Meat and dairy substitutes: nutritional content

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Background document to:
A healthy protein transition
No. 2023/19e, The Hague, 13 December 2023

Health Council of the Netherlands

Contents

1 Aim and methods

The aim of this background document is to provide an overview of recent literature on the nutritional composition of commercially available plant-based meat, dairy, and fish alternatives.
For this, a literature search for studies (up to November 2022) investigating the nutritional composition of plant-based meat, dairy, and fish alternatives was performed in PubMed. The literature search terms can be found in the appendix (Appendix A). The search yielded 819 studies. Relevant studies were selected via title and abstract screening, as well as after full-text selection.

Inclusion criteria:

- Studies are performed in Europe
- Studies include information on the nutritional content of plant-based meat, fish,- and/or dairy alternative products
- Products are commercially available products (at the time of the study)
- Studies were original studies. Review studies were screened for relevant original studies.

Based on the literature search, a total of 12 relevant individual studies were identified, including one from the Netherlands.[1-12] In addition, two reviews were found and screened for relevant studies.[13,14] This yielded two additional original studies.[15,16] Two more additional individual studies were found through other sources.[17,18] Thus, a total of 16 individual studies were included in this background document.

2 Findings

2.1 General characteristics

A total of 16 individual studies were found that investigated the nutritional composition of commercially available plant-based (PB) meat and dairy substitutes in Europe, of which one from the Netherlands. Of these, 10 studies investigated the nutritional composition of plant-based dairy alternatives (PBDAs),[7-10,12,13,17] while 4 studies looked at the nutritional composition of plant-based meat alternatives (PBMAs),[1-4] and 2 studies looked at the nutritional composition of both PBDAs and PBMAs.[5,6] The studies were published between 2017 and 2022. The majority of the studies performed a comparison of the composition of PB meat and dairy substitutes with traditional meat and dairy products. No studies were found on the nutritional composition of PB fish alternatives. Studies reported mostly on nutrients that are mandatory to report on product labels or on the nutritional content from manufacturers websites. Few studies performed laboratory analyses to assess nutritional content. Most studies compared averages of the nutritional content of PB alternatives to traditional meat or dairy products on an aggregated level. That is, the average nutritional content of a product group of PB alternatives was compared with the average nutritional content of another PB or animal product group.

Results on PBMAs are summarized in paragraph 2.2 and results on PBDAs are summarized in paragraph 2.3. An overview of individual studies can be found in Table 1 (PBMAs) and Table 2 (PBDAs).

2.2 Plant-based meat alternatives

A total of 6 individual studies were found that looked at the nutritional content of PBMAs in Europe.[1-6] The number of PBMA products included in the studies ranged from 82 to 337 products.
One out of six studies looked at the bioavailability of different nutrients in PBMAs based on laboratory analyses and did not compare PBMAs with traditional meat products.[4] The other five[1-3,5,6] out of the six studies aimed at comparing the nutritional composition of PBMAs with traditional meat products (per 100g[1-3,5,6] or per portion size[2]). These five studies obtained information on nutritional composition of PBMAs from product label information and manufacturers websites, and one of them also obtained nutritional composition information from laboratory analyses.[5] Fortification levels of the included PBMAs was reported in one of the five studies.[2] Three out of the five studies compared the nutritional composition of PBMAs and meat products of all products taken together as well as per product category,[2,3,6] and two studies only presented the results per product category.[1,5]
Four of the six individual studies provided a definition of PBMAs, where they If studies provided a definition of PDMAs, they were usually defined as products meant to mimic the taste, texture, and full consumer experience of meat. These included both vegan

and vegetarian products, but often excluded products such as tofu and tempeh. The traditional meat products in the studies included processed as well as unprocessed meat products. Different types of meat (alternative) products were included and analysed in these studies (e.g. burgers, sausage, mince, etc.).

The main protein sources used in PBMAs were soy protein, followed by pea protein. Other protein sources were wheat protein, vegetable proteins, and mycoprotein, among others.

Results from individual studies comparing all PBMAs to all meat products taken together (n=5)[1-3,5,6]:

- Macronutrient and sodium content:
  - Studies showed that PBMAs were generally higher in carbohydrates (4 out of 4 studies),[2,3,5,6] sugars (3 out of 3 studies),[3,5,6] and fibre (4 out of 4 studies),[1-3,6] compared to traditional meat products.
  - Three out of the five studies found that PBMAs were generally higher in sodium than meat products,[1,2,5] while two studies found that sodium content in PBMAs varied compared to meat products (sometimes higher, sometimes lower).[3,6]
  - Most studies found that PBMAs were generally lower in protein (4 out of 5 studies),[1,2,5,6] total fat (4 out of 5 studies),[1-3,5] and saturated fat content (5 out of 5 studies),[1-3,5,6] compared to traditional meat products.
  - Three studies showed that PBMAs were lower in energy compared to traditional meat products,[1,2,5] while the other two studies showed varied results on energy being higher or lower in PBMA products versus traditional meat products.[3,6]
- Fortification and micronutrient content:
  - One study reported on the prevalence of fortification of the included products.[2] It showed that approximately 10% of included PBMA products were fortified with nutrients such as iron and vitamin B12.
  - Three studies reported on micronutrient and mineral content of PBMAs.[2,5,6] These studies showed that PBMAs were higher in iron, vitamin B2, and in folate than traditional meat products, but lower in vitamin B12 content. One study reported on zinc content, and this study showed varied results.[5]

Results from the individual study on bioavailability of nutrients in PBMAs (n=1)[4]:

- This study found that PBMAs are not a good source of iron (due to a high phytate content and/or a low iron content found in products) and that PBMAs had low zinc bioavailability.
- This study reported on the prevalence of fortification. It showed that 11% of the PBMAs were fortified with iron.

