<u>Supplementary Information 1</u> to the publication "Environmental and nutritional implications of replacing meat and dairy with alternatives"

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Content

1 Supplementary Method

1.1 Product grouping

Both the alternative products and the reference products are grouped. For the reference products, the groups represent the most common products on the Swiss market [1, 2]. Butter is not considered, as margarine is a well-established product on the market since over 100 years that can be used as a replacement. The alternative products are grouped based on their main ingredients and processing methods. These two characteristics were selected since they influence both the environmental impacts as well as the nutrient contents of the products, while simultaneously providing a detailed enough differentiation to allow a thorough analysis. Only processed products were included in the analysis. While unprocessed foods such as legumes can be consumed with the intention of replacing meat or dairy, they are not specifically designed as substitutes for animal products and hence do not align with the study's objective. Supplementary Table 1 provides examples for each product group investigated. Biochemical processing approaches such as coagulation and fermentation are mostly associated to traditional alternative products such as tofu and tempeh, which were kept in a separate group. Falafel was also kept as a separate traditional product group, since it is a commonly known and consumed product. Moreover, its processing involves much simpler techniques compared to ultra-high processed alternatives. While many novel food products include fermentation processing steps (www.gfieurope.org/fermentation), only few are currently on the market. Among these, yoghurt alternatives are particularly relevant. Unfortunately, the available data for yoghurt alternatives did not allow for differentiation between different processing approaches, since the metadata often lacked detailed process descriptions.

Supplementary Table 1: Examples of products considered in each of the alternative and reference product groups.

Product group	**Exemplary products**
Alternative products	
Plant-based (mechanically texturised), *average*	In addition to the groups below: patties based on other vegetables and/or cereals such as beetroots, cabbage, kale, rice and rye
Soy-based (mechanically texturised)	Soy-based meatballs, patties, steaks, nuggets, schnitzel, sausages, mince, pieces and cold cuts
Wheat-based (mechanically texturised)	Seitan and wheat-based meatballs, patties, steaks, nuggets, sausages, pieces and ham
Legume-based (excl. soy, mechanically texturised)	Legume-based meatballs and patties
Falafel	Falafel and falafel patties
Tofu (and tempeh)	Raw and smoked tofu, and tempeh
Insect-based	Insect patties and whole insects
Mycoprotein-based (Quorn®)	Mycoprotein-based pieces
Milk alternatives, *average*	In addition to the groups below: cashew, chestnut, coconut and rice drinks
Soy drink	Sweetened and unsweetened, fortified and non-fortified soy drink
Oat drink	Sweetened and unsweetened, fortified and non-fortified oat drink

Almond drink	Sweetened and unsweetened, fortified and non-fortified almond drink
Yoghurt alternatives	Sweetened and unsweetened, fortified and non-fortified soy yoghurt with and without fruits
Cheese alternatives	Alternatives to hard and soft cheese based on coconut, cashew and soy
Cream alternatives	Oat-, soy- and coconut-based cream
Reference products	
Beef (unprocessed)	Raw beef without offal
Pork (unprocessed)	Raw pork without offal
Poultry (unprocessed)	Raw poultry without offal
Veal (unprocessed)	Raw veal without offal
Beef (processed)	Dry meat and sausages
Pork (processed)	Sausages, cold cuts, ham and bacon
Poultry (processed)	Sausages
Veal (processed)	Sausages
Cow's milk	Whole, semi-skimmed and skimmed milk
Yoghurt	Sweetened and unsweetened yoghurt
Semi-hard cheese	Raclette and Appenzeller
Cream	Cream with different fat contents and sour cream

1.2 Consumption patterns

1.2.1 Average- self-selected diet

The average diet was modelled based on data provided by the Swiss Federal Food Safety and Veterinary Office (FSVO/BLV) [3], which summarized the product-specific average consumption of the adult Swiss population (18-75 years), as observed in the menuCH study from 2014/15 [4]. The original dataset showed discrepancies between product level and food group level consumption values. Following a plausibility assessment, food group level values were used as reference amounts and the relative contributions of individual food items within each group were based on the product level data (Supplementary Table 2).

Due to data availability constrains regarding the nutrient composition and environmental impacts of food items, only the most relevant food items were included in the later analyses. To determine these, the list of food items was filtered using two cut-off criteria. Food items were only considered if they were consumed at least 5 g per capita per day or contributed at least 3% to the consumption of a food group. This ensured the inclusion of the most relevant food items by mass, while maintaining representation of all food groups. In a few cases, the cut-off criteria had to be overruled, if no suitable nutrient composition and/or environmental inventory data were available (e.g., herbal tea and coffee creamer), if the product descriptions were too generic (e.g., mixed vegetables and mixed nuts), or if the food group was very small, making a contribution of 10% negligible if the food group was already well represented by other products (e.g., 0.4 g pistachios per person and day representing 5% of the 8.9 g of nuts and seeds consumed).

To account for the full mass of food and beverages consumed, proxies were applied for the excluded items. This was achieved by scaling the included items to represent 100% of the respective food group's consumption (Supplementary Table 2).

Supplementary Table 2: Example of how mean consumption of the most relevant food items was modelled for the average Swiss diet. First, the percentage contribution of the different food items to the food group is calculated (1). Then, minor food products are excluded and the remaining products rescaled to represent 100% of the food group (2). During this step, the original ratios between the sub-groups are preserved (e.g., butter is not used as a proxy for vegetable oils). Lastly, the absolute consumption amounts of the food items are calculated based on the reported total food group consumption (3).

Product group ***Product sub-group*** Products	Reported mean consumption [g/(person*day)]		(1) Contribution to food group	(2) Contribution to food group with proxies		(3) Calculated mean consumption [g/(person*day)]
Oils and fats	**22.0**		**100%**	**100%**		**22.0**
Fats						
Cooking fat	0.1	/22.8	1%	0%	*22.0	0
Butter	10.3		45%	46%		10.1
Coconut fat	0.1		0%	0%		0
Margarine	2.0		9%	9%		2.0
Oils						
Olive oil	6.6		29%	30%		6.6
Rapeseed oil	1.7		7%	8%		1.7
Sunflower oil	1.6		7%	7%		1.6
…	0.4		2%	0%		0

The consumption of alternative products was excluded from the reference diets, even though some consumption was reported in 2015. This decision was justified by the low consumption amounts (4 g meat alternatives, 8 g milk alternatives and 3 g yoghurt alternatives per day) and aimed to enable a more consistent analysis of the consequences of replacing meat and dairy in the diet. As the dietary data was collected in 2014 and 2015, some consumption values may not be up to date. To reduce uncertainty, meat consumption figures were updated using more recent market data [1]. Since the total meat consumption has remained relatively stable since 2015, only the distribution across different meat types was updated.

