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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

Miriam E Clegg^{ac*}, Ariana Tarrado Ribes^a, Reece Reynolds^a, Kirsty Kliem^{bc} and Sokratis Stergiadis^{bc*}

^a Department of Food and Nutritional Sciences, Harry Nursten Building, University of Reading, Whiteknights, Reading RG6 6DZ, UK

^b Department of Animal Sciences, School of Agriculture, Policy and Development, University of Reading, New Agriculture Building, Earley Gate, PO Box 237, Reading RG6 6EU, UK

^c Institute for Food, Nutrition and Health, University of Reading, Whiteknights, Reading, RG6 6AH

*Corresponding author(s):

Dr Miriam Clegg, Department of Food and Nutritional Sciences, Harry Nursten Building, University of Reading, Whiteknights, Reading RG6 6DZ, Ph: 0118 378 8723. Email: m.e.clegg@reading.ac.uk.

Dr Sokratis Stergiadis, Department of Animal Sciences, School of Agriculture, Policy and Development, University of Reading, New Agriculture Building, Earley Gate, Reading RG6 6EU, UK, Ph: 0118 378 6634. Email: s.stergiadis@reading.ac.uk.

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 B₂, vitamin B₁₂ 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 they 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,

100 Wanhalinna, Zannini, & Arendt, 2016). Households are therefore viewing plant-based products as
101 a healthier alternative to dairy products with little evidence to reinforce their choices (Graca,
102 Truninger, Junqueira, & Schmidt, 2019).

103
104 Whilst PBDAs are known for their inclusion of dietary fibre, vitamins and antioxidants, they contain
105 much lower proportions of essential nutrients such as vitamin B₁₂, calcium and iodine, compared
106 with dairy products, which are also often less bioavailable (Aydara, Tutuncua, & Ozcelik, 2020;
107 Vanga & Raghavan, 2018). Removing dairy products from the diet could cause deficiencies in these
108 nutrients. This means that plant-based products need to be fortified to recreate a similar
109 nutritional composition of dairy products. The quality of protein in dairy products is also higher
110 than that of plant protein due to the presence of all essential amino acids (Gorissen et al., 2018).
111 Foods with lower biological value such as plant proteins need to be consumed in combination to
112 ensure all of the essential amino acids are obtained from the diet, which requires considerable
113 planning and knowledge. Vanga and Raghavan (2018) found soya-based liquid products to be the
114 nutritionally best alternative to dairy products, when compared with other PBDAs, due to their
115 higher and more complete protein content. However, soya's 'beany flavour' and potential
116 allergens can deter consumers. Despite being marketed as alternatives to dairy, these findings
117 indicate that the like-for-like substitution of dairy with plant-based products will not provide the
118 same nutritional benefits.

119
120 There is concern that the variation in the nutritional profile of PBDAs (Scholz-Ahrens, Ahrens, &
121 Barth, 2020) may affect the most vulnerable groups in society, including infants and children and
122 the elderly, who rely on the nutrients in dairy products, such as calcium, iodine and vitamin B₁₂
123 (Haug et al., 2007). Studies have shown that the consumption of dairy products contributes to
124 greater growth in children compared to PBDAs (Morency et al., 2017), while the use of PBDAs in
125 infants resulted in severe nutritional deficiencies, which could be preventable (Le Louer et al.,
126 2014). As many as 30% of British parents believe their child has a food allergy when the correct
127 figure is around 6%. This self- diagnosis of allergies is a problem with parents removing whole food
128 groups from their children's diet without proper knowledge (Savage & Johns, 2015). It has
129 previously been identified that there are significant differences across the nutritional composition
130 of plant-based milk alternatives and dairy products and it is essential that parents only convert
131 their children to PBDAs for the correct reason as the elimination of food groups can cause
132 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 B₁₂ deficiency, so are well advised to regularly consume sources of vitamin B₁₂ 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.

139

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.

147

148 **2. Method**

149 **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.

156

157 **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 B₁₂ (µg), vitamin B₂ (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 B₂, iron, iodine and potassium in yogurt category, and vitamin B₂,

165 iron and iodine in the cheese category, these nutrients were not included in the corresponding
166 categories.