2.3 Plant-based dairy alternatives

A total of 12 individual studies were found that looked at the nutritional content of PBDAs.[5-12,15-18] The number of PBDA products included in these studies ranged from 8 to 399 products. Eleven of the 12 studies aimed at comparing the nutritional composition of PBDAs with traditional dairy products (per 100mL or 100g) and are further described in the sub-paragraphs on findings.[5-8,10-12,15-18] The remaining study aimed at investigating the nutritional composition of PB beverages and its contribution to nutrient guidelines.[9] As this study did not make a comparison with traditional dairy products, it was not integrated in the paragraph on findings. Results of this study are incorporated in table 2.

All twelve studies looked at macronutrient composition of PBDAs, and 6 reported on micronutrient contents.[5,8-10,17,18] Studies with information on micronutrient composition mostly focussed on calcium, vitamin B12, vitamin B2, and iodine content, or in some cases vitamin D and potassium content. Furthermore, there were two of the 12 studies that looked at protein quality and digestibility aspects.[11,17]

Eleven out of 12 studies obtained information on nutritional composition from product label information and manufacturers website.[5-12,16-18] Four of these studies also analysed nutritional content (micronutrient content, and protein content or quality and bioavailability aspects) through laboratory analyses.[5,11,15,17] Nine studies provided information on fortification of the studied products.[5,7-10,15-18]

In sub-paragraphs 2.3.1 until 2.3.3 findings on the eleven studies that made a comparison between PBDAs and traditional dairy products are described. Sub-paragraph 2.3.1 is about the nutritional content of PB beverages; nine studies.[6-8,10,11,15-18] Sub-paragraph 2.3.2 is about the nutritional content of PB cheese; five studies.[5,6,8,10,12] Sub-paragraph 2.3.3 is about the nutritional content of PB yoghurt; two studies.[6,8]

2.3.1 Findings plant-based beverages

Results from individual studies comparing all **PB beverages** to all dairy milk products (n=9):[6-8,10,11,15-18]

The most used main ingredients of PB beverages were soy, oat, pea, almond, rice, coconut, cashew, other nuts, and blends of these.

- Macronutrient and sodium content:
  - PB beverages were generally lower in energy compared to cow's milk (7 out of 9 studies).[8,10,11,15-18]
  - All nine studies found that PB beverages were lower in protein content compared to cow's milk, except soy drink, which had a comparable protein content.[6-8,10,11,15-18]
  - Three out of six studies that reported on sugar content found that PB beverages were lower in sugar content compared to cow's milk.[7,8,10] while three study concluded that sugar content was lower or higher dependent on the source.[15,17,18]
  - Six out of nine studies found that PB beverages were lower in total fat compared to cow's milk,[7,8,11,15,16,18] while the other three studies found that total fat content was comparable.[6,10,17]
  - Five out of seven studies that reported on saturated fat found that PB beverages were lower in saturated fat content compared to cow's milk.[6,10,11,15,18]. One study

found that the saturated fat content was generally lower, except for coconut milk.[17] And one study found that saturated fat content of PB beverages was similar to that of cow's milk, except from coconut milk. That had a higher saturated fat content.[8]

- Four studies reported on fibre content. All four studies showed that PB beverages were higher in fibre content compared to cow's milk.[6,8,10,18]
- Four studies reported on sodium content. All four studies showed that sodium content in PB beverages was comparable to cow's milk.[6,8,10,18]
- Eight studies reported on carbohydrate content of PBDAs.[8,10,156,11,16-18]. The carbohydrate content varied,[8,15], was sometimes higher[6,17,18], and sometimes lower (depending on the source) [10,11,16] than cow's milk

- Fortification and micronutrient content:
  - Seven out of nine studies reported on fortification of PB beverages.[7,8,10,15-18] PB beverages were mostly fortified with calcium (30-100% of the products), vitamin D (50% of the products), vitamin B12 (40-100%), vitamin B2 (30-40%). Less than 5% of the products were fortified with iodine and potassium.
  - Six studies reported on calcium content. Four of these showed that PB beverages had a comparable calcium content compared to cow's milk,[7,8,16,17] while the other two showed that PB beverages contained less calcium than cow's milk.[10,18]
  - Three studies reported on vitamin B2 content in PB beverages. [8,17,18] Two of the three studies showed that PB beverages contained comparable amounts of vitamin B2 compared to cow's milk.[8,17] The other study showed that PB beverages contained less vitamin B2.[18]
  - Four studies reported on vitamin B12 content in PB beverages.[8,10,17,18] One of these studies showed that PB beverages contained comparable amounts of vitamin B12 compared to cow's milk,[17] while the other three studies showed that PB beverages had lower amounts of vitamin B12.[8,10,18]
  - Two studies reported on vitamin D content.[17,18] One showed that PB beverages had comparable vitamin D content than cow's milk,[17] while the other study showed that PB beverages contained more vitamin D than cow's milk.[18]
  - Two studies reported on iodine content.[10,17] Both these studies found that PB beverages were lower in iodine content than cow's milk.
  - One study reported on potassium content.[10] This study found that PB beverages were lower in potassium content compared to cow's milk.

2.3.2 Findings plant-based cheese

Results from individual studies comparing all **PB cheese** to all dairy cheese products (n=5):[5,6,8,10,12]

The most used main ingredients of PB cheese were nuts, seeds, and oils (coconut oil).

