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Comparative analysis of the nutritional quality of plant-based processed foods and animal-origin counterparts in the Portuguese and UK markets

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A B S T R A C T

The increasing demand for healthier and more sustainable foods has led to the rise of plant-based processed foods that serve as alternatives to animal-origin products. While plant-based diets are often considered healthful, these products frequently present nutritional limitations. This study aimed to compare the nutritional composition and quality of plant-based and animal-origin processed foods available in the Portuguese and UK markets. A total of 1170 plant-based and 2452 animal-origin counterparts were analysed, using two reference frameworks: the Portuguese Integrated Strategy for the Promotion of Healthy Eating (EIPAS) and the Directorate-General for Health (DGS) Label Decoder reference values. Findings indicated that 92.9 % of plant-based foods in Portugal, and 95.4 % in UK, exceeded EIPAS sugar and salt limits (evaluated together), suggesting that the perceived health benefits may not be aligned with their nutritional content. Compliance with EIPAS varied significantly by food type, for each country. Plant-based alternatives often had higher energy, carbohydrates, and fibre, but lower levels of saturates and protein compared to their counterparts. According to the DGS Label Decoder, 17.7 %, 18.1 %, and 29.0 % of plant-based alternatives in PT market, and 18.4 %, 22.6 %, and 26.7 % in UK market, had high levels of fat, saturates, and salt, respectively. These findings underscores that, despite the perceived health benefits of plant-based foods, not all present a balanced and healthy nutritional profile. Additionally, this study highlights significant nutritional variability across plant-based alternatives and markets. This reinforces the need for informed consumer choices, better product formulations, and public health actions to improve their nutritional quality.

1. Introduction

The demand for healthier, more sustainable, and environmentally friendly food products is increasing worldwide, driven by concerns related to health, climate change, environment impact, animal welfare, and sustainability (Alessandrini et al., 2021; Poore et al., 2018; Springmann et al., 2018; Sultan et al., 2024; Willett, 2019; Rizzolo-Brime el al., 2023). The food system is a major contributor to the degradation of terrestrial and aquatic ecosystems, deforestation, depletion of water resources, and greenhouse gas emissions, thereby driving climate change (Poore et al., 2018; Alessandrini et al., 2021). Livestock production, in particular, is one of the main drivers of these environmental and sustainability challenges, with the impacts of animal product production and consumption markedly exceeding those of their vegetable substitutes (Poore et al., 2018). As a result, changes in food management, including reducing food loss and waste, advances in technology, and shift in dietary patterns, particularly toward increased production and consumption of plant-based foods, have been promoted as sustainable strategies to mitigate environmental impact and enhance food system resilience (Springmann et al., 2018).

These sustainability and environmental concerns, alongside health-related motivations, have decisively contributed to the rapid development and commercialization of a multiplicity of new plant-based processed foods (Alessandrini et al., 2021; Rizzolo-Brime el al., 2023), based on a diverse range of ingredients, such as: vegetables, legumes, grain proteins, dried fruits, seeds, condiments, seasonings and flavorings, and which can also be enriched with various vitamins and other bioactive compounds (Benković et al., 2023). In most cases, the plant-based analogues adopt formats, designations, organoleptic and chemical characteristics that resemble those of their animal-origin counterparts (Bryant, 2022; Curtain, et al., 2019; Petersen et al., 2023; Sultan el al., 2024). With this approach, they are expected to constitute a very real, valid and effective alternative to animal-origin products, contributing to a healthier and more sustainable food consumption and,

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consequently, to the protection of people and the environment.

A predominantly plant-based diet, low in salt, saturated fats and added sugars, is recommended as part of a healthy lifestyle (WHO, 2021a). Such diets are also generally associated with improved health outcomes, particularly when based on minimally processed plant-based foods, due to their nutritional profile, which includes healthy sources of protein and higher content of fiber, vitamins, and bioactive compounds (Wang et al., 2023; Zhao et al., 2022).