167 **2.3 Data categorisation**

168 *2.3.1 Milk*

169 Milks and PBDAs were categorised into 6 different groupings, based on their primary ingredient/s
170 (cow's milk, coconut, grains, legumes, nuts and seeds, and mixed where a mixture of primary
171 ingredients was used). Each category was split into sub-categories; the cow's milk category
172 included skimmed (% fat: 0.05-0.3%), semi-skimmed (% fat: 1.6-1.8%) and whole milk (% fat: 3.5-
173 4.0%). The coconut included coconut-based milk alternatives. The grains category included oat,
174 rice and rice and quinoa -based milk alternatives. The legumes category included soya and pea -
175 based milk alternatives. The nuts and seeds category included almond, hazelnut, cashew, tiger nut,
176 walnut and almond and hazelnut -based milk alternatives. The mixed category included
177 alternatives that had more than one main plant source, such as coconut and almond, almond and
178 oat, coconut and rice, and rice and almond.

179

180 *2.3.2 Yogurt*

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

186

187 *2.3.3 Cheese*

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

194

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

197

198 **2.4 Nutritional intake and cost from cow's milk, yogurt and cheese**

199 National Diet and Nutrition Survey (NDNS) data years 7 to 8 (conducted in 2014/15-2015/16) was
200 used to identify the daily intake from milk, yogurt, cheddar and other cheeses (Public Health
201 England., 2018). Intake data in the NDNS is broken down into different age categories (1.5-3 years;
202 4-10 years; 11-18 years; 19-64 years; 65+ years; 75-74 years; 75+ years) and these categories were
203 used throughout our analysis. Intakes for the different product categories (milk, yogurt, cheddar
204 and other cheese) from NDNS data were given as a percentage of total energy intake per age group.
205 To convert the NDNS intake data from a percentage of energy intake to absolute intake in g/mg/μg,
206 food composition data from McCance and Widdowson food tables (Public Health England., 2019)
207 were used. Following this, the nutrient content per unit of mass/volume (as found in product label)
208 was multiplied by the mass of product consumed (as calculated from the NDNS) in order to calculate
209 the specific intake of energy and nutrients per product category (milk, yogurt, cheddar and other
210 cheese) and per age group. In order to explore a scenario whereby cow-based dairy products in the
211 diets were entirely replaced by corresponding PBDAs, the nutrient intakes from PBDAs were
212 calculated by using the same intakes (of the equivalent milk/dairy product) for each age group but
213 multiplied with the label information from the plant-based alternative. The data for cows' milk
214 within NDNS was broken down into whole, semi-skimmed and skimmed milk intake, these were
215 combined to create one milk intake category to compensate for the lack of milk types within each
216 milk PBDA. Cheese intake was divided into cheddar cheese and other cheese within the NDNS, and
217 this division was also followed within our database for accuracy. The nutrient intakes from the
218 consumption of the different product types were then compared to the UK DRV. Estimated
219 Average Requirements (EAR) for energy intake were based on the average of male and female
220 intake and for middle age groups for children (e.g in the 1.5-3 year age group, 2 year old EAR data
221 was used; in children aged 4-10 years, 7 year old EAR data was used) (Scientific Advisory Committee
222 on Nutrition., 2011). Fat was based on 35% of daily food energy based on recommendations and
223 saturated fat was based on no more than 11% of daily food energy for population aged 5 years and
224 above (Committee on Medical Aspects of Food Policy, 1991). Protein was based on the Reference
225 Nutrient Intake (RNI) for adults and children, and for older adults the higher recommendation by
226 European Society for Clinical Nutrition and Metabolism (ESPEN) of 1.1g/kg (Deutz et al., 2014) was
227 used. DRVs for carbohydrate were set at 50% of daily food energy based on the Scientific Advisory
228 Committee on Nutrition report on Carbohydrate (Scientific Advisory Committee on Nutrition,
229 2015). Currently UK sugar guidance is based on free sugars, and as milk sugar is not classified as free
230 sugar this comparison was not completed. Vitamin and mineral intakes were based on RNIs, and

231 where male and female requirements differed, these were averaged (Committee on Medical
232 Aspects of Food Policy, 1991; Scientific Advisory Committee on Nutrition., 2016). The cost of
233 consumption of dairy products milk, cheese and yogurt per year was calculated for each age group
234 and the corresponding cost was calculated when these dairy products were substituted for equal
235 quantities of corresponding PBDAs.

