100ml)	0	*	3	0.17±0.067	0	*	5	1.38±0.441	2	0.20±0.000	0	*	0.102
Iodine (µg/100ml)	4	31.25±0.250[a]	1	13.00±0.000[b]	0	*	5	26.28±2.027[a]	0	*	0	*	0.006
Potassium (mg/100ml)	4	163.00±1.683	2	116.50±33.50	4	151.00±0.000	0	*	0	*	0	*	0.056

SE = standard error of mean
[1] skimmed, semi-skimmed and whole cow milk
[2] plant-based alternatives made of coconut
[3] plant-based alternatives made of oat, rice, or rice/quinoa
[4] plant-based alternatives made of soya or pea
[5] plant-based alternatives made of almond, hazelnut, cashew, tiger nut, walnut or almond/hazelnut
[6] plant-based alternatives that had more than one main plant source, including coconut/almond, almond/oat, coconut/rice, rice/almond.

[7] Significant differences were declared at P<0.05. Different lower-case letters within a row indicate significant differences between product categories (Fisher's Least Significant Difference test; P < 0.05)

Table 2: Per day energy and nutritional intake from cows' milk in UK population across the lifespan and change in nutrient intake when substituted for coconut, grain, legume, nuts and seed or mixed plant-based milk alternatives, together with EAR/DRV/RNI

Vari-able	Age group	Cow[1]		Coconut[2]		Grains[3]		Legumes[4]		Nuts and Seeds[5]		Mixed[6]		
		Mean±SE	% EAR/ DRV/ RNI	Mean±SE	% EAR/ DRV/ RNI	Mean±SE	% EAR/ DRV/ RNI	Mean±SE	% EAR/ DRV/ RNI	Mean±SE	% EAR/ DRV/ RNI	Mean±SE	% EAR/ DRV/ RNI	P-value[7]
Energy Intake (kcal/d)	Child 1.5-3	121.30±4.301[a]	12.53	81.20c±9.404[c]	8.39	116.50±4.848[ab]	12.04	99.44±5.487[bc]	10.27	72.84±5.297[d]	7.52	108.50±14.380[ab]	11.21	<0.001
	Child 4-10	84.64±3.002[a]	5.32	56.68c±6.564[c]	3.57	81.36±3.384[ab]	5.12	69.41±3.83[bc]	4.37	50.84±3.697[d]	3.20	75.76±10.040[ab]	4.77	<0.001
	Child 11-18	66.11±2.345[a]	2.54	44.27c±5.127[c]	1.70	63.54±2.643[ab]	2.44	54.21±2.992[bc]	2.08	39.71±2.888[d]	1.52	59.17±7.839[ab]	2.27	<0.001
	Adults 19-64	67.03±2.377[a]	2.79	44.89c±5.198[c]	1.90	64.43±2.68[ab]	2.72	54.97±3.033[bc]	2.32	40.26±2.928[d]	1.70	60.00±7.949[ab]	2.54	<0.001
	Adults 65+	76.12±2.700[a]	3.15	50.97c±5.903[c]	2.43	73.17±3.043[ab]	3.49	62.43±3.445[bc]	2.98	45.73±3.325[d]	2.18	68.13±9.027[ab]	3.25	<0.001
	Adults 65-74	78.91±2.799[a]	3.11	52.84c±6.119[c]	2.48	75.84±3.155[ab]	3.57	64.71±3.571[bc]	3.04	47.40±3.447[d]	2.23	70.63±9.357[ab]	3.32	<0.001
	Adults 75+	86.59±3.071[a]	3.20	57.99c±6.715[c]	2.81	83.23±3.462[ab]	4.03	71.02±3.919[bc]	3.44	52.02±3.783[d]	2.52	77.51±10.270[ab]	3.75	<0.001
Fat Intake (g/d)	Child 1.5-3	4.60±0.499	*	4.53±0.616	*	3.25±0.311	*	5.08±0.351	*	4.42±0.305	*	3.35±0.381	*	0.062
	Child 4-10	3.21±0.348	5.19	3.16±0.430	5.11	2.27±0.217	3.67	3.55±0.245	5.74	3.08±0.213	4.98	2.34±0.266	3.79	0.062
	Child 11-18	2.51±0.272	2.48	2.47±0.336	2.44	1.77±0.17	1.75	2.77±0.191	2.73	2.41±0.166	2.38	1.83±0.208	1.81	0.062
	Adults 19-64	2.55±0.276	2.77	2.50±0.341	2.72	1.80±0.172	1.96	2.81±0.194	3.05	2.44±0.169	2.65	1.85±0.211	2.01	0.062
	Adults 65+	2.89±0.313	3.54	2.84±0.387	3.48	2.04±0.195	2.50	3.19±0.22	3.91	2.77±0.192	3.40	2.11±0.239	2.59	0.062
	Adults 65-74	3.00±0.325	3.63	2.95±0.401	3.57	2.11±0.203	2.55	3.31±0.228	4.00	2.88±0.199	3.48	2.18±0.248	2.64	0.062
	Adults 75+	3.29±0.356	4.09	3.23±0.440	4.02	2.32±0.222	2.89	3.63±0.25	4.52	3.16±0.218	3.93	2.39±0.272	2.97	0.062
Saturated Fat Intake (g/d)	Child 1.5-3	2.96±0.329[b]	*	3.93±0.484[a]	*	0.49±0.045[d]	*	0.74±0.044[c]	*	0.48±0.045[d]	*	1.64±0.300[c]	*	<0.001
	Child 4-10	2.07±0.23[b]	10.66	2.74±0.338[a]	14.10	0.34±0.031[d]	1.75	0.52±0.031[c]	2.68	0.33±0.031[d]	1.54	1.15±0.209[c]	5.92	<0.001
	Child 11-18	1.62±0.179[b]	5.09	2.14±0.264[a]	6.72	0.27±0.025[d]	0.85	0.41±0.024[c]	1.29	0.26±0.024[d]	0.82	0.90±0.163[c]	2.83	<0.001
	Adults 19-64	1.64±0.182[b]	5.67	2.17±0.267[a]	7.50	0.27±0.025[d]	0.93	0.41±0.024[c]	1.42	0.26±0.025[d]	0.90	0.91±0.166[c]	3.15	<0.001
	Adults 65+	1.86±0.206[b]	7.26	2.47±0.304[a]	9.64	0.31±0.028[d]	1.21	0.47±0.028[c]	1.83	0.30±0.028[d]	1.17	1.03±0.188[c]	4.02	<0.001
	Adults 65-74	1.93±0.214[b]	7.42	2.56±0.315[a]	9.85	0.32±0.029[d]	1.23	0.48±0.029[c]	1.85	0.31±0.029[d]	1.19	1.07±0.195[c]	4.12	<0.001