1.2.2 Recommended diet

The recommended diet was modelled based on the Swiss food pyramid, supplemented with the supportive information provided by the [5] (see also: www.sge-ssn.ch/ich-und-du/essen-und-trinken/ausgewogen/schweizer-lebensmittelpyramide, information available in German, French and Italian). Explicit recommendations for individual food items were translated into daily consumption amounts. For example, the recommendation for rapeseed oil states: "Two to three tablespoons (20-30 g) of vegetable oil daily, at least half of it in the form of rapeseed oil". Where guidance was at the food group level, the composition of the group was derived from the average diet. For instance, the recommendation for fruits and vegetables states: "Five portions a day in different colours, including three portions of vegetables and two portions of fruit. One portion corresponds to 120 g". In cases where recommendations were general, i.e., not linked to a specific product or food groups, principles of a balanced diet were applied. For instance, for sweets, salty snacks and alcoholic products, a maximum of one small portion per day is advised. Where portion sizes were given as ranges, the average of the minimum and maximum values was used for modelling the diet.

1.2.3 Alternative dietary patterns

The alternative dietary patterns were constructed by replacing meat and dairy with the different alternative product groups, individually. For each replacement scenario, the nutritional and environmental performance was calculated. When both meat and dairy were replaced, all possible combinations of the respective alternative product groups were tested. For each dietary pattern, three values are reported for each nutrient and environmental impact category: the minimum and maximum value observed across all replacement scenarios, as well as the value obtained when using the respective average groups, namely the plant-based mechanically texturised meat alternatives and milk alternatives.

All dietary patterns were modelled based on reported or recommended food amounts. Replacements were performed on a weight-equivalent basis. As a result, the diets were not isocaloric. An isocaloric comparison would have required assumptions that are not aligned with the objective of the study, such as consumers replacing meat and dairy strictly based on energy equivalence, or that average and recommended diets are expected to provide the same total energy. Since the study builds on self-selected dietary patterns, weight-based substitutions were considered more representative and appropriate. However, as the energy content is reported for all dietary patterns in SI2-T4, isocaloric adjustments could be derived for future analyses.

1.3 Nutritional data

1.3.1 Identification of alternative products available in nutritional databases

Nutrient composition data for alternative products was retrieved from seven countries within the EuroFIR database: France, Greece, Portugal, Slovenia, Spain, Switzerland and the United Kingdom. The data were obtained in July 2023. Unlike the other food items, which were all sourced from the Swiss EuroFIR dataset, including additional countries allowed for the identification of a broader range of alternative products. Seven countries were selected, as this was the maximum permitted by the purchased license. The datasets were searched using terms likely to identify alternative products, such as “plant-based”, “substitute”, “vegan” and “tofu”. In addition, the datasets were filtered by the relevant food groups: “meat or meat product”, “milk, milk product or milk substitute”, “beverage (non-milk)” and “grain or grain product”, which were examined in detail to detect any remaining alternative products. Two researchers conducted the search independently to ensure completeness.

1.3.2 Selection of food composition data for the food items included in the dietary patterns

Datasets representing the various food items (excluding alternative products) were selected using targeted searches. This included the reference products. If multiple food items matched a given search, either the most relevant item was selected, or all were included with potential adjustments of the contribution where necessary (see chapter 1.3.3). The choice between these two approaches was guided by the aim to best reflect the real-life consumption data.

1.3.3 Combining datasets for product representation

Whenever several entries were available in the EUROFIR database that plausibly represent the nutritional composition of a given food item, all relevant entries were included and given a contribution share. The following list outlines the selected combinations used in the dietary models.

Supplementary Table 3: Dataset combinations when the nutrient composition data for several food products was available.

Product	Options	Contributions
Applesauce	Sweetened and unsweetened	Even contribution
Beer	Lager and five grain	Even contribution
Bell pepper	Red and green	Even contribution
Chocolate	Dark and milk	Even contribution
Crustaceans	Norway lobster and shrimp	Even contribution
Dough and pastry	Curd cheese puff pastry with butter, curd cheese puff pastry with vegetable oil, pizza dough, puff pastry, yeast dough, short pastry with butter, short pastry with vegetable oil, cake dough	Even contribution
Milk-based dessert	Flavoured yoghurt and blanc battu with fruits	Even contribution
Pasta	With and without egg	Even contribution
Pork, processed	Bacon, coppa, cotechino, cotto, ham, liver sausage, luganighe, luncheon meat, mortadella, pancetta, pork sausage (Schweinsbratwurst), pork sausage (Schweinswurst), cured and smoked pork meat (Rollschinken), salametti, salami, salami farmer style, salsiz sausage, saucisson sausage, sausage vaudois and smoked salami	Even contribution
Red wine	9%, 12% and 13.5% vol alcohol	Even contribution
Rosé wine	11% and 12.5% vol alcohol	Even contribution
Rye bread	Sour dough and rye grist	Even contribution
Sweet pastry	Biscuit, biscuit with chocolate covering, puff pastry biscuit, chocolate croissant and chou pastry filled with custard	Even contribution
Sweets	Hard and soft caramel candies, and jelly candy	25:25:50 (even contribution of caramel and jelly candies)
White wine	11% and 12.5% vol alcohol	Even contribution
Yoghurt	Sweetened and natural	53:47 [6]

1.3.4 Unavailable nutrients complemented from other databases or literature

In the EuroFIR database and the accompanying nutrient composition datasets, some relevant nutrients were either missing entirely or listed without value. To ensure accurate calculation of the daily nutrient provision for the proposed dietary patterns, missing nutrient data were supplemented using the decision priority list outlined below. This approach was particularly relevant for the micronutrients: iodine, vitamin A and vitamin E.

1 – If a value was not available in the EuroFIR database, the original national database from which the EuroFIR entry was derived was consulted.

2 – If the nutrient was also missing in the original country database, a similar product from the same country was used as a proxy (e.g., yogurt mocha vs yoghurt mocha organic).

3 – If no suitable proxy was available within the same country database, a similar product from another country was used.

4 – If a nutrient content was listed as “traces" (“tr.") in the original country database, a value of zero was assumed.

5 – For iodine, when a value was marked as “beneath limit of detection” or given as a “best estimate”, but the value exceeded the average for the product group, it was adjusted using steps 1 to 4.

1.3.5 Added sugar content workflow

Modern nutrient intake recommendations concerning sugar typically refer to *free* (or *added*) sugar rather than *total* sugar. However, the EuroFIR database mostly reports the total sugar content for food items. As a result, information on added sugar content had to be supplemented using a structured decision-making approach. The prioritization scheme used to estimate the added sugar content is outlined below.