236

237 **2.5 Data Analysis**

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

244

245 **3. Results**

246 A total of 299 PBDA products were identified consisting of 136 milk alternatives, 55 yogurt
247 alternatives and 109 cheese alternatives. A total of 167 dairy products were identified including 51
248 milks, 78 yogurts and 38 cheeses. Out of the 136 plant-based milk alternatives, 60 contained
249 additional sugar as sweetener and 77 were fortified. Of the fortified products, 77 were fortified with
250 calcium, 68 with vitamin D, 44 with vitamin B₂, 68 with vitamin B₁₂, 6 with iodine and 6 with
251 potassium. In the plant-based yogurt alternatives there were 43 sweetened. Of the 55 plant-based
252 yogurt alternatives, 35 products were fortified. Of the fortified products, 35 were fortified with
253 calcium, 32 with vitamin D, 15 with vitamin B₂ and 31 with vitamin B₁₂. In the plant-based cheese
254 alternatives, 50 products were fortified. Of the fortified products, 14 were fortified with calcium, 2
255 with vitamin D and 40 with vitamin B₁₂.

256

257 **3.1 Milk and milk alternatives**

258 There were differences ($P < 0.05$) between milk and milk alternatives in price, and declared energy,
259 saturated fat, carbohydrates, sugars, fibre, protein, vitamin B₁₂, and iodine content (Table 1). Cows'
260 milk was substantially cheaper (by 44-50%; $P < 0.05$) than all PBDAs. Coconut and nuts & seeds
261 PBDAs had the lowest declared energy content (30-33 kcal/100ml) whilst cow's milk was the highest
262 (50 kcal/100ml; $P < 0.05$). Grains, legumes and mixed PBDAs contained intermediate concentrations.
263 Coconut PBDA was highest in declared saturated fat content (1.63 g/100ml; $P < 0.05$) followed by

264 cow's milk (1.23 g/100ml), while grains, legumes, nuts & seeds and mixed PBDAs contained less
265 (<0.3 g/100ml milk). Label carbohydrate content was highest in grains and mixed PBDAs (7.7-8.2
266 g/100ml; $P < 0.05$) and lowest in legumes and nuts and seeds PBDAs (2.2-2.6 g/100ml; $P < 0.05$).
267 Declared sugar content was highest in cows' milk and grains and mixed PBDAs (< 4.7 g/100ml; $P <$
268 0.05), and lower in coconut, legumes and nuts & seeds PBDAs (<2.3 g/100ml). Fibre is not found in
269 cows' milk; among the PBDAs, grains and legumes had higher label concentrations ($P < 0.05$) than
270 coconut, nuts and seeds and mixed. Declared protein content was highest in cows' milk (3.49
271 g/100ml; $P < 0.05$), had intermediate values in legumes (3.08g/ml) and was <1 g/100ml for all other
272 PBDAs. The highest declared content of vitamin B₂ was observed in coconut PBDA with only one
273 sample in this group (0.50 mg/100ml; $P < 0.05$), followed by cows' milk (0.24 mg/100ml) while
274 grains, legumes, nuts and seeds and mixed PBDAs had slightly lower (0.21 mg/100ml). Cow's milk
275 had a higher (+80-108 %; $P < 0.05$) declared content of vitamin B₁₂ compared with PBDAs. Legumes
276 and cows' milk had similar contents of iodine, and more than twice the amounts found in the single
277 coconut PBDA that contained iodine. The other PBDAs did not report iodine contents.

278
279 These differences between declared nutrient contents were reflected in individual nutrient intakes
280 from milk and PBDAs, when these were calculated for each consumer age group, using NDNS data,
281 resulting in changes in their contribution to nutritional requirements for energy, saturated fat,
282 carbohydrates, sugars, fibre, protein, vitamin B₁₂, and iodine (Table 2).