	Adults 75+	2.12±0.235^{b}	8.39	2.81±0.346^{a}	11.12	0.35±0.032^{d}	1.39	0.53±0.032^{c}	2.10	0.34±0.032^{d}	1.35	1.17±0.214^{c}	4.63	<0.001
Carbohydrates Intake (g/d)	Child 1.5-3	11.51±0.060^{b}	9.51	8.91±1.647^{bc}	7.36	19.80±1.005^{a}	16.36	5.27±0.979^{d}	4.36	6.29±1.070^{c}	5.20	18.62±3.284^{a}	15.39	<0.001
	Child 4-10	8.04±0.042^{b}	4.05	6.22±1.149^{bc}	3.13	13.82±0.701^{a}	6.96	3.68±0.684^{d}	1.85	4.39±0.747^{c}	2.21	12.99±2.293^{a}	6.54	<0.001
	Child 11-18	6.28±0.033^{b}	1.93	4.86±0.898^{bc}	1.49	10.79±0.548^{a}	3.31	2.87±0.534^{d}	0.88	3.43±0.583^{c}	1.05	10.15±1.791^{a}	3.12	<0.001
	Adults 19-64	6.36±0.033^{b}	2.15	4.93±0.910^{bc}	1.67	10.94±0.555^{a}	3.70	2.91±0.541^{d}	0.98	3.48±0.591^{c}	1.18	10.29±1.816^{a}	3.48	<0.001
	Adults 65+	7.23±0.038^{b}	2.76	5.60±1.034^{bc}	2.14	12.43±0.631^{a}	4.74	3.31±0.615^{d}	1.26	3.95±0.672^{c}	1.51	11.69±2.062^{a}	4.46	<0.001
	Adults 65-74	7.49±0.039^{b}	2.82	5.80±1.071^{bc}	2.18	12.88±0.645^{a}	4.84	3.43±0.637^{d}	1.29	4.09±0.696^{c}	1.54	12.11±2.137^{a}	4.55	<0.001
	Adults 75+	8.22±0.043^{b}	3.18	6.37±1.176^{bc}	2.47	14.14±0.718^{a}	5.47	3.76±0.699^{d}	1.46	4.49±0.764^{c}	1.74	13.29±2.346^{a}	5.14	<0.001
Sugar Intake (g/d)	Child 1.5-3	11.45±0.081^{a}	*	5.49±0.847^{b}	0.00	11.44±1.086^{a}	*	3.43±0.527^{b}	*	3.75±0.691^{b}	*	12.06±1.773^{a}	*	<0.001
	Child 4-10	7.99±0.057^{a}	*	3.83±0.591^{b}	0.00	7.99±0.758^{a}	*	2.40±0.368^{b}	*	2.62±0.482^{b}	*	8.42±1.238^{a}	*	<0.001
	Child 11-18	6.24±0.044^{a}	*	2.99±0.462^{b}	0.00	6.24±0.592^{a}	*	1.87±0.288^{b}	*	2.04±0.377^{b}	*	6.57±0.967^{a}	*	<0.001
	Adults 19-64	6.33±0.045^{a}	*	3.04±0.468^{b}	0.00	6.33±0.600^{a}	*	1.90±0.292^{b}	*	2.07±0.382^{b}	*	6.67±0.980^{a}	*	<0.001
	Adults 65+	7.19±0.051^{a}	*	3.45±0.532^{b}	0.00	7.18±0.682^{a}	*	2.16±0.331^{b}	*	2.35±0.434^{b}	*	7.57±1.113^{a}	*	<0.001
	Adults 65-74	7.45±0.053^{a}	*	3.57±0.551^{b}	0.00	7.45±0.707^{a}	*	2.23±0.343^{b}	*	2.44±0.450^{b}	*	7.85±1.154^{a}	*	<0.001
	Adults 75+	8.17±0.058^{a}	*	3.92±0.605^{b}	0.00	8.17±0.776^{a}	*	2.45±0.377^{b}	*	2.68±0.493^{b}	*	8.61±1.266^{a}	*	<0.001
Fibre Intake (g/d)	Child 1.5-3	0.00±0.000^{c}	0.00	0.39±0.136^{bc}	2.60	1.32±0.214^{a}	8.80	1.25±0.161^{a}	8.33	0.65±0.109^{b}	4.33	0.20±0.112^{bc}	1.33	<0.001
	Child 4-10	0.00±0.000^{c}	0.00	0.27±0.095^{bc}	1.35	0.92±0.149^{a}	4.60	0.87±0.112^{a}	4.35	0.45±0.076^{b}	2.25	0.14±0.078^{bc}	0.70	<0.001
	Child 11-18	0.00±0.000^{c}	0.00	0.21±0.074^{bc}	0.84	0.72±0.117^{a}	2.88	0.68±0.088^{a}	2.72	0.35±0.060^{b}	1.40	0.11±0.061^{bc}	0.44	<0.001
	Adults 19-64	0.00±0.000^{c}	0.00	0.22±0.075^{bc}	0.73	0.73±0.118^{a}	2.43	0.69±0.089^{a}	2.30	0.36±0.060^{b}	1.20	0.11±0.062^{bc}	0.37	<0.001
	Adults 65+	0.00±0.000^{c}	0.00	0.25±0.085^{bc}	0.83	0.83±0.134^{a}	2.77	0.79±0.101^{a}	2.63	0.41±0.069^{b}	1.37	0.12±0.070^{bc}	0.40	<0.001
	Adults 65-74	0.00±0.000^{c}	0.00	0.25±0.088^{bc}	0.83	0.86±0.139^{a}	2.87	0.82±0.105^{a}	2.73	0.42±0.071^{b}	1.40	0.13±0.073^{bc}	0.43	<0.001
	Adults 75+	0.00±0.000^{c}	0.00	0.28±0.097^{bc}	0.93	0.94±0.153^{a}	3.13	0.89±0.115^{a}	2.97	0.46±0.078^{b}	1.53	0.14±0.080^{bc}	0.47	<0.001
Protein Intake (g/d)	Child 1.5-3	8.41±0.040^{a}	58.00	0.68 ±0.164^{e}	4.69	1.34±0.161^{c}	9.24	7.42±0.343^{b}	51.17	1.78±0.186^{c}	12.28	0.700±0.196^{d}	4.83	<0.001
	Child 4-10	5.87±0.028^{a}	24.46	0.47±0.114^{e}	1.96	0.94±0.113^{c}	3.92	5.18±0.239^{b}	21.58	1.24±0.130^{c}	5.17	0.490±0.137^{d}	2.04	<0.001
	Child 11-18	4.59±0.022^{a}	10.01	0.37±0.089^{e}	0.81	0.73±0.088^{c}	1.59	4.05±0.187^{b}	8.83	0.97±0.101^{c}	2.11	0.380±0.107^{d}	0.83	<0.001
	Adults 19-64	4.65±0.022^{a}	9.25	0.38±0.090^{e}	0.76	0.74±0.089^{c}	1.47	4.10±0.189^{b}	8.16	0.99±0.103^{c}	1.97	0.390±0.109^{d}	0.78	<0.001
	Adults 65+	5.28±0.025^{a}	7.16	0.43±0.103^{e}	0.58	0.84±0.101^{c}	1.14	4.66±0.215^{b}	6.32	1.12±0.117^{c}	1.52	0.440±0.123^{d}	0.60	<0.001
	Adults 65-74	5.48±0.026^{a}	7.44	0.44±0.106^{e}	0.60	0.87±0.105^{c}	1.18	4.83±0.223^{b}	6.55	1.16±0.121^{c}	1.57	0.460±0.128^{d}	0.62	<0.001
	Adults 75+	6.01±0.028^{a}	8.15	0.48±0.117^{e}	0.65	0.96±0.115^{c}	1.30	5.30±0.245^{b}	7.19	1.27±0.133^{c}	1.72	0.500±0.140^{d}	0.68	<0.001
Vitamin B_2	Child 1.5-3	0.59±0.012^{b}	73.75	1.21±0.000^{a}	151.25	0.51±0.000^{c}	63.75	0.51±0.000^{c}	63.75	0.51±0.000^{c}	63.75	0.51±0.000^{c}	63.75	<0.001
	Child 4-10	0.41±0.008^{b}	45.56	0.84±0.000^{a}	93.33	0.35±0.000^{c}	38.89	0.35±0.000^{c}	38.89	0.30±0.000^{c}	38.89	0.35±0.000^{c}	38.89	<0.001