- Macronutrient and sodium content:

- All five studies showed that PB cheese were lower in energy and protein content and higher in carbohydrate content compared to dairy cheese.[5,6,8,10,12]
- Studies showed varied results on sugar content in PB cheese. Two out of five studies found that PB cheese was higher in sugar content compared to dairy cheese,[10,12] while two other studies found that PB cheese was lower in sugar content,[5,6] and one study found varied results.[8]
- Four out of five studies found that PB cheese was lower in total fat compared to dairy cheese,[6,8,10,12] while the remaining study found that PB cheese and dairy cheese had comparable total fat amounts.[5]
- Four out of five studies showed that PB cheese contained comparable amounts of saturated fat compared to dairy cheese [5,6,8,12] (except for PB cheese based on coconut milk [8]).One study showed higher amouts.[10]
- Four studies reported on fibre content in PB cheese. All four showed that PB cheese contain more fibre than dairy cheese.[6,8,10,12]
- Four out of five studies found that PB cheese had comparable sodium content as dairy cheese.[6,8,10,12] The remaining study found that PB cheese had higher amounts of sodium.[5]

- Fortification and micronutrient content:
  - Three studies reported on fortification of PB cheese.[5,8,10] PB cheese were mostly fortified with calcium (13-52% of PB cheese products). Two percent of the product were fortified with vitamin D and 0-37% with vitamin B12.
  - Three studies reported on calcium content. All three showed that calcium content in PB cheese was lower than in dairy cheese.[5,8,10]
  - Two studies reported on vitamin B12 content. One of these showed that vitamin B12 content in PB cheese was higher than in dairy cheese[5], while the other showed the opposite.[10]
  - One study reported on vitamin B2 content. This study found that vitamin B2 content was lower in PB cheese compared to dairy cheese.[5]
  - One study reported on iodine and potassium content. In that study iodine and potassium content were lower in PB cheese compared to dairy cheese.[10]
  - There were no studies that reported on the comparison of the vitamin D content of PB cheese versus dairy cheese.

2.3.3 Findings plant-based yogurt

Results from individual studies comparing all **PB yogurt** to all dairy yogurt products (n=2):[6,8]

The most used main ingredients of PB yogurt were coconut, nuts, and soy.

- Macronutrient composition:
  - Both studies showed that PB yogurts were lower in sugars, saturated fat, and protein, higher in fibre, and comparable in sodium content compared to dairy yogurt.[6,8]

  - The two studies showed different results regarding energy, carbohydrate, and total fat content. One study showed that PB yogurts were lower in energy, carbohydrate, and total fat content compared to dairy yogurt,[6] while the other study showed that PB yogurts varied in energy and carbohydrate content (sometimes higher sometimes lower than dairy yogurt), but were higher in total fat content compared to dairy yogurt.[8]
- Fortification and micronutrient composition:
  - One study reported on fortification of PB yogurt.[8] This study showed that around 60% of PB yogurt products were fortified with calcium, vitamin D, and vitamin B12, and around 30% with vitamin B2.
  - One study reported on calcium content. In that study PB yogurt had comparable amounts of calcium compared to dairy yogurt.[8]
  - Both studies did not report on the comparison of vitamin D, vitamin B2, vitamin B12, iodine, and potassium content of PB yogurt versus dairy yogurt.

2.4 General discussion points

- Since this is an emerging field, the commercial availability of PB alternatives may change rapidly over time and is variable across regions, the present data may not be representative for the current commercial availability in Europe, or even more so, the Netherlands.
- Since most studies compared the nutritional content of PB meat and dairy products to the traditional meat or dairy products per 100g or 100mL, the actual of nutrients may be underestimated or overestimated if commercially available portions of PB alternatives are different than portion sizes of traditional products.
- The studies comparing the nutritional content of PBMAs to traditional meat products included both processed and unprocessed traditional meat products, which impairs the comparison with PBMAs. Generally, processed meat already contains salt when sold, whereas the consumer may add salt to unprocessed meat during cooking.

Table 1 Characteristics and results of individual studies on the nutritional composition of plant-based meat alternatives

Author, year and country	Aim of study	Methods	Meat products	PBMAs (main protein sources and fortification)	Results and conclusion
Alessandrini et al. (2021),[1] UK	1) To compare the nutrient content of PBMAs with the nutrient content of their corresponding meat products. 2) To compare the nutritional profile of PBMA products available in UK retailers using the UK's Nutrient Profiling Model and FoP labelling criteria and compare it with the nutritional profile of corresponding meat products. 3) To compare the salt content of PBM products with the current UK salt reduction targets.	Information on nutritional composition obtained from product labels and information on manufacturers website.	226 processed and unprocessed meat products (sausages, burgers, plain poultry, breaded poultry, mince, meatballs).	168 PBMAs (6 categories: sausages, burgers, plain poultry, breaded poultry, mince, meatballs) *Main protein sources*: NR *Fortification*: NR in study	*PBMAs vs. meat (per 100g)*: • Fibre and salt were significantly higher in most (5-6 out of 6) PBM categories compared to equivalent meat products. • Overall, PBM categories had around four times more fibre than their corresponding meat products. • Energy (kcal), protein, and total and, saturated fat were significantly lower in most (4-5 out of 6) PBM categories compared to equivalent meat products. • Overall, PBMAs had less than half the amount of saturated fat compared to meat products. • Wide variation in energy density and nutrient content of all PBMA and meat categories. (especially in salt).