283

284 **3.2 Yogurt and yogurt alternatives**

285 There were differences ($P < 0.01$) between cows' milk yogurt and PBDAs in price and declared
286 energy, fat, saturated fat, carbohydrates, sugars, fibre, protein, salt, and calcium content (Table 3).
287 Cow's milk yogurt was substantially cheaper (by 43-66%; $P < 0.05$) than PBDAs based on coconut,
288 nuts and soya. Declared energy content was highest ($P < 0.05$) in coconut PBDA (112 Kcal/100g),
289 lowest in soya PBDA (68 Kcal/100g) and showed intermediate values in nuts PBDA and cows' milk
290 yogurt. Labels on coconut and nuts PBDAs suggested these products contained more fat ($P < 0.05$)
291 than cows' milk yogurt and soya PBDA. Declared saturated fat was nearly three times greater ($P <$
292 0.05) in coconut PBDA than cows' milk yogurt, while nuts and soya PBDA contained the lowest
293 amounts (<1.2 g/100g). Declared carbohydrate contents were 1.4-1.8 times higher ($P < 0.05$) in
294 coconut PBDA than any other product. For label sugar contents, there was no difference ($P > 0.05$)
295 between cows' milk, coconut and soya but the nuts category had 2.5-2.9 times less sugar ($P < 0.05$)
296 than these. Declared fibre content was highest ($P < 0.05$) in soya PBDA (1.03 g/100g), lowest in cows'

297 milk yogurt (0.10 g/100g) and showed intermediate values in coconut and nuts PBDA. Cows' milk
298 yogurt had more ($P < 0.05$) declared protein than PBDAs, while soya had more than twice the
299 amount ($P < 0.05$) of protein than the nuts and coconut PBDAs. Cows' milk yogurt contained 20-33%
300 less salt ($P < 0.05$) than PBDAs. There was no information on calcium content for the nuts PBDA, but
301 cows' milk yogurt declared 39% more calcium than soya PBDA; while coconut PBDA was not
302 different to any of the other products. As with liquid milk, these differences in declared nutrient
303 composition also affected the individual nutrient intakes from yogurt and PBDAs when these were
304 calculated for each consumer age group, according to NDNS, this resulted in difference in the yogurt
305 and PBDA yogurt contribution to nutritional requirements for energy, fat, saturated fat,
306 carbohydrates, sugars, fibre, protein, salt, and calcium in each age group (Table 4).

307

308 **3.3 Cheese and cheese alternatives**

309 There were differences ($P < 0.05$) between cows' milk cheese and PBDAs in price and declared
310 energy, fat, saturated fat, carbohydrates, sugars, fibre, protein, salt, and calcium contents (Table 5).
311 Cows' milk cheese was 1.7 times cheaper than oil PBDA and 3.5 times cheaper than nuts and seeds
312 PBDA ($P < 0.05$). The label energy content was highest for cows' milk cheese, followed by oils, and
313 then nuts and seeds ($P < 0.05$). Cows' milk cheese had 14-24% more ($P < 0.05$) declared fat content
314 than PBDAs. However, declared saturated fat was higher ($P < 0.05$) for oils PBDA compared with
315 cows' milk, while nuts and seeds contained 8.2-9.0 times less saturated fat compared with both
316 other sub-categories. The oil PBDA sub-category also had 3.2-9.8 times more ($P < 0.05$) declared
317 carbohydrate, but 2.5-4.0 times less ($P < 0.05$) declared sugar, compared with the other two product
318 categories. Cows' milk cheese had less ($P < 0.05$) fibre than the other two product categories, but
319 the protein content of cows' milk cheese was higher ($P < 0.05$) compared with the nuts and seeds,
320 and oils PBDAs, respectively. Oils PBDA had a higher salt content than cows' milk cheese. Cows'
321 milk cheese had higher ($P < 0.05$) amounts of calcium (+85%) than oils PBDA. There was insufficient
322 data on vitamin D, vitamin B₁₂ and potassium to make statistical comparisons but means for oils
323 PBDA (the only one reporting these values in label) are presented in Table 5. These differences
324 affected the individual nutrient intakes from cheese and PBDAs when these were calculated for each
325 consumer age group, according to NDNS resulting in changes in their contribution to nutritional
326 requirements (Table 6).