Intake (mg/d)	Child 11-18	0.32±0.006^{b}	27.23	0.66±0.000^{a}	56.17	0.28±0.000^{c}	23.83	0.28±0.000^{c}	23.83	0.28±0.000^{c}	23.83	0.28±0.000^{c}	23.83	<0.001
	Adults 19-64	0.32±0.006^{b}	35.56	0.67±0.000^{a}	74.44	0.28±0.000^{c}	31.11	0.28±0.000^{c}	31.11	0.28±0.000^{c}	31.11	0.28±0.000^{c}	31.11	<0.001
	Adults 65+	0.37±0.007^{b}	43.53	0.76±0.000^{a}	89.41	0.32±0.000^{c}	37.65	0.32±0.000^{c}	37.65	0.32±0.000^{c}	37.65	0.32±0.000^{c}	37.65	<0.001
	Adults 65-74	0.38±0.008^{b}	44.71	0.79±0.000^{a}	92.94	0.33±0.000^{c}	38.82	0.33±0.000^{c}	38.82	0.33±0.000^{c}	38.82	0.33±0.000^{c}	38.82	<0.001
	Adults 75+	0.42±0.008^{b}	49.41	0.86±0.000^{a}	101.18	0.36±0.000^{c}	42.35	0.36±0.000^{c}	42.35	0.36±0.000^{c}	42.35	0.36±0.000^{c}	42.35	<0.001
Vitamin B_{12} Intake (µg/d)	Child 1.5-3	1.91±0.129^{a}	382.00	0.94±0.080^{b}	188.00	0.92±0.000^{b}	184.00	1.07±0.103^{b}	214.00	0.92±0.000^{b}	184.00	0.92±0.000^{b}	184.00	<0.001
	Child 4-10	1.33±0.090^{a}	147.78	0.66±0.056^{b}	73.33	0.64±0.000^{b}	71.11	0.75±0.072^{b}	83.33	0.64±0.000^{b}	71.11	0.64±0.000^{b}	71.11	<0.001
	Child 11-18	1.04±0.070^{a}	77.04	0.51±0.044^{b}	37.78	0.50±0.000^{b}	37.04	0.58±0.056^{b}	42.96	0.50±0.000^{b}	37.04	0.50±0.000^{b}	37.04	<0.001
	Adults 19-64	1.05±0.071^{a}	70.00	0.52±0.044^{b}	34.67	0.51±0.000^{b}	34.00	0.59±0.057^{b}	39.33	0.51±0.000^{b}	34.00	0.51±0.000^{b}	34.00	<0.001
	Adults 65+	1.20±0.081^{a}	80.00	0.59±0.050^{b}	39.33	0.58±0.000^{b}	38.67	0.67±0.065^{b}	44.67	0.58±0.000^{b}	38.67	0.58±0.000^{b}	34.00	<0.001
	Adults 65-74	1.24±0.084^{a}	82.67	0.61±0.052^{b}	40.67	0.60±0.000^{b}	40.00	0.69±0.067^{b}	46.00	0.60±0.000^{b}	40.00	0.60±0.000^{b}	34.00	<0.001
	Adults 75+	1.36±0.092^{a}	90.67	0.67±0.057^{b}	44.67	0.66±0.000^{b}	44.00	0.76±0.074^{b}	50.67	0.66±0.000^{b}	44.00	0.66±0.000^{b}	34.00	<0.001
Calcium Intake (mg/d)	Child 1.5-3	300.1±1.376	85.74	260.7±33.43	74.49	289.4±0.000	82.69	268.3±23.12	76.66	276.2±17.05	78.91	289.4±0.000	0.83	0.547
	Child 4-10	209.5±0.961	41.90	182.0±23.33	36.40	202.0±0.000	40.40	187.2±16.14	37.44	192.8±11.90	38.56	202.0±0.000	0.40	0.547
	Child 11-18	163.6±0.750	18.18	142.1±18.22	15.79	157.8±0.000	17.53	146.2±12.61	16.24	150.6±9.295	16.73	157.8±0.000	0.18	0.547
	Adults 19-64	165.9±0.761	23.70	144.1±18.48	20.59	160.0±0.000	22.86	148.3±12.78	21.19	152.7±9.425	21.81	160.0±0.000	0.23	0.547
	Adults 65+	188.4±0.864	26.91	163.7±20.98	23.39	181.7±0.000	25.96	168.4±14.51	24.06	173.4±10.700	24.77	181.7±0.000	0.26	0.547
	Adults 65-74	195.3±0.896	27.90	169.7±21.75	24.24	188.3±0.000	26.90	174.6±15.05	24.94	179.7±11.100	25.67	188.3±0.000	0.27	0.547
	Adults 75+	214.3±0.983	30.61	186.2±23.87	26.60	206.7±0.000	29.53	191.6±16.51	27.37	197.2±12.180	28.17	206.7±0.000	0.30	0.547
Iodine Intake (µg/d)	Child 1.5-3	75.37±0.603^{a}	107.67	31.35±0.000^{b}	44.79	*	*	63.38±4.889^{a}	90.54	*	*	*	*	0.006
	Child 4-10	52.61±0.421^{a}	50.10	21.89±0.000^{b}	20.85	*	*	44.24±3.413^{a}	42.13	*	*	*	*	0.006
	Child 11-18	41.09±0.329^{a}	30.44	17.09±0.000^{b}	12.66	*	*	34.56±2.666^{a}	25.60	*	*	*	*	0.006
	Adults 19-64	41.66±0.33^{a}	29.76	17.33±0.000^{b}	12.38	*	*	35.04±2.703^{a}	25.03	*	*	*	*	0.006
	Adults 65+	47.31±0.379^{a}	33.79	19.68±0.000^{b}	14.06	*	*	39.79±3.069^{a}	28.42	*	*	*	*	0.006
	Adults 65-74	49.05±0.392^{a}	35.04	20.40±0.000^{b}	14.57	*	*	41.25±3.182^{a}	29.46	*	*	*	*	0.006
	Adults 75+	53.83±0.431^{a}	38.45	22.39±0.000^{b}	15.99	*	*	45.26±3.492^{a}	32.33	*	*	*	*	0.006
Potassium Intake (mg/d)	Child 1.5-3	393.10±4.060	49.14	281.00±80.800	35.13	364.20±0.000	45.53	*	*	*	*	*	*	0.056
	Child 4-10	274.40±2.834	17.70	196.10±56.400	12.65	254.20±0.000	16.40	*	*	*	*	*	*	0.056
	Child 11-18	214.30±2.213	6.49	153.20±44.050	4.64	198.50±0.000	6.02	*	*	*	*	*	*	0.056
	Adults 19-64	217.30±2.244	6.21	155.30±44.600	4.44	201.30±0.000	5.75	*	*	*	*	*	*	0.056
	Adults 65+	246.80±2.549	7.05	176.40±50.720	5.04	228.60±0.000	6.53	*	*	*	*	*	*	0.056