1 – If a product was likely to contain no added sugar (e.g., natural products), an added sugar content of zero was assumed.

2 – If a comparable natural product was available, the added sugar content was estimated as the difference between the total sugar content of the product and that of the natural product (e.g., flavoured versions of plain products).

3 – If information on the main ingredients was available, added sugar was estimated based on the nutrient composition of the ingredients (e.g., milk alternatives with unusual ingredients).

4 – When sugar content was not reported and the food would not naturally contain sugars (e.g., hard cheese and meat), zero added sugar was assumed.

5 – For tofu and tempeh with total sugar contents below 2 g per 100 g, added sugar was assumed to be zero.

6 – For mechanically texturised meat alternatives, a standard added sugar content of 1 g per 100 g was assumed. This corresponds to the highest value observed among processed meat products and therefore represents a conservative approach avoiding the unjustified preference of alternatives.

7 – For fruit juices, fruit sauces, alcoholic drinks, sweets, and sweet pastries, the total sugar content was considered equivalent to free (added) sugars due to their similar health effects [7].

1.3.6 Added nutrient composition datasets

Due to a lack of suitable nutrient composition data for three alternative product groups, four new datasets were created using literature sources, EuroFIR and USDA data. The four products and their respective data sources are described below.

Insect-based burger

The insect burger composition was based on the ingredient list provided in Smetana, Profeta [8]. Since the publication reported only selected nutrients, missing values were estimated from the listed ingredients. Nutrient composition data for lemon juice, mustard, onion, potato starch, rapeseed oil, table salt and soy sauce were extracted from the EuroFIR database. USDA data were used for egg white protein and soy protein isolate. Finally, nutrient data for dried mealworm larvae were sourced from the Swiss feed composition database (www2.feedbase.ch).

Cricket, raw

Nutrient composition data for raw crickets were taken from Ververis, Boué [9]. Raw rather than dried crickets were used as the reference, since their reported water content more closely matches that of the insect-based burger. This approach ensured that insect-derived nutrient levels remain comparable. However, disqualifying nutrients, specifically sodium and saturated fatty acids, are likely underestimated compared to processed insect-based foods such as the burger described above.

Pea-based alternative

The nutrient composition of the pea-based alternative was based on USDA data for a “beyond meat” burger (ID: 1907072). Missing nutrients were complemented using data from Ložnjak Švarc, Jensen [10], taking average values from both pea mince and pea sausage products.

Mycoprotein-based alternative

To construct the nutrient profile of mycoprotein-based alternatives, an average of eight datasets was used. Five datasets were retrieved from the USDA (IDs: 2014513, 2025444, 2117675, 2145386 and 2543838), one from Ložnjak Švarc, Jensen [10], and two from Mazac, Järviö [11]. Because not all datasets reported values for every nutrient considered in this analysis, averages were calculated only from those sources that included the relevant nutrient. For example, if only three datasets included values for a specific micronutrient, only those three were used in its calculation.

1.3.7 NRF11.3 calculation

The nutrient density index NRF11.3, based on the NRF9.3 proposed by Fulgoni, Keast [12] with the addition of iodine and vitamin B12, was calculated based on the three formulas:

I $$NR11 = \sum(\frac{QN}{DRI})$$

II $$LIM3 = \sum(\frac{DN}{DRI})$$

III $$NRF11.3 = NR11 - LIM3$$

With the variables:

NR11 – Nutrient density index of 11 qualifying nutrients

QN – Amounts of qualifying nutrients in the analysed food item

DRI – Dietary reference intake (specified for each nutrient in SI2-T6)

LIM3 – Nutrient density index of 3 disqualifying nutrients

DN – Amount of disqualifying nutrients in the analysed food item

1.4 Environmental data

The environmental impact assessment requires the definition of life cycle inventories (LCIs). The following sections explain how these LCIs were compiled.

1.4.1 Alternative product selection in the databases

As with the nutritional composition data, suitable LCIs for alternative products were identified using keyword searches and systematic screening of relevant food categories in LCI databases. In other words, product categories within each database that could potentially include alternative products were examined in detail. The databases included in this analysis were Agribalyse v3.1, AgriFootprint v6.3, ecoinvent v3.9, SALCA v3.4 and v4.0, and WFLDB v3.5.

LCIs for insect-based products were generally not available in the databases, only LCIs for whole insects could be found. A comparison with literature showed that the environmental impacts of whole insect products are typically higher than those of processed insect-based products. Hence, as a conservative approach, the LCIs for whole insect were retained in the analysis.

1.4.2 Additional LCIs for alternative products

Additional LCIs were created for key alternative products relevant to the Swiss market (see SI2-T5) that were not available in the background databases. Specifically, two LCIs were developed for mycoprotein-based products, and one for a faba-pea burger. Additionally, one LCI for a soy-based burger, as described in Herrmann, Mehner [13], was included.

Mycoprotein-based LCIs

Two LCIs were developed based on data from Upcraft, Tu [14], differing only in the sugar source used during fermentation. One LCI assumes maize starch, while the other uses sugar beet molasses [15]. The process described by Upcraft, Tu [14] yields a mycoprotein paste with a protein content of 45%. To align with the protein content of commercial mycoprotein products (14%, based on "Cornatur Quorn Geschnetzeltes Vegetarisch" – www.migros.ch/product/130986700000), additional ingredients were added. According to the product's ingredient list, these include rehydrated egg white, water, and minor amounts of natural aroma, calcium acetate and calcium chloride. The fat content of 2.6% also indicates the presence of vegetable oil in the original Quorn™ formulation. As a result, the final product was modelled using the following composition: 29.4 g of mycoprotein paste, 5 g of egg (15% protein content), 2.6 g of rapeseed oil and 63 g of tap water. Infrastructure impacts were considered negligible relative to the fermentation process.

Faba-pea-based burger LCI

The LCI for the faba-pea-based burger was constructed following the same approach used by Herrmann, Mehner [13] for a soy-based burger. The composition of the texturised high-moisture extrusion faba-pea-protein was based on Sousa, Portmann [16], incorporating a faba protein concentrate and a pea protein isolate. Energy consumption data were obtained from Saerens, Smetana [17].

1.4.3 Reference products

The LCIs of the reference products produced in Switzerland were retrieved from the literature [18-20] and included the production of milk, beef, pork and poultry. LCIs for unprocessed veal, cheese, cream, yoghurt and all processed meats were based on Agribalyse v3.1 and ecoinvent v3.9 data, which were adapted to reflect Swiss production conditions. Regionalization of the LCIs was carried out by replacing background flows with more spatially appropriate ones. The priority order for selecting background flow was: Switzerland > Europe > European country other than Switzerland > Rest of the World > Global. If a background flow was itself a processing step that could be regionalized (unit process), the same procedure was applied. The production chain was followed backward in this manner until all input flows were regionalized as far as possible. Where allocation between several products or by-products was required, economic allocation was preferred.