Several studies have shown that populations adhering to healthful plant-based dietary patterns tend to have lower risks of metabolic disorders, chronic diseases, including cardiovascular diseases, type 2 diabetes and certain cancers, and premature mortality (Baden et al., 2019; Wang et al., 2023; Zhao et al., 2022). However, despite the recognized health, sustainability, and environmental benefits associated with the increasing consumption of plant-based alternatives in place of animal-origin products (Alessandrini et al., 2021, Baden et al., 2019; Maganinho et al., 2024; Poore et al., 2018; Springmann et al., 2018; Sultan et al., 2024), some concerns remain about potential micronutrient deficiencies in strict plant-based diets as well as with the expanding availability of these new products in the processed/ultra-processed forms, to meet changing consumer demands (Petersen et al., 2023). These products may present formulations and nutritional characteristics, namely high energy and levels of salt, saturates, and added sugars, which are inappropriate for a healthy eating pattern (Ketelings, et al., 2023; Maganinho et al., 2024; Pointke et al., 2022).

According to the World Health Organization (WHO), plant-based processed and ultra-processed foods are gaining popularity and becoming widely available in the WHO European region, however there is a lack of data on their nutritional qualities and health impacts (WHO, 2021b). The WHO further reinforces that some of these plant-based meat, fish and dairy alternatives, often presented as healthier than animal-based counterparts, may not be better for people's health, as many can be classified as ultra-processed foods (WHO, 2021c). Their ultra-processing makes them highly profitable, intensely appealing and intrinsically unhealthy (Monteiro et al., 2019), as they tend to have a high energy density and be rich in salt, saturated fats and free sugars, while lacking dietary fibre, vitamins and minerals, which are usually found in unprocessed foods, including those of animal-origin, and in minimally processed plant-based foods (WHO, 2021c; Wickramasinghe et al., 2021).

Several studies have shown that many plant-based alternatives present in the market are ultra-processed (Alessandrini et al., 2021; Monteiro et al., 2019; Ketelings et al. 2023; Maganinho et al., 2024; Petersen et al., 2023; Rizzolo-Brime el al., 2023) and that consuming these unhealthful foods is associated with an increased risk of cardiovascular diseases, diabetes, as well as a higher disease-specific mortality and total mortality rates, in contrast to minimally processed plant-based foods (Rauber et al., 2024, Kim et al., 2021; Baden et al., 2019; Gan et al., 2021; Helmer et al., 2019). Due to their ultra-processed nature, several others potentially harmful health issues, such as malnutrition, overweight, obesity, gastrointestinal disorders, cholesterol, hypertension, and cancer (Alessandrini et al., 2021; Monteiro et al., 2019; Rizzolo-Brime el al., 2023) should not be neglected. These findings highlight the need for a critical evaluation of food processing and its impacts on nutritional quality and health outcomes, even within the context of plant-based consumption and dietary patterns.

According to the Good Food Institute Europe report (GFIE, 2023), the sales of plant-based foods in Portugal increased by 20 % between 2020 and 2022, reaching a value of 64.7 million euros. Despite ranking as one of the smallest countries in terms of sales in Europe (12th position, with Germany leading with a total sales value of 1.911 million euros), this growing demand underscores the critical importance of assessing the nutritional profiles and overall healthiness of these products.

In Portugal, 9.5 % of the number of years of healthy life lost is due to inadequate eating habits, making it the third most significant risk factor (PNPAS, 2017a). Excessive intake of salt, sugars, and fat, coupled with insufficient consumption of fruit, vegetables, whole grains and oilseed fruits are among the main inadequate eating behaviors. The average salt intake in Portugal is 7.3 g/day (Lopes et al., 2017), with 72.4 % of women and 82.0 % of men exceeding the WHO recommendation of 5 g/day (PNPAS, 2017b). Similarly, a considerable portion of the Portuguese population exceeds the recommended intake levels for sugars and fat. The Portuguese national average consumption of simple sugars is 84 g/day, of which 35 g/day correspond to free sugars. Approximately 24 % of the population consumes free sugars above the limit recommended by the WHO (10 % of daily energy reference intake). Additionally, around 24 % of the population ingests fat above the WHO recommended amount (30 % of energy reference intake) (Lopes et al., 2017).