Adults 65-74	255.80±2.642	7.31	182.80±52.580	5.22	237.00±0.000	6.77	*	*	*	*	*	*	0.056
Adults 75+	280.80±2.899	8.02	200.70±57.700	5.73	260.10±0.000	7.43	*	*	*	*	*	*	0.056

SE = standard error of mean
[1] skimmed, semi-skimmed and whole cow milk
[2] plant-based alternatives made of coconut
[3] plant-based alternatives made of oat, rice, or rice/quinoa
[4] plant-based alternatives made of soya or pea
[5] plant-based alternatives made of almond, hazelnut, cashew, tiger nut, walnut or almond/hazelnut
[6] plant-based alternatives that had more than one main plant source, including coconut/almond, almond/oat, coconut/rice, rice/almond.
[7] Significant differences were declared at $P<0.05$. Different lower-case letters within a row indicate significant differences between product categories (Fisher's Least Significant Difference test; $P < 0.05$)

Table 3: Price and energy and nutritional content of cows' milk yogurt and coconut, nuts and soya plant-based yogurt alternatives available on the UK market.

Variable	Cow[1]		Coconut[2]		Nuts[3]		Soya[4]		
	n	Mean±SE	n	Mean±SE	n	Mean±SE	n	Mean±SE	P-value[5]
Price (GBP/100g)	78	0.30±0.017[d]	10	0.55±0.038[b]	10	0.87±0.034[a]	35	0.44±0.04[c]	<0.001
Energy (kcal/100g)	78	83.31±3.672[b]	10	111.70±4.854[a]	10	96.80±3.777[ab]	35	68.43±2.019[c]	<0.001
Fat (g/100g)	78	3.26±0.366[b]	10	6.17±0.888[a]	10	6.69±0.43[a]	35	2.25±0.064[b]	<0.001
Saturated fat (g/100g)	78	2.14±0.239[b]	10	6.14±0.914[a]	10	1.17±0.485[bc]	35	0.40±0.025[c]	<0.001
Carbohydrates (g/100g)	78	8.13±0.412[b]	10	11.57±1.295[a]	10	6.43±0.61[b]	35	7.05±0.57[b]	0.003
Sugars (g/100g)	78	7.58±0.375[a]	10	7.80±1.437[a]	10	2.71±0.726[b]	35	6.71±0.568[a]	<0.001
Fibre (g/100g)	45	0.10±0.030[c]	8	0.35±0.135[b]	8	0.13±0.125[bc]	35	1.03±0.067[a]	<0.001
Protein (g/100g)	78	5.32±0.192[a]	10	0.82±0.092[c]	10	1.89±0.061[c]	35	3.93±0.097[b]	<0.001
Salt (g/100g)	78	0.16±0.006[b]	10	0.24±0.062[a]	10	0.22±0.037[a]	35	0.20±0.014[a]	0.003
Vitamin D (µg/100g)	0	*	6	0.75±0.000	0	*	26	0.76±0.032	0.932
Vitamin B_{12} (µg/100g)	0	*	6	0.38±0.000	0	*	25	0.37±0.006	0.310
Calcium (mg/100g)	44	153.80±4.385[a]	6	128.00±0.000[ab]	0	*	32	111.00±7.487[b]	<0.001

n = number of samples, SE = standard error of mean
[1] yogurt made of cow's milk, including plain full-fat, plain low-fat, plain fat-free, Greek full-fat, Greek low-fat, Greek fat-free, fruit and vanilla
[2] plant-based alternatives made of coconut, including plain, fruit and vanilla
[3] plant-based alternatives made of cashew or almonds, including Greek, fruit and vanilla
[4] plant-based alternatives made of soya, including plain, Greek, fruit and vanilla
[5] Significant differences were declared at P<0.05. Different lower-case letters within a row indicate significant differences between product categories (Fisher's Least Significant Difference test; P < 0.05)