Author, year and country	Aim of study	Methods	Meat products	PBMAs (main protein sources and fortification)	Results and conclusion
Bryngelsson et al. (2022),[2] Sweden	1) To assess the nutritional characteristic of PBMAs available on the Swedish retail market. 2) To provide an overview of the PBMAs nutritional profile and evaluate their nutritional content in relation to the Nordic Nutritional Recommendations (NNR) and compare them to meat-based products.	Information on nutritional composition obtained from product labels and information on manufacturers website.	10 meat products (similar to PBMAs). Mostly processed meat.	142 PBMAs from 24 different brands (10 categories: bacon, ball, bite/fillet, burger, cold cut, mince, nugget, sausage, schnitzel and others). *Main protein sources*: soy and pea *Fortification*: 14 products were fortified with one or several nutrients: iron (n=12), vitamin B12 (n=8), vitamin B3 (n=5), vitamin B1 (n=5), vitamin B2 (n=4), vitamin D2 (n=1). Non-mandatory nutrients were not declared on all products (e.g. fibre was most frequently reported n=96, iron was reported on 18 products, and vitamin B12 on 8 products). All products declaring iron content had higher iron content than meat products. Info on bioavailable iron not provided on labels and not analysed in study.	*PBMAs vs. meat (per 100g)*: • PBMAs were on average significantly higher in carbohydrate, fibre, iron, folate, and vitamin B2. • PBMAs contained slightly more salt than meat products, but this difference was not significant. • PBMAs were on average significantly lower in saturated fat. • PBMAs contained slightly less energy (kcal), less protein, less total fat, and less vitamin B12 than meat. However, these differences were not significant. Mostly similar. • Per product category: Results varied when looking at the different categories of PBMAs. • Data on vitamins and minerals were very limited but indicated that PBMAs are generally higher in iron (both fortified and non-fortified) and folate (all non-fortified, soy-based). Vitamin B12 content varied between product categories. • Results per portion size: similar results *Nutritional claims*: 97% of the PBMAs had a claim on source of protein; 77% had a claim on high in protein; 71% had a claim low in saturated fat; 1 product met the criteria to claim ‘low in salt’; 83% had a claim ‘source of fibre’, and 47% had a claim high in fibre. Of the PBMAs which reported their content of iron and vitamin B12, all met the nutrient criteria for claiming to be a source of iron or vitamin B12.

Author, year and country	Aim of study	Methods	Meat products	PBMAs (main protein sources and fortification)	Results and conclusion
Cutroneo et al. (2022),[3] Italy	1) To investigate the nutritional quality of meat substitutes by comparing to meat products, determining the presence/absence of nutrition or health claim and organic declarations, as well as the Nutri-Score.	Information on nutritional composition obtained from product labels and information on manufacturers website.	269 processed and unprocessed meat counterparts (steaks, burgers, meatballs, and cutlets).	269 PBMAs (steaks, burgers, meatballs, and cutlets). *Main ingredients*: mostly pulses, also vegetables, (pseudo)cereals, and oils *Fortification*: NR in study	*PBMAs vs. meat (per 100g)*: • PBMAs were higher in carbohydrate, sugars, and fibre content than meat controls • Most PBMA product categories contained more protein than their meat counterparts (except burgers and meatballs) • Most PBMA product categories had less total and saturated fat • Energy content varied between product categories, with some containing more energy and some less than their meat counterparts • Salt content was similar between PBMAs and meat counterparts, except PB cutlets which had less salt than cured meats Health claims: • More than 70% of the PBMAs had a nutrition claim related to the protein content. Less than 4% had vitamin- and mineral related claims.
Mayer Labba et al. (2022),[4] [a] Sweden	1) To examine the nutritional composition, total phenolic content and levels of mineral-absorption-inhibiting phytate, and estimate the iron and zinc bioavailability of meat substitutes commonly available on the Swedish market. The aim of the study was to investigate if there are nutritional limitations connected to including meat substitutes in the diet.	Nutritional content of meat substitutes was analysed. Bioavailability of iron and zinc was estimated based on the phytate:mineral molar ratio.	NA: PBMAs were not compared to traditional meat products.	44 PBMAs *Main protein source categories*: Soy protein, pea protein, soy and wheat protein, whole bean, cheese, mycoprotein, other, and tempeh. *Fortification*: - 11% of the PBMAs were fortified with iron. • -60% of all PBMAs had iron contents high enough to have a nutrition claim of iron according to EU regulations.	*Nutritional composition and bioavailability of iron and zinc*: • PBMAs could not be regarded as a good source of iron due to very high content of phytate and/or low content of iron. • Significant differences depending on the main protein source were found for both iron and zinc content, as well as for phytate. Soy had the highest iron content, followed by pea protein, and mycoprotein the lowest. • PBMAs showed low bioavailability of zinc, except mycoprotein products (due to low content of phytate). • Large variations in nutritional composition were found: salt and saturated fat were high in certain products, while other products were more in line with nutritional recommendations. • Large variations in protein content within categories based on protein source. Between categories protein content was similar (on average). • Amino acid profiles seemed to be affected by processing methods.

Author, year and country	Aim of study	Methods	Meat products	PBMAs (main protein sources and fortification)	Results and conclusion
Pointke & Pawekzik (2022),[5] Germany	1) To provide an overview of the PBMAs and PB cheese alternatives available in online stores in 2019 and 2021 2) To characterize their nutrient composition, focusing on micronutrients compared to animal-based products, as well as the newly approved Nutri-Score as an FOPL	Information on nutritional composition from almost exclusively products available on the European market obtained from online product label data. Vitamin and mineral content of a sample of products was analysed in laboratory.	300 meat products (counterparts to PBMAs)	337 PBMAs (categorized into hot products e.g. fillet, steak, burger, and cold products e.g. salami, sausage) *Main protein sources*: mostly soy protein, followed by wheat protein, and pea protein *Fortification*: NR in study	*PBMAs vs. traditional meat products (per 100g)*: • PBMAs were generally higher in carbohydrates, sugars, salt, and iron • PBMAs were generally lower in energy, protein, total and saturated fat, and zinc • Variation in nutrient content among products (especially in salt, total fat, saturated fat, and protein) • Daily requirements for iron, calcium, phosphorus, magnesium, copper, and sodium were better covered by PBMAs than by animal-based products (based on laboratory analyses) • Daily requirements for vitamin B1, B2, B12, B3, and B5 were covered by PB alternatives to an equal or lesser extent than by animal-based products. Requirements for vitamin B6, E, and K, are met to an equal or higher extent by PBMAs. • Daily requirements for vitamin B2 are covered better by PBMAs than by PB cheese, but PB cheese cover daily requirements of vitamin B12 better than PBMAs. • There was an increase of 57% in the number of hot PBMA products and of 110% in the number of cold PBMA products since 2019 (to 2021)
Tonheim et al. (2022),[6] Norway	1) To evaluate the macronutrient composition of meat and dairy substitutes available on the Norwegian market, and compare them with their animal-based analogues.	Information on nutritional composition obtained from online product label data.	28 healthiest meat products (with Keyhole label), and 70 regular meat products. Categorized into burgers, sausages, mince, meatballs, nuggets, schnitzels, and cold cuts.	82 PBMAs (burgers, sausages, mince, meatballs, nuggets, schnitzels, and cold cuts) *Main ingredients*: NR *Fortification*: NR	*PBMAs vs. Keyhole meat products and vs. regular meat products (per 100g)*: • PBMAs had more fibre, carbohydrates, and sugars than Keyhole and regular meat products • PBMAs were 2x lower in saturated fat than Keyhole meat products, and 6x lower than regular meat products • PBMAs were lower in protein than Keyhole and regular meat products • PBMAs were higher in energy and total fat than Keyhole products but lower in energy and total fat than regular products • PBMAs were similar in salt content, except for mince, which contained more salt