The increasing consumption of plant-based products by the Portuguese population may indeed represent an opportunity to improved eating habits. However, it is essential to simultaneously recognize the inadequate nutritional quality of some processed/ultra-processed plant-based products and not neglect the negative impacts that these products can have. Additionally, it is crucial to be able to prevent these products from contributing to increase national salt, sugars and fat intakes.

In this context, the Portuguese National Programme for the Promotion of Healthy Eating (PNPAS), in line with the WHO and the European Commission (EC) recommendations, considers that the food industry must provide food products with high nutritional value and low energy density, with reduced sugars and salt and reduced or null *trans* fatty acid content. As a result, the PNPAS has established some national main goals related to promoting the reduction of the average amount of sugars, salt and *trans* fat in food products available in the Portuguese market. While these goals do not explicitly target plant-based products, they are broadly applicable to all foods and should also be considered for these food types.

Seeking to characterize the reality of the Portuguese market regarding processed plant-based foods, an assessment was performed on the nutritional characteristics and overall healthiness of these products, across nine different food categories. The contents of sugars and salt were compared with the corresponding reduction values defined in the Integrated Strategy for the Promotion of Healthy Eating (EIPAS) (Diário da República, 2017), and of various nutritional components with the reference values established in the label decoder of the Directorate-General for Health (DGS) (DGS, 2018), as well as, in parallel, with the nutritional values of equivalent animal-origin products. The assessment additionally included a comparison with both equivalent plant-based and animal-origin products available in the UK market. This broader comparison, through the verification of potential variations in the nutritional content, quality and overall healthiness between similar products in different markets, allowed a more comprehensive analysis and knowledge of the nutritional profiles of the Portuguese processed plant-based foods.

The key results revealed that a significant percentage of plant-based foods - 92.9 % in the Portuguese market, and 95.4 % in the UK market - exceeded EIPAS reference values for sugars and salt when evaluated jointly. Additionally, these products often had higher energy, carbohydrates and salt content. Significant variability in the nutritional characteristics was also observed across all plant-based and animal-origin food categories in both markets and between them.

These findings raise concerns about their overall nutritional quality and underscore the need and possibility of implementing food reformulation strategies to improve the healthiness of plant-based products. Additionally, they highlight the potential implications for consumer health and also provide foresight regarding the importance of regulatory measures to improve labelling and restrict marketing practices of processed/ultra-processed plant-based foods, to ensure that plant-based foods contribute effectively to public health goals.

2. Material and methods

2.1. Data collection

A cross-sectional survey of plant-based and animal-origin products was carried out between 2022 and 2023. The nutritional information for eligible meat, fish and dairy alternatives, as well as their animal-origin counterparts, was collected from food products available online.

To ensure a large and representative sample, all available plant-based products were first collected from national websites of major hypermarkets, supermarkets and specialized stores for organic, vegetarian, vegan and healthy foods in Portugal and the UK. Corresponding animal-origin products were then collected to form homogeneous comparison groups. In the absence of any mandatory nutritional declaration component(s), the necessary missing information was gathered from the producer's websites whenever possible.

The plant-based foods eligible for the study included all the found ambient, chilled or frozen stored vegan/vegetarian products designed to mimic the taste, texture and overall consumer experience of meat, fish or dairy. This encompassed products made of plant-based or fungi ingredients, as well as those whose name or description included terms typically associated with animal-origin products (e.g., burger, patty, sausage, hot dog, meatballs, nuggets, kebab, beef, chicken, steak, fillets, fish, pork, prosciutto, chorizo, pepperoni, ham, cheese, yogurt,…). Plant-based products made from alternative novel protein sources, such as algae or insects, were not included.

Regarding the animal-origin foods information, it was collected for processed and unprocessed, liquid and solid, and ambient, chilled or frozen stored products, made from cow, pork, poultry, and lamb meat, as well as fish and dairy.

Each food product was recorded only once, regardless of being encountered multiple times or in different formats, to avoid duplication and ensure that each recipe was analysed only once. Those, for which the missing mandatory nutritional information, according to the European Regulation No 1169/2011 (European Parliament and Council of the European Union, 2011), was not possible to collect, were excluded. Additionally, plant-based ready meals and products not intended to replicate animal-origin foods, such as tofu, tempeh, falafels and vegetable fritters, were not considered.