Table 4: Per day energy and nutritional intake from cows' milk yogurt in UK population across the lifespan and change in nutrient intake when substituted for coconut, nuts or soya plant-based yogurt alternatives, together with EAR/DRV/RNI

Variable	Age group	Cow[1]	Coconut[2]	Nuts[3]	Soya[4]

	Years	Mean±SE	% EAR/ DRV/ RNI	Mean±SE	% EAR/ DRV/ RNI	Mean±SE	% EAR/ DRV/ RNI	Mean±SE	% EAR/ DRV/ RNI	P-value
Energy Intake (kcal/d)	Child 1.5-3	36.32±1.601^{b}	3.75	48.70±2.116^{a}	5.03	42.20±1.646^{ab}	4.36	29.83±0.880^{c}	3.08	<0.001
	Child 4-10	34.91±1.539^{b}	2.20	46.81±2.034^{a}	2.94	40.57±1.583^{ab}	2.55	28.68±0.846^{c}	1.80	<0.001
	Child 11-18	18.54±0.817^{b}	0.71	24.86±1.080^{a}	0.95	21.54±0.840^{ab}	0.83	15.23±0.449^{c}	0.58	<0.001
	Adults 19-64	22.30±0.983^{b}	0.94	29.90±1.299^{a}	1.26	25.91±1.011^{ab}	1.10	18.31±0.541^{c}	0.77	<0.001
	Adults 65+	33.05±1.457^{b}	1.58	44.32±1.926^{a}	2.11	38.40±1.498^{ab}	1.83	27.15±0.801^{c}	1.29	<0.001
	Adults 65-74	34.26±1.510^{b}	1.61	45.94±1.996^{a}	2.16	39.81±1.553^{ab}	1.87	28.14±0.830^{c}	1.32	<0.001
	Adults 75+	25.65±1.131^{b}	1.24	34.39±1.494^{a}	1.66	29.81±1.163^{ab}	1.44	21.07±0.622^{c}	1.02	<0.001
Fat Intake (g/d)	Child 1.5-3	1.42±0.160^{b}	*	2.93±0.387^{a}	*	2.92±0.188^{a}	*	0.98±0.028^{b}	*	<0.001
	Child 4-10	1.37±0.153^{b}	2.22	2.81±0.372^{a}	4.55	2.80±0.180^{a}	4.53	0.95±0.027^{b}	1.54	<0.001
	Child 11-18	0.73±0.082^{b}	0.72	1.49±0.198^{a}	1.47	1.49±0.096^{a}	1.47	0.50±0.014^{b}	0.49	<0.001
	Adults 19-64	0.87±0.098^{b}	0.95	1.80±0.238^{a}	1.96	1.79±0.115^{a}	1.95	0.60±0.017^{b}	0.65	<0.001
	Adults 65+	1.29±0.145^{b}	1.58	2.66±0.352^{a}	3.26	2.65±0.171^{a}	3.25	0.89±0.025^{b}	1.09	<0.001
	Adults 65-74	1.34±0.151^{b}	1.62	2.76±0.365^{a}	3.34	2.75±0.177^{a}	3.32	0.93±0.026^{b}	1.12	<0.001
	Adults 75+	1.00±0.113^{b}	1.24	2.07±0.273^{a}	2.58	2.06±0.133^{a}	2.56	0.69±0.020^{b}	0.86	<0.001
Saturated Fat Intake (g/d)	Child 1.5-3	0.93±0.104^{b}	*	2.68±0.398^{a}	*	0.51±0.211^{bc}	*	0.17±0.011^{c}	*	<0.001
	Child 4-10	0.90±0.100^{b}	4.63	2.57±0.383^{a}	13.23	0.49±0.203^{bc}	2.52	0.17±0.010^{c}	0.875	<0.001
	Child 11-18	0.48±0.053^{b}	1.51	1.37±0.203^{a}	4.30	0.26±0.108^{bc}	0.82	0.09±0.005^{c}	0.283	<0.001
	Adults 19-64	0.57±0.064^{b}	1.97	1.64±0.245^{a}	5.67	0.31±0.130^{bc}	1.07	0.11±0.007^{c}	0.380	<0.001
	Adults 65+	0.85±0.095^{b}	3.32	2.44±0.363^{a}	9.52	0.46±0.192^{bc}	1.79	0.16±0.010^{c}	0.624	<0.001
	Adults 65-74	0.88±0.098^{b}	3.39	2.53±0.376^{a}	9.73	0.48±0.199^{bc}	1.85	0.17±0.010^{c}	0.654	<0.001
	Adults 75+	0.66±0.074^{b}	2.61	1.89±0.281^{a}	7.48	0.36±0.149^{bc}	1.42	0.12±0.008^{c}	0.475	<0.001
Carbohydrates Intake (g/d)	Child 1.5-3	3.54±0.180^{b}	2.93	5.04±0.565^{a}	4.17	2.80±0.266^{b}	2.31	3.07±0.249^{b}	2.54	0.003
	Child 4-10	3.41±0.173^{b}	1.72	4.85±0.543^{a}	2.44	2.70±0.256^{b}	1.36	2.96±0.239^{b}	1.49	0.003
	Child 11-18	1.81±0.092^{b}	0.56	2.58±0.288^{a}	0.79	1.43±0.136^{b}	0.44	1.57±0.127^{b}	0.48	0.003
	Adults 19-64	2.18±0.110^{b}	0.74	3.10±0.347^{a}	1.05	1.72±0.163^{b}	0.58	1.89±0.153^{b}	0.64	0.003
	Adults 65+	3.23±0.163^{b}	1.23	4.59±0.514^{a}	1.75	2.55±0.242^{b}	0.97	2.80±0.226^{b}	1.07	0.003
	Adults 65-74	3.34±0.169^{b}	1.26	4.76±0.533^{a}	1.79	2.64±0.251^{b}	0.99	2.90±0.235^{b}	1.09	0.003
	Adults 75+	2.50±0.127^{b}	0.97	3.56±0.399^{a}	1.38	1.98±0.188^{b}	0.77	2.17±0.176^{b}	0.84	0.003