Abbreviations: FoP: front of package; FOPL; front of package label; NA: not applicable; NR: not reported; PBM: plant-based meat; PBMA: plant-based meat alternative; TVP: textured vegetable protein; UK: United Kingdom; USA: United States of America

[a] The study by Mayer Labba et al. (2022) was funded by the Bertebos Foundation, Swedish Research Council FORMAS, and the Region of Västra Götaland

Table 2 Characteristics and results of individual studies on the nutritional composition of plant-based dairy alternatives

Author, year and country	Aim of study	Methods	Meat products	PBMAs (main protein sources and fortification)	Results and conclusion
Angelino et al. (2020),[7] Italy	1) To investigate the nutrition facts of PB beverages as declared on their food labels. 2) To compare the energy and nutrient content of the products, classified for the type of vegetable source as well as for the presence or absence of nutrition claims (NC) or health claims (HC), or for being organic or conventional beverages. 3) To compare the nutritional values of PB beverages to those of cow milk.	Information on nutritional composition obtained from product labels and information on manufacturers website.	Cow's milk (whole and skimmed)	330 PB beverages *Main types*: mostly soy and rice drinks, followed by blended drinks, oat, and almond drinks. *Fortification*: 33% of PB beverages contained an amount of (added) calcium comparable to milk.	*PB beverages vs. cow's milk (whole and skimmed) (per 100mL)*: • *Energy*: 15% of PB products had an energy content lower than that of skimmed milk, 72% fell between the energy value of skimmed and regular milk, and 13% had a higher content of regular milk. • *Fat*: No PB beverages had a total fat content lower than skimmed milk, while 3% had a total fat amount higher than the regular milk. • *Sugar*: the sugar content of skimmed and regular milk is quite similar, thus only a few products (3%) fell within this range, while 73% had a sugar content lower than regular milk. • *Protein*: the protein amount of skimmed and regular milk is very similar thus only 7% of products fell within the reference values, while 88% of PB beverages had a lower content (except soy drinks). • Median energy content differed among product types (oat, almond, rice, soy, blends, others). Nutrient contents among different product types differed as well, except for salt. • Median calcium levels of products with a claim of 'source of calcium' were very similar to those found in whole and skimmed milk, while calcium amount of products without this nutrition claim was unknown (not reported on nutritional labels).

Author, year and country	Aim of study	Methods	Meat products	PBMAs (main protein sources and fortification)	Results and conclusion
Clegg et al. (2021),[8] UK	1) To examine the label nutrient composition of PBDAs (milk, yogurt and cheese alternatives) available in the UK market and compare these to equivalent dairy products (in terms of nutritional content as well as price) 2) To 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.	Information on nutritional composition obtained from information on manufacturers website.	• 136 milk products from cow (skimmed, semi-skimmed, and whole milk) • 78 yogurts (from cow's milk) • 36 cheeses (from cow's milk)	• 136 PB beverages • 109 PB cheeses • 55 PB yogurts *Main types*: • *PB beverages*: coconut-based, grains (oat, rice, and rice-quinoa), legumes (soya and pea), nuts and seeds (almond, hazelnut, cashew, tiger nut, walnut, and almond-hazelnut), mixed • *PB cheeses*: nuts and seeds (almond, sunflower, and cashew), oils (coconut oil, soybean oil, and palm fruit oil) • *PB yogurts*: coconut, nuts (cashew and almond nuts) and soya-based *Fortification*: • *PB beverages*: 57% were fortified with calcium, 50% with vitamin D and vitamin B12, 32% with vitamin B2, and 4% with iodine and potassium. • *PB cheeses*: 13% were fortified with calcium, 2% with vitamin D and 37% with vitamin B12. • *PB yogurts*: 63% fortified with calcium, 58% with vitamin D, 56% with vitamin B12, and 27% with vitamin B2.	*PB beverage, yogurt and cheese alternatives vs. dairy milk, yogurt and cheese (per 100 mL or g)*: • Price: Cow's milk, yogurt and cheese were all substantially (2x) cheaper than all PBDAs. • Energy intake: significant differences in energy content within all the milks, cheese and yogurt groups (some more and some less than the dairy counterpart). • Protein: PBDAs generally contained less protein than their dairy counterpart, except for soya and pea milk. • Total and saturated fat: there were no differences between milk sources and plant-based dairy alternatives for fat content. However, coconut milk, yogurt and cheese were much higher in saturated fat than their plant-based dairy alternatives. • Carbohydrate: there were no consistent patterns when comparing carbohydrate content of PB beverage and yogurt alternatives with milk and yogurt. However, PB cheese alternatives had higher carbohydrate content across all categories compared with dairy cheese. • Sugar: several PB beverages had lower sugar content. • Fibre: PBDAs contained more fibre in general • Calcium: no significant differences between PBDAs and their dairy counterparts (due to fortification). • Vitamin B12: despite fortification, cow's milk had higher levels of vitamin B12 compared to PB beverages.