2.2. Product categorization

The plant-based products were aggregated into nine main categories: burgers; sausages; chorizo&similar products; nuggets & similar breaded foods; meatballs; meat & minced meat & meat strips; ham & charcuterie products; cheeses; and yogurts (Table 1); to be compared with their correspondent animal-origin categories.

The categorization of the plant-based products was defined and carried out regardless of whether they aimed to replicate foods sourced from cow, pork, poultry, lamb, goat or fish. The focus lied on globally analysing the nutritional quality and healthiness of plant-based foods as alternatives to animal-origin products, independently of the particular type of source they were attempting to imitate.

2.3. Nutritional composition and profiles

For the purpose of this study, the information on the nutritional declaration, including: energy value (kcal), fat (g), saturates (g), carbohydrate (g), sugars (g), fibre (g), protein (g) and salt (g), per 100 g or 100 ml, was collected and checked for any inconsistencies and errors. This verification, with all information grouped by food category, included checking for missing mandatory nutritional information, ensuring values were in the correct decimal format (when applicable), and identifying any abnormally high or low values.

It was not possible to collect data on fibre for a large number of the studied products, as its inclusion in the nutritional declaration presented on the label is not mandatory. Therefore, to accomplish a complete evaluation of these products, we calculated the mean fibre content in each category with the available values.

The nutritional profiles of all food categories were analysed regarding their energy and nutritional composition in the key macronutrients referred.

2.3.1. EIPAS sugars and salt reference values

Firstly, all food products were analysed in terms of their content in sugars and salt, per 100 g or 100 ml, and compared with the corresponding reference reduction values defined in EIPAS for food products in general, excluding soups and ready-to-eat meals. These reference values are set at - sugars: ≤ 5 g/100 g for solids, and ≤ 2.5 g/100 ml for liquids; and salt: ≤ 0.3 g/100 g (thresholds aligned with the values defined by Regulation (EC) No 1924/2006 (European Parliament and Council, 2006), on nutrition and health claims made on foods, for foods with low sugar and salt content).

In this study all the plant-based and animal-origin yogurts were regarded as solid foods. Therefore, instead of a sugar reference value of 2.5 g/100 ml, 5 g/100 g was used. There are no specific reference target values defined for plant-based products in Portugal.

Subsequently, the percentages of products meeting or not EIPAS sugars and salt reference values, evaluating both nutritional components separately and jointly, were calculated for the plant-based and animal-origin products global data as well as for each food category, across both markets. However, considering the nutritional profile differences

Table 1
Food categories established for plant-based meat, fish and dairy alternatives and animal-origin products. Correspondent plant-based foods abbreviations and products included in each category.

Plant-based categories / Animal-origin categories	Plant-based categories abbreviation*	Plant-based categories description**
Burgers	BurgVeg	Meat or fish alternatives products appearing to mimic "burgers", "patties".
Sausages	SausVeg	Meat-alternatives products appearing to mimic "sausages", "hot dogs" "bangers", "chipolata".
Chorizo & similar products	ChorzVeg	Meat-alternatives products appearing to mimic "chourizo", "pepperoni", "sujuk".
Nuggets & similar breaded foods	NuggVeg	Meat or fish alternatives products appearing to mimic "nuggets", "fish fingers", "tenders", "bites", "escalope", "goujons", "schnitzel".
Meatballs	MeatBVeg	Meat or fish alternatives products appearing to mimic "meatballs".
Meat & minced meat & meat strips	MeatMSVeg	Meat or fish alternatives products appearing to mimic animal-origin products, including "steak", "beef", "chunks", "fillets", "strips", "tenderstrips", "pulled", "mince", "roll", "kebab".
Ham & charcuterie products	CharcVeg	Meat-alternatives products appearing to mimic "ham", "salami", "bacon", "lardons", "rashers", "pastrami".
Cheeses	CheesVeg	Dairy-alternatives products appearing to mimic cheese, including all types of "cheese slices", "spread/cream cheese" "grated cheese", "cheese shreds", "cheese cubs", "cheese blocks".
Yogurts	YogVeg	Dairy-alternatives products appearing to mimic solid or liquid "yogurt", "yogurt dessert".