327

328 **3.4 Cost of dairy products and alternatives**

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

339

340 **4. Discussion**

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

352

353 ***4.1 Implications for consumers' energy intake***

354 There were significant differences in the energy content within all of the milks, cheese and yogurt
355 groups which was reflected in the corresponding changes in energy intake across the lifespan.
356 Replacing cows' milk with milk from nuts/seeds would decrease energy intake. For many age groups
357 in the UK, obesity is an issue and a reduction in energy intake would be beneficial (NHS Digital,
358 2019). However, in the 1.5-3-year-old age group where milk intake reflects a significant proportion
359 of their daily energy intake, replacing cows' milk in the diet with nut/seed-based milk would
360 account for a 5.01% drop in their EAR for energy. In contrast, the declared energy content of yogurt
361 was both higher and lower depending on the alternative type, and all of the cheese alternatives

362 had less energy than cows' milk cheese. In England in 2019/20, obesity prevalence in children aged
363 4-5 years was at 9.9% in 2019/20 increasing to 21% by age 10-11 years (NHS Digital., 2020). This
364 also reflects an increase in obesity prevalence in both groups compared to data from the previous
365 year (NHS Digital., 2019). With growing levels of obesity across the population, reductions in energy
366 intake through the substitution of milk from alternative sources may seem of benefit. However,
367 with milk, cheese and yogurt accounting for a cumulative of 17.9% of the energy intake in the diet
368 of 1.5-3 years and 8.4% in children aged 4-10 years, the overall nutrient density of each product
369 line needs to be considered to ensure there are no nutritional consequences (De Matteis et al.,
370 2017).

371

372 ***4.2 Implications for consumers' protein intake***

373 One notable difference across all the categories of plant-based dairy alternatives was the
374 difference in protein content, with PBDAs generally lacking protein. Protein is essential for healthy
375 growth and development, with many people relying on dairy milk (3.49g protein/100ml) as an
376 essential protein source (Graham et al., 1996). All the plant-based milk alternatives had lower
377 declared protein content compared with cows' milk, apart from soya and pea milk in the legumes
378 category with 3.08g/100ml. When focusing on protein intake by age group, replacing dairy milk
379 with plant-based milk alternatives such as coconut resulted in a protein intake of less than 1 g/day
380 for all age groups, while the protein intake with dairy milk is between 4.1g and 8.4g depending on
381 the age group. The protein content of yogurts demonstrated a similar difference between yogurt
382 sources as liquid milk, with soya being the only plant source to come close to matching dairy milk's
383 protein content. Consumers may rightly consider cheese a high protein food source and
384 consequently assume plant-based cheese alternatives will have a similar nutritional value.
385 However, this study demonstrated that plant-based cheese alternatives only contained between
386 1.05 and 6.45 g/100 g protein (oil and nuts and seeds PBDAs, respectively). This compared poorly
387 with cheese made from cow milk, which had a declared content of 16.57g/100g of protein.

388

389 Due to anabolic resistance that limits muscle maintenance and accretion, adults over the age of
390 65 years of age are recommended to increase their protein intake to 1.0–1.2g protein/kg body
391 weight/day for a healthy older adult (over 60 years), and to 1.2–1.5g protein/kg body weight/day
392 for older people who are malnourished or at risk of malnutrition (Bauer et al., 2013; Deutz et al.,
393 2014). UK dietary reference nutrient intake values indicate that protein requirements for adults
394 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.

400

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.

420

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

428 higher in saturated fat. Coconut oil is widely used in the PBDAs as it has desirable properties, which
429 include enhanced flavour and sensory properties. However, these improved properties result in an
430 increased fat and saturated fat content, particularly lauric acid (12:0) (Lal, Sreeranjit Kumar, &
431 Indira, 2003). Despite dairy fat being relatively high in saturated fatty acids, a recent meta-analysis
432 concluded that dairy milk intake was not associated with an increased risk of mortality, CHD or CVD
433 (Guo et al., 2017). The consumption of fermented dairy products was even marginally associated
434 with a lower mortality risk, coronary heart disease (CHD) and CVD risk, with cheese outperforming
435 yogurt (Guo et al., 2017). However, another meta-analysis highlighted that the consumption of
436 coconut oil significantly increased low density lipoprotein cholesterol (Neelakantan, Seah, & van
437 Dam, 2020), which is a risk factor for CVD. This difference in response between dairy milk and
438 coconut oil could be due to differences in fatty acid profile, with dairy milk fat containing a range
439 of different saturated fatty acids (C4:0 – C18:0) as well as unsaturated fatty acids (particularly *cis*-
440 9 C18:1) which may help to mitigate increases in LDL-cholesterol. However it is more likely that
441 other nutrients within dairy products, and the matrix of products themselves (particularly cheese)
442 are possible mechanisms for the lack of effect on CVD risk factors when consuming dairy products
443 (Feeney & McKinley, 2020). These findings emphasise the importance of the whole food matrix
444 when exploring different high saturated fat products which may include the presence of
445 micronutrients.