Author, year and country	Aim of study	Methods	Meat products	PBMAs (main protein sources and fortification)	Results and conclusion
Craig & Fresán (2021),[9] USA, Australia, Western Europe[b]	1) To conduct a cross-sectional survey of PB non-dairy beverages to assess the nutritional content (levels of protein, sodium, saturated fat, sugar, and dietary fibre) and health profile of the PB beverages. 2) The fortification level of calcium, vitamins D and B12 for each beverage was determined. In addition, the chemical form of calcium fortification was documented.	Information on nutritional composition obtained from product labels and information on manufacturers website.	NA: PB beverages were not compared to cow's milk	148 PB beverages *Main types*: Almond, followed by soy, oats, rice, coconut, cashew, pea protein, hazelnuts, macadamia, flax, quinoa, hemp, followed by mixtures *Percentage of beverages that are fortified and median values used in fortification*: [a] Calcium (63%, median value 30% DV/ serving), vitamin D (50%, median value 9% DV/ serving), vitamin B12 (40%, median value 36.5% DV/ serving) *Extra info*: DV of calcium is 1300 mg, DV of vitamin D is 20 mcg, DV of vitamin B12 is 2.4 mcg	*Percentage of non-dairy beverages meeting the suggested nutrient guideline per serving (based on the USDA Dietary guidelines)*: [b] at least 5 g protein (20%), no more than 1 g saturated fat (88%), no more than 5 g total sugars (43%), no more than 120 calories (75%), no more than 115 mg sodium (73%), at least 1.5 g dietary fibre (28%). • Protein content varied per product. *Extra info*: Serving sizes: 240 mL for USA, 250 mL for Australia and Europe.

Author, year and country	Aim of study	Methods	Meat products	PBMAs (main protein sources and fortification)	Results and conclusion
Fresán & Rippin (2021),[12] Spain	1) To evaluate the nutritional composition of the PB cheese options available in Spanish supermarkets, and how they compare with dairy cheese.	Information on nutritional composition obtained from product labels and information on manufacturers website.	Data on generic cheese (from Spanish food composition database)	40 PB cheese alternatives *Main ingredients*: mostly coconut oil, followed by cashew nuts and tofu-based. *Fortification*: NR in study	*PB cheese alternatives vs. dairy cheese (per 100g)*: • PB cheese alternatives were higher in carbohydrate, and fibre content. • PB cheese alternatives were lower in calories, protein, and total fat content. There were no significant differences in saturated fat and salt content between PB cheese alternatives and dairy cheese. • Coconut-oil based cheese alternatives could not be considered as healthy foods. They were similar to dairy cheese in nutritional composition, but contained less protein. Cashew nut- and tofu-based showed a healthier nutritional profile. They were less caloric, lower in total fat and saturated fat, and salt, but higher in fibre. Cashew nut-based products had more sugars and less protein, whereas protein content was similar between tofu-based products and dairy cheese. • No micronutrient data provided

Author, year and country	Aim of study	Methods	Meat products	PBMAs (main protein sources and fortification)	Results and conclusion
Glover et al. (2022),[10] UK	1) To compare the price and nutritional composition of dairy and non-dairy milks and cheeses in UK supermarkets	Information on nutritional composition obtained from product labels and information on manufacturers website. Food composition database was used for missing data.	7 dairy milks (skimmed, semi-skimmed, and whole milk) and 10 dairy cheeses (cheddar).	57 PB beverages and 25 PB cheese alternatives. *Main types*: • *Milk alternatives* : soy, oat, almond, and coconut. • *Cheese alternatives*: cheddar cheese alternatives. *Fortification*: All PB beverages were fortified with calcium and vitamin B12. However, no PB beverages were fortified with iodine. A total of 52% of PB cheeses were fortified with calcium. PB cheeses were not fortified with other nutrients such as potassium, iodine or vitamin B12.	*PB beverages vs. dairy milk (per 100mL)*: • PB beverages were generally lower in energy, carbohydrates (except oat drink) and sugars compared to cow's milk, but higher in fibre. • Protein was significantly lower for all PB beverages compared to dairy milk except for soy milk. • PB beverages had similar sodium and fat content compared to cow's milk, but lower saturated fat content • PB beverages were lower in calcium, iodine, potassium, and vitamin B12 compared to dairy milk • Median prices were similar between PB beverages and dairy milks. *PB cheese alternatives vs. dairy cheeses (per 100g)*: • PB cheese alternatives were lower in energy, protein, total fat, calcium, iodine, potassium, and vitamin B12 than dairy cheeses. • PB cheese was higher in fibre, carbohydrate, sugars, and saturated fat content • PB cheese was similar in sodium content • PB cheese alternatives were significantly more expensive than dairy cheeses.
Jeske, Zannini & Arendt (2017),[15] Ireland	1) To give an overview on physicochemical and glycaemic properties of different PB milk alternatives.	Nutritional composition (protein, fat, sugars) was assessed through laboratory analyses.	Cow's milk	17 PB milk substitutes *Main types*: soy, almond, coconut, cashew, hemp, macadamia, oat, quinoa, and rice drinks. *Fortification*: 7 (41%) of the PB milk substitutes were fortified with calcium.	*PB milk substitutes vs. cow's milk (per 100g)*: • PB milk substitutes were generally lower in energy and protein content than cow's milk. Soya milk however was comparable in protein content. • PB milk substitutes were higher or lower in carbohydrates and sugars than cow's milk, dependent on the source. • Most PB milk substitutes were lower in total fat and saturated fat content than cow's milk