Sugar Intake (g/d)	Child 1.5-3	3.30±0.164^{a}	*	3.40±0.627^{a}	*	1.18±0.317^{b}	*	2.93±0.247^{a}	*	<0.001
	Child 4-10	3.18±0.157^{a}	*	3.27±0.602^{a}	*	1.14±0.304^{b}	*	2.81±0.238^{a}	*	<0.001
	Child 11-18	1.69±0.084^{a}	*	1.74±0.32^{a}	*	0.60±0.162^{b}	*	1.49±0.126^{a}	*	<0.001
	Adults 19-64	2.03±0.100^{a}	*	2.09±0.385^{a}	*	0.73±0.194^{b}	*	1.80±0.152^{a}	*	<0.001
	Adults 65+	3.01±0.149^{a}	*	3.10±0.57^{a}	*	1.08±0.288^{b}	*	2.66±0.225^{a}	*	<0.001
	Adults 65-74	3.12±0.154^{a}	*	3.21±0.591^{a}	*	1.12±0.299^{b}	*	2.76±0.233^{a}	*	<0.001
	Adults 75+	2.33±0.115^{a}	*	2.40±0.442^{a}	*	0.83±0.224^{b}	*	2.07±0.175^{a}	*	<0.001
Fibre Intake (g/d)	Child 1.5-3	0.04±0.013^{c}	0.27	0.15±0.059^{b}	1.00	0.05±0.055^{bc}	0.33	0.45±0.029^{a}	3.00	<0.001
	Child 4-10	0.04±0.013^{c}	0.20	0.15±0.057^{b}	0.75	0.05±0.052^{bc}	0.25	0.43±0.028^{a}	2.15	<0.001
	Child 11-18	0.02±0.007^{c}	0.08	0.08±0.030^{b}	0.32	0.03±0.278^{bc}	0.12	0.23±0.015^{a}	0.92	<0.001
	Adults 19-64	0.03±0.008^{c}	0.10	0.09±0.004^{b}	0.30	0.03±0.034^{bc}	0.10	0.28±0.018^{a}	0.93	<0.001
	Adults 65+	0.04±0.012^{c}	0.13	0.14±0.054^{b}	0.47	0.05±0.050^{bc}	0.7	0.41±0.026^{a}	1.37	<0.001
	Adults 65-74	0.04±0.013^{c}	0.13	0.14±0.056^{b}	0.47	0.05±0.051^{bc}	0.17	0.43±0.027^{a}	1.43	<0.001
	Adults 75+	0.03±0.009^{c}	0.10	0.11±0.042^{b}	0.37	0.04±0.039^{bc}	0.13	0.32±0.021^{a}	1.07	<0.001
Protein Intake (g/d)	Child 1.5-3	2.32±0.084^{a}	16.00	0.36±0.04^{c}	2.48	0.82±0.026^{c}	5.66	1.71±0.042^{b}	11.79	<0.001
	Child 4-10	2.23±0.081^{a}	9.29	0.34±0.038^{c}	1.42	0.79±0.025^{c}	3.29	1.65±0.041^{b}	6.88	<0.001
	Child 11-18	1.19±0.043^{a}	2.59	0.18±0.020^{c}	0.39	0.42±0.014^{c}	0.92	0.88±0.022^{b}	1.92	<0.001
	Adults 19-64	1.43±0.051^{a}	2.85	0.22±0.025^{c}	0.44	0.51±0.016^{c}	1.01	1.05±0.026^{b}	2.09	<0.001
	Adults 65+	2.11±0.076^{a}	2.86	0.33±0.036^{c}	0.45	0.75±0.024^{c}	1.02	1.56±0.039^{b}	2.12	<0.001
	Adults 65-74	2.19±0.079^{a}	2.97	0.34±0.038^{c}	0.46	0.78±0.025^{c}	1.06	1.62±0.040^{b}	2.20	<0.001
	Adults 75+	1.64±0.059^{a}	2.23	0.25±0.028^{c}	0.34	0.58±0.019^{c}	0.79	1.21±0.030^{b}	1.64	<0.001
Calcium Intake (mg/d)	Child 1.5-3	67.04±1.911^{a}	19.15	55.80±0.000^{ab}	15.94	*	*	48.41±3.264^{b}	13.83	<0.001
	Child 4-10	64.44±1.837^{a}	12.89	53.64±0.000^{ab}	10.73	*	*	46.53±3.138^{b}	9.31	<0.001
	Child 11-18	34.22±0.976^{a}	3.80	28.49±0.000^{ab}	3.17	*	*	24.71±1.666^{b}	2.75	<0.001
	Adults 19-64	41.17±1.174^{a}	5.88	34.27±0.000^{ab}	4.90	*	*	29.72±2.004^{b}	4.25	<0.001
	Adults 65+	41.01±1.740^{a}	5.86	50.78±0.000^{ab}	7.25	*	*	44.05±2.970^{b}	6.29	<0.001
	Adults 65-74	63.24±1.803^{a}	9.03	52.64±0.000^{ab}	7.52	*	*	45.66±3.079^{b}	6.52	<0.001
	Adults 75+	47.35±1.350^{a}	6.76	39.41±0.000^{ab}	5.63	*	*	34.19±2.305^{b}	4.88	<0.001

SE = standard error of mean

[1] yogurt made of cow's milk, including plain full-fat, plain low-fat, plain fat-free, Greek full-fat, Greek low-fat, Greek fat-free, fruit and vanilla

[2] plant-based alternatives made of coconut, including plain, fruit and vanilla

[3] plant-based alternatives made of cashew or almonds, including Greek, fruit and vanilla

[4] plant-based alternatives made of soya, including plain, Greek, fruit and vanilla

[5] Significant differences were declared at $P<0.05$. Different lower-case letters within a row indicate significant differences between product categories (Fisher's Least Significant Difference test; $P < 0.05$)

Table 5: Price and energy and nutritional content of cows' milk cheese and nuts and seed and oil plant-based cheese alternatives available on the UK market.

Variable	Cow[1]		Nuts & Seeds[2]		Oils[3]		
	n	Mean	n	Mean	n	Mean	P-value[4]
Price (GBP/100g)	38	0.76±0.073[c]	7	2.52±0.496[a]	102	1.29±0.042[b]	<0.001
Energy (kcal/100g)	38	312.90±13.730[a]	6	240.50±12.000[c]	102	284.30±2.569[b]	<0.001
Fat (g/100g)	38	26.04±1.402[a]	6	21.00±2.066[b]	102	22.94±0.262[b]	0.003
Saturated fat (g/100g)	37	17.36±0.723[b]	6	2.13±0.304[c]	102	19.22±0.315[a]	<0.001
Carbohydrates (g/100g)	38	1.80±0.299[b]	6	5.42±1.496[b]	102	17.58±0.757[a]	<0.001
Sugars (g/100g)	37	1.52±0.284[a]	6	2.48±1.041[a]	102	0.62±0.128[b]	<0.001
Fibre (g/100g)	25	0.25±0.124[b]	3	2.47±0.203[a]	46	3.17±0.277[a]	<0.001
Protein (g/100g)	38	16.57±1.304[a]	6	6.45±0.220[b]	102	1.05±0.182[c]	<0.001
Salt (g/100g)	37	1.10±0.099[b]	6	1.25±0.115[ab]	102	1.77±0.067[b]	<0.001
Vitamin D (µg/100g)	0	*	0	*	9	0.22±0.148	*
Vitamin B_{12} (µg/100g)	0	*	0	*	43	2.23±0.113	*
Calcium (mg/100g)	7	651.70±44.090	0	*	21	352.8±71.510	0.027
Potassium (mg/100g)	0	*	0	*	7	68.81±18.800	*