446 447 **4.5 Implications to consumers' carbohydrate, sugar and fibre intakes**

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

454
455 Current UK public health policy focuses on reducing sugar in the diet (Scientific Advisory Committee
456 on Nutrition, 2015) and several of the plant-based milk alternatives had a lower sugar content.
457 However, UK public health guidance acknowledges the benefits of milk in the diet and hence the
458 guidance only includes the free sugars (all monosaccharides and disaccharides added to foods by
459 the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and
460 unsweetened fruit juices). Under this definition, lactose when naturally present in milk and milk

461 products is excluded (Scientific Advisory Committee on Nutrition, 2015). So, although cow's milk
462 may contribute 11.5g/day of sugar to children aged 1-3 years diet it does not contribute to free
463 sugars (which are the sugars that should be restricted according to the nutritional
464 recommendations).

465

466 Dietary fibre is known to have many health benefits including potential reduction in CVD, type 2
467 diabetes and cancer (Scientific Advisory Committee on Nutrition, 2015). Increases in fibre were seen
468 following theoretical substitution of milk and dairy products with some of the PBDA. In the 1.5-3-
469 year-old age group, the substitution of cow's milk with grain-based milk resulted in an increase of
470 1.32g of fibre per day consisting of 8.8% of the requirements for fibre in this age group. The PBDA
471 are likely to contain soluble dietary fibres. The physicochemical properties of different dietary
472 fibres (including the solubility, viscosity and fermentability) can vary greatly depending on the origin
473 and processing which can impact their functional characteristics and clinical utility (Gill, Rossi, Bajka,
474 & Whelan, 2021). Further work is required to better understand the role that fibre in PBDA can play
475 in human health, which should consider both the type and processing it has undertaken.

476

477 ***4.6 Implications to consumers micronutrient intakes***

478 The amount of calcium provided by all milk and consequently the differences in theoretical intake
479 of calcium if milk was substituted with plant-based milk alternatives were not significant. This was
480 due to plant-based milk alternatives being fortified with calcium more often than other PBDA
481 products, resulting in significant decreases in calcium in the plant-based cheese and yogurt
482 alternatives compared to dairy products. This provides a clear example of why fortification of plant-
483 based products is essential in order to match the micronutrients present in dairy (Sethi, Tyagi, &
484 Anurag, 2016). The Codex Alimentarius Commission (1994) has indicated that where a substitute
485 food is intended to replace another food which has been identified as a significant source of either
486 energy or essential nutrients in the diet, and particularly where there is a demonstrated public
487 health need, nutritional equivalence is strongly recommended. Dairy products are a vital source of
488 many vitamins and minerals; in this research nutritional information from vitamin D, B₂, B₁₂, calcium,
489 iron, iodine and potassium was collected when available. In the present work, fortification varied
490 significantly across PBDA and categories with some manufacturers exceeding expectations with
491 fortification. These products were fortified with a variety of nutrients which were not recorded in
492 this analysis, including vitamin C, omega-3 fatty acids and folic acid. These products were a very
493 small minority. It is also important to highlight that several of the PBDAs were labelled as 'organic',

494 and inline with organic regulations cannot contain any fortification despite consumers associating
495 'organic' with a more premium and healthful product (Vukasovič, 2016).