Author, year and country	Aim of study	Methods	Meat products	PBMAs (main protein sources and fortification)	Results and conclusion
Martínez-Padilla et al. (2020),[11] Denmark	1) To investigate commercially available PB beverage alternatives, with a focus on their fatty acid profiles, as well as in vitro protein digestibility, to obtain a more detailed view of the nutritional values of different PB beverage alternatives in comparison to cow's milk.	Information on nutritional composition obtained from online product label data. Fatty acid composition, as well as protein digestibility of the products was analysed in laboratory.	Cow's milk (whole)	8 PB beverages *Main types*: almond, coconut, hazelnut, hemp, oat, quinoa, rice, and soy drinks. *Fortification*: NR	*PB beverages vs. cow's milk (per 100 mL)*: • All PB beverages were lower in energy, total fat, and saturated fat compared to cow's milk. • Most PB beverages were lower in protein (except soy drink), and carbohydrates (except rice and oat drink) compared to cow's milk. • This study only reported on macronutrient composition of PB beverages vs. cow's milk. *Fatty acid composition*: • PB beverages showed a significant variability in terms of fatty acids depending on the plant source. • Most PB beverages predominantly contained oleic acid and linoleic acid, except coconut drink. Coconut drink contained the highest amount of saturated fatty acids. • Hemp drink was found as the product with the highest nutritional value with respect to the fatty acids, due to the ratio of omega 6 to omega 3 ratio, which was within the recommended ratio for a healthy diet.

Author, year and country	Aim of study	Methods	Meat products	PBMAs (main protein sources and fortification)	Results and conclusion
Pointke & Pawekzik (2022),[5] Germany	1) To provide an overview of the PB beverage alternatives and PB cheese alternatives available in online stores in 2019 and 2021 2) To characterize their nutrient composition, focusing on micronutrients compared to animal-based products, as well as the newly approved Nutri-Score as an FOPL	Information on nutritional composition obtained from online product label data. Vitamin and mineral content of a sample of products was analysed in laboratory.	141 cheese products (counterparts to PBDAs)	123 PB cheese alternatives in 2021 *Main ingredients*: mostly coconut oil, as well as palm oil, cashew nuts, and almonds. *Fortification*: Two alternative cheese products (2%) were supplemented with vitamin B12.	*PB cheese alternatives vs. dairy cheese products (per 100g)*: • PB cheese alternatives were generally higher in carbohydrate, salt, and iron • PB cheese alternatives were generally lower in energy, sugars, protein, calcium and zinc • PB cheese alternatives were similar in total and saturated fat content • Variation in nutrient content among products (especially of fat, saturated fat, and salt). • Most PB cheeses met the daily nutritional recommendations for single micronutrients • Daily requirements for iron, magnesium, copper, and sodium were better covered by PB cheese products than by animal-based products (based on laboratory analyses) • Daily requirements for vitamin B1, B3, and B5, and calcium were covered by PB alternatives to an equal or lesser extent than by animal-based products. Requirements for vitamin B6, E, and K, are met to an equal or higher extent by PBMAs. • Daily requirements for vitamin B2 are covered better by PBMAs than by PB cheese, but PB cheese cover daily requirements of vitamin B12 better than PBMAs. • There was an increase of 89% in the number of PB cheese alternative products since 2019 (to 2021)

Author, year and country	Aim of study	Methods	Meat products	PBMAs (main protein sources and fortification)	Results and conclusion
Singh-Povel et al. (2022),[17 c] the Nether-lands[d]	1) To compare the nutritional composition of cow's milk and several PB beverages with a focus on protein and essential amino acid content. Furthermore, insight in the prevalence of fortification practices for the different plant-based drinks will be generated. 2) To determine the ratio of essential amino acids to greenhouse gas emission and price for cow's milk and for PB beverages.	Information on nutritional composition obtained from product label data (from Innova Database). Protein quantity and quality analyses were performed in laboratory.	Semi-skimmed cow's milk	399 products in total[d] (the Netherlands: 26 brands of PB beverages, and 13 brands of semi-skimmed milk) *Main types*: soy, oat, almond, coconut, and rice drinks (regular, organic, and unsweetened varieties were included) *Fortification*: On average, 70% of PB beverages were fortified with calcium and vitamin B12, 55% with vitamin D, 40% with vitamin B2, and 0% with iodine. All soy drinks were fortified with calcium, vitamin B2, vitamin B12, and 75% with vitamin D. Organic PB beverages were unfortified, except for calcium, where 50% of soy drinks were fortified.	*PB beverages vs. semi-skimmed cow's milk (per 100g)*: • PB beverages were lower in protein content compared to cow's milk. Only soy drink was similar in protein content. • Protein content of PB beverages measured through laboratory analyses was similar to those found on the labels. • Energy content of PB beverages was in general lower than in cow's milk (except oat and rice drink). • Fat content of PB beverages was comparable to cow's milk. • Saturated fat content was lower in PB beverages compared to cow's milk, except for coconut drink, which was higher than cow's milk. • Total carbohydrate and sugar content varied per PB beverage type, but was on average higher than in cow's milk. • PB beverages that were fortified with nutrients such as calcium, vitamin B2, vitamin B12, and vitamin D reached similar nutrient content as found in cow's milk. *Regular vs. organic vs. unsweetened types*: • Macronutrient composition of the regular and organic varieties of all products were comparable • Unsweetened PB beverages had no or very little sugar, and were lower in energy than their respective regular types. *Protein quality*: One glass (200 mL) of cow's milk contained at least 24% of the WHO requirements for each of the essential amino acids. Contribution to the required level of PB beverages was significantly lower: 14.2% for soy drink, and less than 3% for the rest of the PB beverages.