1.4.4 Domestic production of foods

Whenever possible, domestic food production was modelled using LCIs from the Life Cycle Assessment research group at Agroscope, which are expected to be available in ecoinvent in 2025. If no such data was available, Swiss-specific LCIs from ecoinvent v3.9 was used. This included datasets specific to other regions, if the underlying background data was Switzerland-specific (e.g., bell pepper and cucumber in ecoinvent v3.9). Where Swiss background data was also unavailable, data from France served as a proxy (e.g., cherry and peach from Agribalyse v3.1). Agricultural production processes were not regionalised since not enough information was available to accurately adjust biosphere flows and material usage according to local practices.

1.4.5 Processing LCIs with Swiss background data

Several food items of Swiss origin required additional processing steps, such as rapeseed oil and bread. When Swiss-specific processing LCIs were unavailable, they were created by regionalising existing LCIs following the approach described in chapter 1.4.3. The affected products are shown in Supplementary Table 4.

Supplementary Table 4: Food processing inventories that were adapted to match Swiss production conditions.

Product	Process(es) modelled	Original inventory
Apple juice	juicing	Apple juice, industrial production, Agribalyse v3.1
Rapeseed oil, crude	extraction	Rape oil, ecoinvent v3.9
Sunflower seed oil, crude	extraction	Sunflower oil, ecoinvent v3.9

Sugar, refined	refinery	Beet sugar production, ecoinvent v3.9
Short crust pastry	dough making, baking	Short crust pastry, Agribalyse v3.1
Pizza dough	dough making, baking	Pizza base, Agribalyse v3.1
Puff pastry	dough making, baking	Puff pastry, Agribalyse v3.1
Biscuit	dough making, baking	Biscuit, Agribalyse v3.1
Biscuit with chocolate covering	dough making, baking	Biscuit with chocolate covering, Agribalyse v3.1
Puff pastry biscuit	dough making, baking	Puff pastry biscuit, Agribalyse v3.1
Chocolate croissant	dough making, baking	Chocolate croissant, Agribalyse v3.1
Chou pastry filled with custard	dough making, baking	Chou pastry filled with custard, Agribalyse v3.1
Pasta, dry	dough making	Dry durum wheat pasta, ecoinvent v3.9
Eggs (chicken)	outdoor egg production	Egg, conventional, outdoor, Agribalyse v3.1

1.4.6 Imported foods

A reproducible workflow was developed to model the environmental impacts of imported foods. First, the import mix, based on total imported amount and country of origin for all considered food items, was retrieved from the Swiss import-export-statistics (www.gate.ezv.admin.ch/swissimpex/). All relevant food-related entries were manually consolidated into harmonized product categories. For instance, multiple entries referring to different forms of wheat were unified under the generic category "wheat". In many cases, imports originated from a wide range of countries. However, the contribution from many of these countries was negligible. Moreover, comprehensive inventory data were not available for all source countries. To ensure data quality and manageability, a cut-off threshold was applied. Countries contributing less than 3% of the total import volume for a given food item were excluded from country-specific modelling. To account for these minor contributors, the remaining countries were extrapolated to represent the full import volume, consistent with the approach applied for diet modelling (see Chapter 1.2.1).

Second, for each retained country of origin, the environmental impact of transport to Switzerland was modelled based on the estimated shares of road, rail and sea transportation. Third, the impact of food production in the country of origin was modelled. For this purpose, the best-suited life cycle inventory was identified based on the accuracy of regional representation. The same background databases as listed in Chapter 1.4.1 were considered. Required processing steps were regionalised following the procedure described in Chapter 1.4.3.

1.4.7 Ratio of domestic production to import

The ratio of the domestic production to imports was considered in the environmental impact calculations wherever corresponding data was available. The applied ratios were derived from a report by the Swiss Farmers' Union and agristat [21]. All food products used in the model were matched to the food categories reported in the reference publication. The allocation of the food products to the categories and the respective share of domestic production are detailed in SI2-T10. Values exceeding 100% were capped for the calculations.

1.4.8 Combining datasets for product representation

Whenever multiple suitable LCIs were available that plausibly represented the same food product, and no single best match could be identified, all relevant datasets were included and combined to represent the product. A representative mix was calculated by assigning contribution shares to each dataset. Supplementary Table 5 lists the affected products along with assigned contributions.

Supplementary Table 5: Dataset combinations used when several LCIs were available for one food product.

Product	Options	Contributions
Beef, processed	Sausage with and without offal	Even contribution
Beer	Domestic and import	Even contribution
Chips	Potato crisps and salty snacks	Even contribution
Chocolate	Dark, milk and white	Even contribution (dark and milk)
Cream cheese	Cream cheese and fresh cheese	Even contribution (since the group included both types of cheese)
Crustaceans	Cold water prawn, crab, langoustine, lobster, Norway lobster and prawn	Even contribution
Dough and pastry	Short crust pastry, pizza base and puff pastry	Even contribution
Hard and semi-hard cheese	Emmental, Gruyere, Raclette and Tomme	20:20:30:30 (ratio of hard cheese to semi-hard cheese 40:60 [22])
Jam	Apricot, cherry, raspberry, strawberry and orange	Even contribution
Milk drinks	Dairy drink or fermented milk with fruits, and skimmed milk	Even contribution
Milk-based desserts	Custard dessert and ice cream	Even contribution
Mussels	Scallops and mussels	Even contribution
Olive oil	Crude and refined	Even contribution
Pork, processed	Bacon, dry ham, cooked ham, dry sausage, fresh sausage, mortadella, sausage with offal, salted pork (imported) and smoked pork (imported)	Even contribution, accounting for ratio domestic to import
Poultry, processed	Sausage, smoked chicken liver (import), salted chicken liver (import), smoked chicken (import), salted chicken (import) and preserved chicken (import)	Even contribution, accounting for ratio domestic to import
Rapeseed oil	Crude and refined	Even contribution
Salmon	Atlantic and Pacific	Even contribution
Soft cheese	Soft cheese (import), Brie and Vacherin	Even contribution, accounting for ratio domestic to import
Soft drink	Fruit soft drink, lemonade with sugar, lemonade with syrup and soft drink with tea extract	Even contribution
Strawberry (proxy for berries)	Berry production mix, raspberry (import), blackberry (import) and blueberry (import)	Even contribution, accounting for ratio domestic to import.