n = number of samples, SE = standard error of mean
[1] cheese made of cow's milk, including mature cheddar, soft cheese and mozzarella
[2] plant-based alternatives made of almond, sunflower, and cashew, including soft cheese
[3] plant-based alternatives made of coconut oil, soybean oil and palm fruit oil, including soft cheeses, cheddars, hard cheeses and mozzarella
[4] Significant differences were declared at P<0.05. Different lower-case letters within a row indicate significant differences between product categories (Fisher's Least Significant Difference test; P < 0.05)

Table 6: Per day energy and nutritional intake from cows' milk cheese in UK population across the lifespan and change in nutrient intake when substituted for coconut, nuts and seed or oil plant-based cheese alternatives, together with EAR/DRV/RNI.

Variable	Age group	Cows		Nuts & Seeds		Oils		
	Years	Mean±SE	% EAR/ DRV/ RNI	Mean±SE	% EAR/ DRV/ RNI	Mean±SE	% EAR/ DRV/ RNI	P-value
Energy Intake (kcal/d)	Child 1.5-3	15.73±1.268[a]	1.63	8.43±0.456[b]	0.87	12.86±0.385[a]	1.33	0.013
	Child 4-10	13.88±1.012[a]	0.87	8.77±0.474[c]	0.55	12.27±0.270[b]	0.77	0.006
	Child 11-18	15.73±2.044[a]	0.60	5.93±0.320[b]	0.23	13.18±0.769[ab]	0.51	0.042
	Adults 19-64	19.90±1.508[a]	0.84	12.31±0.666[c]	0.52	17.54±0.417[b]	0.74	0.008
	Adults 65+	18.58±1.520[a]	0.89	10.99±0.594[c]	0.52	16.29±0.445[b]	0.78	0.011
	Adults 65-74	19.26±1.576[a]	0.91	11.40±0.616[c]	0.54	16.88±0.462[b]	0.79	0.011
	Adults 75+	22.63±1.779[a]	1.10	13.72±0.742[c]	0.66	19.90±0.506[b]	0.96	0.009
Fat Intake (g/d)	Child 1.5-3	1.23±0.111[a]	*	0.74±0.072[b]	*	1.03±0.029[b]	*	0.009
	Child 4-10	1.16±0.090[a]	1.88	0.77±0.075[b]	1.25	0.99±0.020[b]	1.60	0.005
	Child 11-18	1.32±0.174[a]	1.30	0.52±0.051[b]	0.51	1.05±0.059[ab]	1.04	0.026
	Adults 19-64	1.66±0.134[a]	1.80	1.08±0.106[b]	1.17	1.41±0.031[b]	1.53	0.006
	Adults 65+	1.55±0.134[a]	1.90	0.96±0.094[b]	1.18	1.31±0.033[b]	1.61	0.007
	Adults 65-74	1.61±0.139[a]	1.95	1.00±0.098[b]	1.21	1.35±0.035[b]	1.63	0.007
	Adults 75+	1.89±0.157[a]	2.35	1.20±0.118[b]	1.49	1.60±0.038[b]	1.99	0.006
Saturated Fat Intake (g/d)	Child 1.5-3	0.05±0.010[a]	*	0.09±0.037[a]	*	0.03±0.005[b]	*	0.002
	Child 4-10	0.04±0.007[a]	0.21	0.06±0.026[a]	0.31	0.02±0.004[b]	0.10	<0.001
	Child 11-18	0.06±0.010[a]	0.19	0.09±0.038[a]	0.28	0.03±0.005[a]	0.09	0.049
	Adults 19-64	0.08±0.015[a]	0.28	0.13±0.053[a]	0.45	0.04±0.007[b]	0.14	0.001
	Adults 65+	0.07±0.013[a]	0.27	0.11±0.048[a]	0.43	0.03±0.006[b]	0.12	0.002
	Adults 65-74	0.07±0.013[a]	0.27	0.12±0.049[a]	0.46	0.03±0.007[b]	0.12	0.002
	Adults 75+	0.09±0.016[a]	0.36	0.14±0.059[a]	0.55	0.04±0.008[b]	0.16	0.001
Carbohydrates Intake (g/d)	Child 1.5-3	0.07±0.011[b]	0.06	0.19±0.053[b]	0.16	0.82±0.043[a]	0.68	<0.001
	Child 4-10	0.05±0.008[b]	0.03	0.13±0.037[b]	0.07	0.87±0.063[a]	0.44	<0.001
	Child 11-18	0.07±0.011[b]	0.02	0.20±0.055[b]	0.06	0.78±0.037[a]	0.24	<0.001
	Adults 19-64	0.09±0.015[b]	0.03	0.28±0.077[b]	0.10	1.11±0.054[a]	0.38	<0.001
	Adults 65+	0.08±0.014[b]	0.03	0.25±0.068[b]	0.10	1.04±0.053[a]	0.40	<0.001
	Adults 65-74	0.09±0.014[b]	0.03	0.26±0.071[b]	0.10	1.08±0.054[a]	0.41	<0.001