Author, year and country	Aim of study	Methods	Meat products	PBMAs (main protein sources and fortification)	Results and conclusion
Sousa & Kopf-Bolanz (2017),[18] Switzerland	1) To assess the nutrient contents of cow's milk and of non-dairy plant-based beverages available in Switzerland, and compare them to each other and to the requirements of different population subgroups. The focus was placed on protein content, composition, and bioavailability.	Information on nutritional composition obtained from online product label data.	Cow's milk	45 PB beverages *Main types*: soy, oat, spelt, coconut, rice, quinoa, and almond *Fortification*: 33% of the PB beverages were fortified with calcium, and 14% with one or more vitamins (e.g. vitamin D, B2 or B12).	*PB beverages vs. cow's milk (per serving: 200mL)*: • Most PB beverages contained less energy, total fat, less saturated fat, and calcium than cow's milk. • PB beverages contained less protein (less than half the amount) than cow's milk (except soy drink, which had more) • Most PB beverages contained more carbohydrates and fibre than cow's milk. • Salt content was similar in PB beverages compared to cow's milk. • Sugar content was higher in some PB beverages compared to cow's milk (rice, quinoa, spelt, and oat drinks), but not in the others. • There was a large variation between product types in nutrient content • Very few products gave information on calcium and vitamins D, B2, and B12. • Fortification: when the PB beverages were fortified, the amounts were equivalent to the amounts of vitamins and calcium present in cow's milk. • Based on literature review, this study found that cow's milk protein had higher amounts of essential amino acids compared to plant-based proteins. Cow's milk also had a higher DIAAS and PDCAAS score.

Author, year and country	Aim of study	Methods	Meat products	PBMAs (main protein sources and fortification)	Results and conclusion
Tonheim et al. (2022),[6] Norway	1) To evaluate the macronutrient composition of meat and dairy substitutes available on the Norwegian market, and compare them with their animal-based analogues.	Information on nutritional composition obtained from online product label data.	15 healthiest dairy products (with Keyhole label), and 90 regular dairy products. Categorized into cheese, creams/crème fraiche, flavoured drinks/iced coffees, milk (unflavoured drinks), ice creams, and yogurts.	162 PBDAs (cheese, creams/crème fraiche, flavoured drinks/iced coffees, milk (unflavoured drinks), ice creams, and yogurts) *Main ingredients*: NR *Fortification*: NR	*PB beverage, cheese, and yoghurt alternatives vs. Keyhole dairy products and vs. regular dairy products (per 100g)*: • PB beverages and cheese were generally higher in carbohydrate content than Keyhole and regular products. PB yoghurt was similar in carbohydrate content to dairy yoghurt. • PB beverages and cheese were 7x lower in protein content than Keyhole products and 23x lower than regular dairy products. PB yoghurts were also lower in protein than dairy yoghurt. • PB cheese was higher in saturated fat than Keyhole products, but no difference was found compared to regular products. • PB beverage and Keyhole products were lower in saturated fat compared to regular products • Salt content was only higher in PB cheese compared to Keyhole and regular products.

Abbreviations: DIAAS: digestible indispensable amino acid score; DRV: dietary reference values; DV: daily value; NA: not applicable; NR: not reported; PB: plant-based; PBDA: plant-based dairy alternative; PDCAAS: protein digestibility-corrected amino acid score; RDI: recommended dietary intake; UK: United Kingdom; USA: United States of America; USDA: United States Department of Agriculture; y: years

[a] Funding sources and potential conflicts of interest were not reported

[b] The presented results are for the subgroup of plant-based milk alternatives analysed in Europe (n=40 products)

[c] The study by Singh-Povel et al. (2022) was funded by FrieslandCampina for the protein (quality) measurement and LCA calculations.

[d] The study by Singh-Povel et al. (2022) included data of the Netherlands, Belgium, Germany, Italy, Spain, and Sweden. These included a total of 399 products. In the table, the results and data are presented for the Netherlands, unless stated otherwise.

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4 Appendix A: Literature search

Literature search voor individuele studies over vlees, vis- en zuivelvervangers

PubMed:

(“plant based meat”[tiab] OR “plant-based meat”[tiab] OR “meat alternative*”[tiab] OR “meat substitut*”[tiab] OR “meat replace*”[tiab] OR “meat analog*”[tiab]

OR “plant based fish”[tiab] OR “plant-based fish”[tiab] OR “fish alternative*”[tiab] OR “fish substitut*”[tiab] OR “fish replace*”[tiab] OR “fish analog*”[tiab]

OR “plant based dairy”[tiab] OR “plant-based dairy”[tiab] OR “dairy alternative*”[tiab] OR “dairy substitut*”[tiab] OR “dairy replace*”[tiab] OR “dairy analog*”[tiab]

OR “plant based milk”[tiab] OR “plant-based milk”[tiab] OR “milk alternative*”[tiab] OR “milk substitut*”[tiab] OR “milk replace*”[tiab] OR “milk analog*”[tiab]

OR “plant based butter”[tiab] OR “plant-based butter”[tiab] OR “butter alternative*”[tiab] OR “butter substitut*”[tiab] OR “butter replace*”[tiab] OR “butter analog*”[tiab]

OR “plant based yoghurt”[tiab] OR “plant-based yoghurt”[tiab] OR “yoghurt alternative*”[tiab] OR “yoghurt substitut*”[tiab] OR “yoghurt replace*”[tiab] OR “yoghurt analog*”[tiab]

OR “plant based cheese”[tiab] OR “plant-based cheese”[tiab] OR “cheese alternative*”[tiab] OR “cheese substitut*”[tiab] OR “cheese replace*”[tiab] OR “cheese analog*”[tiab])

AND (Proteins[Mesh] OR protein*[tiab])

NOT ((kidney diseases[MesH] OR “kidney disease”[tiab]) OR (infant formula[MesH] OR “infant formula”[tiab]))

NOT calves[tiab]

819 hits op 11-11-2022

The Health Council of the Netherlands, established in 1902, is an independent scientific advisory body. Its remit is “to advise the government and Parliament on the current level of knowledge with respect to public health issues and health (services) research...” (Section 22, Health Act).
The Health Council receives most requests for advice from the Ministers of Health, Welfare and Sport, Infrastructure and Water Management, Social Affairs and Employment, and Agriculture, Nature and Food Quality. The Council can publish advisory reports on its own initiative. It usually does this in order to ask attention for developments or trends that are thought to be relevant to government policy.
Most Health Council reports are prepared by multidisciplinary committees of Dutch or, sometimes, foreign experts, appointed in a personal capacity. The reports are available to the public.

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