Sugar	Beet sugar production, beet sugar (import) and cane sugar (import)	Even contribution, accounting for ratio domestic to import.
Sunflower oil	Crude and refined	Even contribution
Sweet pastry	Biscuit, biscuit with chocolate covering, puff pastry biscuit, chocolate croissant and chou pastry filled with custard	Even contribution
Sweets	Hard candy and jelly candy	Even contribution
Tuna	Bigeye tuna, tuna, red tuna and white tuna	Even contribution

1.5 Sensitivity Analyses

Two exemplary sensitivity analyses (SI2-T8 and T9) were performed to investigate how the recipe composition and raw material origin of alternative products influence their comparison to the reference products. These aspects were chosen since previous studies hinted their relevance. For instance, Herrmann et al. (2024) showed that despite high levels of processing, agricultural production still contributed substantially to the environmental impacts of an ultra-high processed soy-based meat alternative. Hence, variations in agricultural practices are expected to notably affect overall environmental impacts. Additionally, beyond the variation in environmental impacts and nutrient density observed among soy-based mechanically texturised meat alternatives (SI2-T7), large differences in product recipes were also noticed. To test the effect of recipe variability, matching nutrient and environmental data pairs were identified, allowing both nutritional composition and environmental performance to be jointly investigated.

2 Supplementary Note on Uncertainty of data and models

2.1 Consumption data

The average Swiss diet was modelled based on a food consumption study performed in 2014/15 [4]. The study used self-reported 24h dietary protocols to gather information on the food consumption of approximately 2000 participants. This type of data entails several sources of uncertainty. Firstly, participants estimated food quantities based on reference images (e.g., small, medium and large portion of pasta with corresponding weights), limiting the precision of the recorded values. Secondly, entries may be incomplete or inaccurate if a participant forgot to log a food product or misidentified it. While these uncertainties are difficult to quantify in the calculations, they should be kept in mind when comparing the resulting dietary patterns to other sources. Thirdly, some of the listed food items are processed products, such as pastries or soft drinks. Since the ingredients of these products are not detailed, the consumption of individual food products, such as wheat flour or eggs, may be underestimated in the dietary pattern. However, since the environmental inventories as well as the nutrient composition data also consider whole products, the overall results are not affected.

To obtain the average consumption amounts of the main food items in the Swiss population, several steps of data aggregation were required. Although this aggregation reduces data precision, it enables broader comparison to different approaches modelling the average consumption. One such approach is the consumption estimation based on production and purchasing data. To validate the data implemented in this study, the total national consumption was calculated for the meat and dairy product groups by multiplying the per capita consumption with the Swiss permanent resident population (8.815 Mio. in 2022) [23]. To align with production data, food losses were accounted for based on Beretta and Hellweg [24]. The final values were then compared to production statistics for meat and dairy [1, 2]. Only minor differences of less than seven percent were observed between the two modelling approaches.

Overall, it is important to note that the study focused on average data. While this allows to identify general hotspots for environmental impacts and nutrient deficiency risks, diets are highly individual. Hence, not every hotspot may be relevant to every consumer and new issues may arise depending on individual dietary behaviours and needs.

2.2 Nutrient contents

One major source of uncertainty in the nutrient composition data relates to neglecting food preparation. Food preparation can potentially have large effects on the nutrient contents and their availability. Many vitamins are heat sensitive and hot preparation can decimate their nutrient content notably [25]. Conversely, preparation with oil can help making lipophile vitamins available for digestion and different methods of food preparation can break down plant cell structures, facilitating the release and absorption of nutrients. In some cases, water loss during preparation increases the concentration of nutrients per gram of food.

Furthermore, the addition of salt, herbs and spices during preparation contributes additional nutrients, particularly iodine when iodised salt is used. In our modelled diets, iodine intake falls below the adequate intake level for average adults. While this risk of deficiency is a known public health concern in Switzerland [26, 27], the modelled intakes in our study may be underestimated. This is primarily because the nutrient composition data used was largely based on raw foods and hence do not fully account for iodized salt added during food processing and preparation. Previous research suggests that most of the iodised salt intake in Switzerland is due to salt used in food processing and preparation outside of households (e.g., during industrial production or in restaurants) [28]. However, iodisation rates remain low, less than 50% of salt used in food processing is iodised, and only 8.4% in vegan products, such as meat and cheese alternatives [29]. In general, iodine intake estimates based on food consumption surveys carry substantial uncertainty [28].

In our study, unprocessed meat was modelled as muscle meat. While a majority of meat consumed In Switzerland is muscle meat [1], offal can contain significantly higher concentrations of certain micronutrients. For example, beef liver provides approximately 23 times more vitamin B12 than beef muscle, according to EuroFIR data. Thus, even occasional consumption of small amounts of offal could meaningfully influence the total micronutrient intake.

Another limitation concerns treatment of processed and convenience foods. The menuCH study, which served as the basis for the average Swiss diet and parts of the recommended diet, does not explicitly account for convenience food such as ready-to-eat meals. These products were instead recorded as their main ingredients, potentially underrepresenting the effects of industrial processing on nutrient composition.

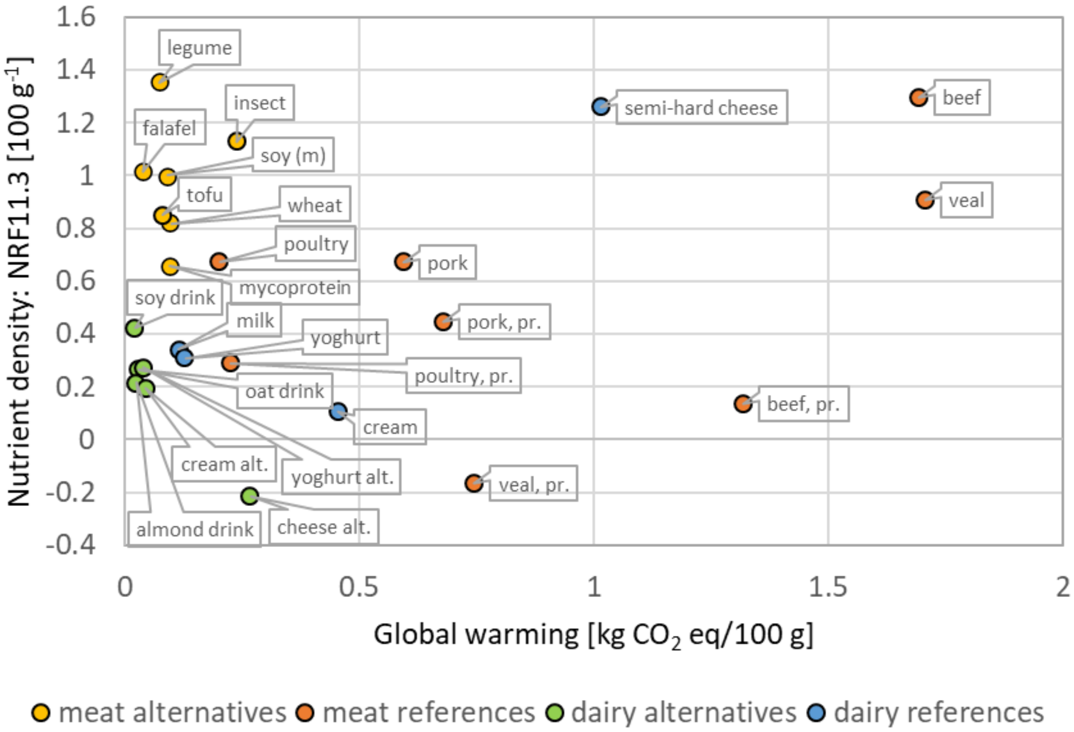
Lastly, nutrient intakes from supplements are not considered in the analysis, despite their common use by individuals at risk of deficiency [30].