	Adults 75+	0.11±0.017[b]	0.04	0.31±0.085[b]	0.12	1.26±0.063[a]	0.49	<0.001
Sugar Intake (g/d)	Child 1.5-3	0.05±0.010[a]	*	0.09±0.037[a]	*	0.03±0.005[b]	*	0.002
	Child 4-10	0.05±0.010[a]	*	0.09±0.038[a]	*	0.03±0.005[b]	*	0.001
	Child 11-18	0.04±0.007	*	0.06±0.026	*	0.02±0.004	*	0.056
	Adults 19-64	0.08±0.014[a]	*	0.13±0.053[a]	*	0.04±0.007[b]	*	0.001
	Adults 65+	0.07±0.013[a]	*	0.11±0.048[a]	*	0.03±0.006[b]	*	0.002
	Adults 65-74	0.07±0.013[a]	*	0.12±0.049[a]	*	0.03±0.007[b]	*	0.002
	Adults 75+	0.09±0.016[a]	*	0.14±0.059[a]	*	0.04±0.008[b]	*	0.002
Fibre Intake (g/d)	Child 1.5-3	0.01±0.004[b]	0.07	0.09±0.007[ab]	0.60	0.15±0.017[a]	1.00	<0.001
	Child 4-10	0.01±0.005[b]	0.05	0.09±0.007[ab]	0.45	0.14±0.015[a]	0.70	<0.001
	Child 11-18	0.01±0.003[b]	0.04	0.06±0.005[ab]	0.24	0.15±0.024[a]	0.60	<0.001
	Adults 19-64	0.01±0.006[b]	0.03	0.13±0.01[ab]	0.43	0.20±0.021[a]	0.67	<0.001
	Adults 65+	0.01±0.006[b]	0.03	0.11±0.009[ab]	0.37	0.19±0.021[a]	0.63	<0.001
	Adults 65-74	0.01±0.006[b]	0.03	0.12±0.01[ab]	0.40	0.19±0.021[a]	0.63	<0.001
	Adults 75+	0.01±0.007[b]	0.03	0.14±0.012[ab]	0.47	0.23±0.025[a]	0.77	<0.001
Protein Intake (g/d)	Child 1.5-3	0.81±0.09[a]	5.59	0.23±0.008[b]	1.59	0.04±0.006[b]	0.28	<0.001
	Child 4-10	0.75±0.076[a]	3.13	0.24±0.008[b]	1.00	0.04±0.007[b]	0.17	<0.001
	Child 11-18	0.89±0.132[a]	1.94	0.16±0.005[b]	0.35	0.04±0.005[b]	0.09	<0.001
	Adults 19-64	1.08±0.112[a]	2.15	0.33±0.011[b]	0.66	0.06±0.009[b]	0.12	<0.001
	Adults 65+	1.02±0.110[a]	1.38	0.30±0.010[b]	0.41	0.05±0.008[b]	0.07	<0.001
	Adults 65-74	1.05±0.114[a]	1.43	0.31±0.270[b]	0.42	0.06±0.009[b]	0.08	<0.001
	Adults 75+	1.24±0.130[a]	1.68	0.37±0.013[b]	0.50	0.07±0.010[b]	0.10	<0.001
Salt Intake (g/d)	Child 1.5-3	0.05±0.007[b]	2.50	0.04±0.004[b]	2.00	0.08±0.004[a]	4.00	<0.001
	Child 4-10	0.05±0.006[b]	1.25	0.05±0.004[b]	1.25	0.08±0.003[a]	2.00	<0.001
	Child 11-18	0.06±0.009[b]	1.00	0.03±0.003[b]	0.50	0.08±0.006[a]	1.33	0.012
	Adults 19-64	0.07±0.008[b]	1.17	0.06±0.006[b]	1.00	0.11±0.005[a]	1.83	<0.001
	Adults 65+	0.07±0.008[b]	1.17	0.06±0.005[b]	1.00	0.10±0.005[a]	1.67	<0.001
	Adults 65-74	0.07±0.008[b]	1.17	0.06±0.005[b]	1.00	0.11±0.005[a]	1.83	<0.001
	Adults 75+	0.08±0.010[b]	1.33	0.07±0.007[b]	1.17	0.13±0.006[a]	2.17	<0.001
Calcium Intake (mg/d)	Child 1.5-3	33.26±5.149	9.50	*		16.25±3.562	4.64	0.020
	Child 4-10	30.60±3.951	6.12	*		15.42±3.252	3.08	0.020

	Child 11-18	38.27±8.871	4.25	*	16.98±4.461	1.89	0.029
	Adults 19-64	44.10±4.95	6.30	*	22.06±4.69	3.15	0.020
	Adults 65+	41.64±6.105	5.95	*	20.54±4.443	2.93	0.020
	Adults 65-74	43.16±6.329	6.17	*	21.30±4.605	3.04	0.020
	Adults 75+	50.42±7.080	7.20	*	25.06±5.369	3.58	0.020

n = number of samples, SE = standard error of mean
[1] cheese made of cow's milk, including mature cheddar, soft cheese and mozzarella
[2] plant-based alternatives made of almond, sunflower, and cashew, including soft cheese
[3] plant-based alternatives made of coconut oil, soybean oil and palm fruit oil, including soft cheeses, cheddars, hard cheeses and mozzarella
[4] Significant differences were declared at P<0.05. Different lower-case letters within a row indicate significant differences between product categories (Fisher's Least Significant Difference test; P < 0.05)

Table 7: Per year cost of cows' milk, yogurt and cheese and the corresponding cost of replacement with plant-based dairy alternatives in the UK population across the lifespan.

Milk	**Age group (years)**	**Cow**	**Coconut**	**Grains**	**Legumes**	**Nuts & Seeds**	**Mixed**
	Child 1.5-3	88.07	167.25	158.40	158.46	176.07	167.21
	Child 4-10	61.46	116.74	110.62	110.60	122.89	116.75
Cost (£/year)	Child 11-18	48.00	91.18	86.39	86.38	95.99	91.19
	Adults 19-64	48.67	92.46	87.60	87.59	97.32	92.47
	Adults 65+	55.27	104.98	99.49	99.48	110.54	105.00
	Adults 65-74	57.29	108.83	103.12	103.12	114.58	108.85

	Adults 75+	62.87	119.44	113.17	113.17	125.74	119.45
Yogurt	**Age group**	**Cow**	**Coconut**	**Nuts**	**Soya**		
Cost (£/year)	Child 1.5-3	47.74	87.52	138.44	70.01		
	Child 4-10	45.88	84.13	133.09	67.31		
	Child 11-18	24.37	44.68	70.66	35.74		
	Adults 19-64	29.31	53.74	85.00	42.97		
	Adults 65+	43.44	79.65	125.97	63.72		
	Adults 65-74	45.03	82.56	130.60	66.04		
	Adults 75+	33.71	61.81	97.79	49.45		
Cheese	**Age group**	**Cow**	**Nuts & Seeds**	**Oils**			
Cost (£/year)	Child 1.5-3	13.95	32.24	21.30			
	Child 4-10	12.31	33.54	20.32			
	Child 11-18	13.95	22.68	21.83			
	Adults 19-64	17.64	47.08	29.05			
	Adults 65+	16.47	42.03	26.98			
	Adults 65-74	17.07	43.60	27.96			
	Adults 75+	20.06	52.47	32.96			