496

497 Calcium is needed for bone mineralisation which is especially important for young children, and
498 the adverse effects of consumption of PBDA in children has been well documented (Merritt et al.,
499 2020). In the current study, 43.4% of plant-based milks and 36.4% of plant-based yogurts
500 contained no calcium at all while none of the plant-based yogurt alternatives in the nuts category
501 were fortified with calcium. Although cheese is a valuable source of calcium for humans
502 (Pampaloni, Bartolini, & Brandi, 2011), 87% of all plant-based cheese alternatives were not
503 fortified with calcium. Additionally, grains, nuts and legumes are high in the absorption inhibitor
504 phytate and evidence suggests that the bioavailability of calcium from these plant-based milk
505 alternatives is therefore still lower than that of dairy milk (Gibson, Bailey, Gibbs, & Ferguson,
506 2010). Children and breastfeeding mothers are age groups that require higher amounts of calcium,
507 with children aged 1.5-3 years obtaining 85.8% of the RNI for calcium from cows' milk. In these
508 demographic groups cow's milk or fortified alternative products should always be recommended.

509

510 Vitamin B₁₂ is an essential nutrient that helps keep the body's brain, nerve and blood cells healthy
511 in addition to synthesising DNA (Vogel, Dali-Youcef, Kaltenbach, & Andres, 2009). Although milk
512 alternatives were also fortified with vitamin B₁₂, cows' milk was higher compared to all other plant-
513 based milk alternatives. From the data collected, 50% of plant-based milk alternatives, 56% of plant-
514 based yogurt alternatives and 80% of plant-based cheese alternatives were fortified with vitamin
515 B₁₂. As observed previously with calcium, none of the plant-based yogurt alternatives made with
516 nuts or plant-based cheese alternatives made with nuts and seeds were fortified with vitamin B₁₂.
517 If fortified products were consumed the ability to meet the RNI for vitamin B₁₂ was not an issue.
518 However, the lack of fortification of products means that consumers need to be aware of their
519 requirements for these key nutrients and make informed decisions when choosing PBDAs.

520

521 Iodine is an essential nutrient, required in the body to make thyroid hormones, which are used to
522 control the body's metabolism. Iodine is of particular importance for pregnant women and young
523 children as iodine deficiency has been shown to slow mental development in young children
524 (Bougma, Aboud, Harding, & Marquis, 2013). Previous studies in the UK reported iodine
525 deficiencies in the population; including 68% of schoolgirls in nine UK centres (Vanderpump et al.,
526 2011), and 22% of women 11-18 years of age and 10% of women 19-64 years of age (Miller, Spiro,

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

533

534 **4.7 Implications to household expenditure**

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

544

545 **5. Conclusion**

546 Despite PBDA products costing almost three times the price of cows' milk and dairy products,
547 which can have a considerable impact on total household expenditure, the plant-based market is
548 continuously expanding and is expected to continue to further attract consumers. This study
549 revealed that nutritional considerations should be made when making food substitutions such as
550 milk/dairy with plant-based alternatives, or excluding milk/dairy from the diet, because there is a
551 risk of nutrient deficiencies; in particular protein, calcium, iodine and vitamin B₁₂. This may affect
552 the population as a whole but would be even more impactful to consumer groups that milk is a
553 major contributor to their nutrient intakes (e.g. toddlers, children) or others that have higher
554 requirement for nutrients that milk is a good source for (e.g. pregnant women, nursing mothers).
555 Fortification provides a potential route for improving the nutritional composition and
556 consequently impact on nutritional intake of PBDAs. However, there was considerable variability
557 in the fortification of PBDAs, with some products fortifying across many micronutrients whilst a
558 large number of others are not. This is particularly true of organic PBDA products which consumers
559 may not realise are not fortified. Consumers need to be informed that PBDA products can act as

560 a practical replacement for dairy products, however they cannot act as a nutritional replacement
561 due to their large differences in nutrient composition.

562

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566

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569

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571 The authors have no conflicts of interest to declare.

572

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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		P-value ⁷
	n	Mean	n	Mean	n	Mean	n	Mean	n	Mean	n	Mean	
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±0.050 ^{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

Variable	Age group	Cow ¹		Coconut ²		Grains ³		Legumes ⁴		Nuts and Seeds ⁵		Mixed ⁶		P-value ⁷
		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	
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		P-value ⁵
	n	Mean±SE	n	Mean±SE	n	Mean±SE	n	Mean±SE	
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
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	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		P-value ⁴
	n	Mean	n	Mean	n	Mean	
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			
			% EAR/ DRV/ RNI		% EAR/ DRV/ RNI		% EAR/ DRV/ RNI	P-value
	Years	Mean±SE		Mean±SE		Mean±SE		
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
Cost (£/year)	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
	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			