2.3 Environmental impacts

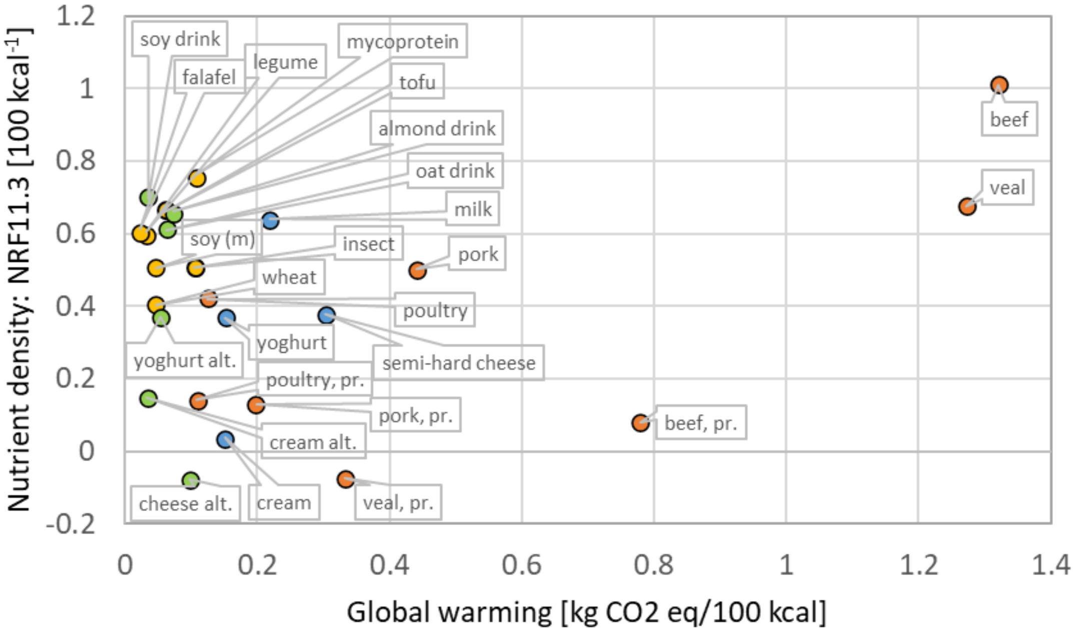
Food waste and its management are considered in many of the life cycle inventories (LCIs) used in this study. However, due to inconsistent assumptions across data sources, this remains a source of uncertainty. Additionally, later life cycle stages such as transport to retail, packaging, and consumer activities including transport to home and food preparation, were not considered in the study, as they are expected to have only minor effects on the comparison between meat, dairy, and their alternatives. Most dairy products and their alternatives are ready-to-eat or require minimal preparation, while meat typically involves more energy-intense preparation than meat alternatives. Therefore, the exclusion of the preparation step represents a conservative choice, avoiding the risk of overstating the environmental benefits of the alternatives. To align the environmental data with the food consumption data used for modelling the diets, food losses [24] and water absorption during preparation were accounted for where applicable.

Since the study relied heavily on background data, some odd values could not be fully investigated. For instance, water scarcity impacts associated to some fish products were very high in comparison to other foods. Detailed analyses revealed that in all four background inventories contributing to the final value, either a very high water use during the raising of fingerlings, or a very high evaporation rate was assumed. To the authors of the present manuscript, the reasons for these assumptions are unknown and in the absence of better assumptions, the values were kept as they were. Meanwhile, for the impact categories of biodiversity loss and soil quality, a few food items showed negative scores, indicating an environmental benefit from their production. Both assessment methods categorise land use and land use change. Hence, the negative values are caused by a change from less favourable to more favourable land use types. For instance, rye production involved a partial transition from pasture to annual crops, and lentil production a shift from unspecified land to annual crops. As with the water consumption data, the rational for these choices was not known to the authors of the present manuscript. Thus, the values were kept as they were. A few entries for the impact categories "Land occupation – Non-Agricultural" and "Land transformation – Deforestation" also showed comparatively high values. The former was largely driven by trout and perch, where marine area occupation associated with fishmeal used in feed is represented as non-agricultural land use in the underlying inventory. As a result, these products showed substantially higher values for this category than most terrestrial foods. For "Land transformation – Deforestation," high values were mainly associated with lentils, reflecting the assumption of land-use change from unspecified land to annual crop in the background inventory. Consequently, scenarios with higher consumption of these products lead to elevated values for the respective indicators at the diet level. As in the cases described above, the inventory values were retained as reported in the background datasets but should be interpreted with caution.

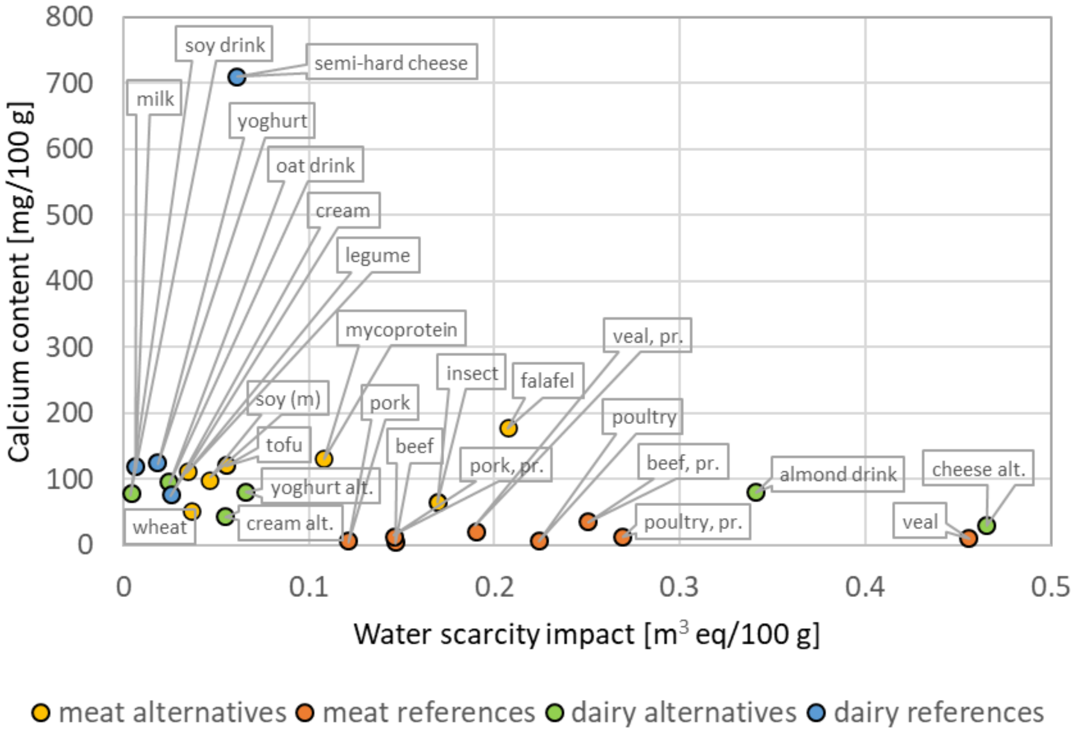
3 Supplementary Figures to Figure 1 in the main manuscript



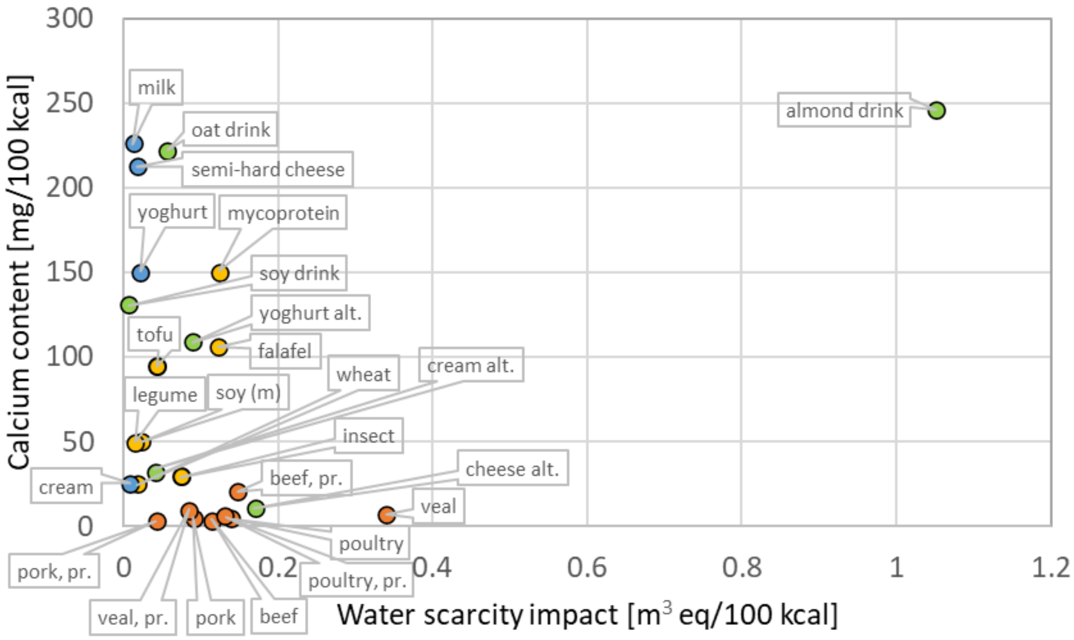
Supplementary Figure 1: Product comparison across environmental and nutritional dimensions, illustrated at the example of global warming and nutrient density (NRF11.3) per 100 g of product.



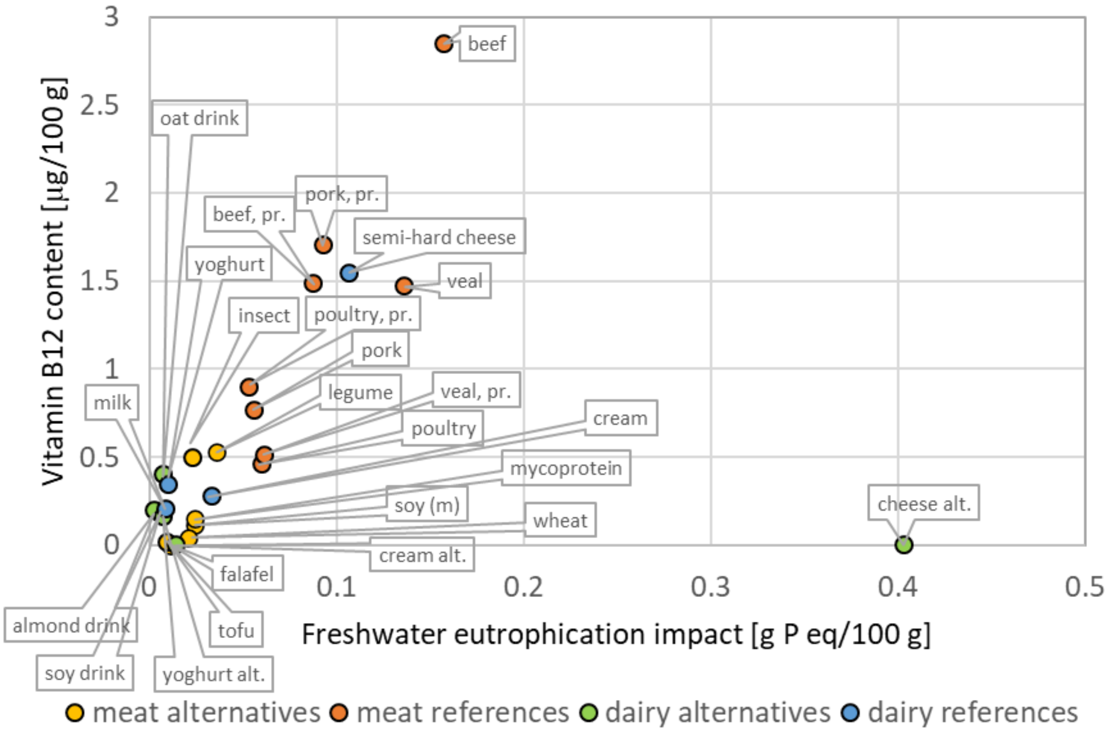
Supplementary Figure 2: Product comparison across environmental and nutritional dimensions, illustrated at the example of global warming and nutrient density (NRF11.3) per 100 kcal of product.



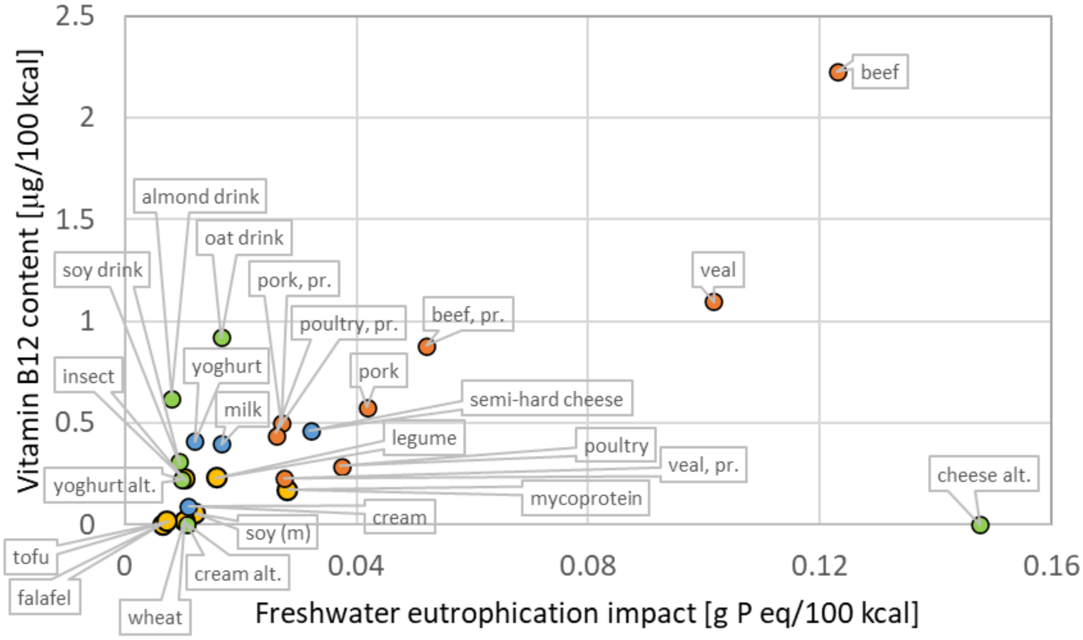
Supplementary Figure 3: Product comparison across environmental and nutritional dimensions, illustrated at the example of water scarcity and calcium content per 100 g of product.



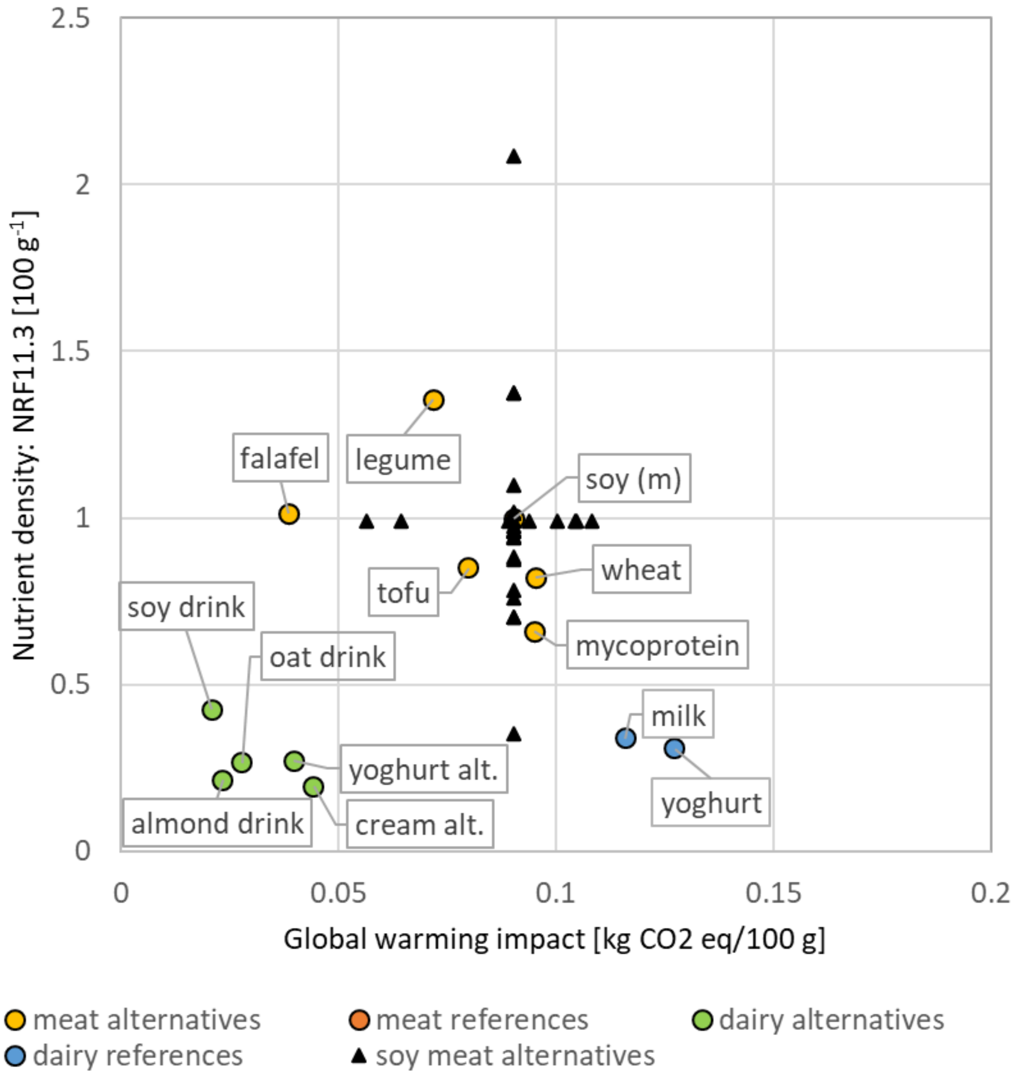
Supplementary Figure 4: Product comparison across environmental and nutritional dimensions, illustrated at the example of water scarcity and calcium content per 100 kcal of product.



Supplementary Figure 5: Product comparison across environmental and nutritional dimensions, illustrated at the example of freshwater eutrophication and vitamin B12 content per 100 g of product.



Supplementary Figure 6: Product comparison across environmental and nutritional dimensions, illustrated at the example of freshwater eutrophication and vitamin B12 content per 100 kcal of product.



Supplementary Figure 7: The product group soy-based mechanically texturised meat alternatives divided into the individual data points (SI2-T7) to illustrate data variation.

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