*The abbreviation nomenclature for the animal-origin categories mirrors the ones used for plant-based products, excluding the "Veg" terminology.
**The description of the animal-based categories is a straightforward description of the products being mimicked.

between the non-dairy plant-based alternatives and animal-origin categories compared to the dairy plant-based alternatives and animal-origin categories, these percentages were also calculated separately for each food subtype created (plant-based; plant-based dairy alternatives; animal-origin; and animal-origin dairy) in both markets.

In the absence of a formally established national nutritional profile model - except for the one defined in the Law No 30/2019, that introduces restrictions on advertising to children under 16 for foods and drinks containing high levels of energy, salt, sugars, saturates, and processed fatty acids (Diário da República, 2019) - the EIPAS was chosen as it is one of the few officially recognized national initiatives that defined reference values for food reformulation. The EIPAS reference values serve as a reference framework due to their national relevance in improving the nutritional composition of food products available in the Portuguese market, and their goal of promoting healthier eating habits among the Portuguese population. Although these values were not originally defined for plant-based products, limiting their use in this context, they can still be applicable to all products, providing a meaningful assessment of the nutritional profile of both plant-based and animal-origin products available in the Portuguese and UK markets.

2.3.2. Nutrient content

Descriptive statistics, including the Mean, Standard Deviation, and Range for energy (kcal/100 g), fat, saturates, carbohydrates, sugars, fibre, protein, and salt (all in g/100 g) were carried out separately for the overall data of plant-based and animal-origin products from the PT and the UK markets. Similar statistical operations were performed across all the plant-based and animal-origin categories for both countries.

Additionally, an assessment for inconsistencies and errors was also conducted at this stage. This included verifying the minimum, median, and maximum values of the nutritional components across all categories to detect potential discrepancies or errors.

2.3.3. DGS label decoder reference values

The DGS label decoder was used to determine the percentage of food products that can be classified as low, medium and high in fat, saturates, sugars, and salt content according to the values referred in Fig. 1. This approach enabled further comparisons between plant-based and animal-origin products, as well as assessments of differences across the two country markets.

This tool was chosen because it is a simple and effective mean of assessing the nutritional quality of food products, and the reference values are common in both the Portuguese and UK markets. Unlike the EIPAS reference values, the Label Decoder is applicable to all types of food products, without limitations. However, despite this advantage and of being a very useful tool, it shares a limitation with EIPAS, as it does not allow for a more comprehensive evaluation of products, since it only provides reference values for fat (lipids), saturated fat, sugars, and salt content.

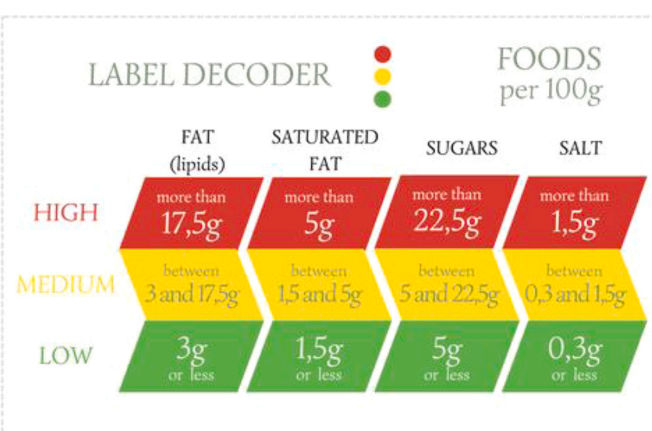

Fig. 1. Directorate-General for Health label decoder (DGS, 2018).

2.4. Statistical analysis

Statistical analysis was carried out using IBM® SPSS® Statistics (version 27). A Pearson's chi-squared test, with a 99.9 % degree of confidence was performed to evaluate de relationship/association between the food types, country markets, and their compliance with EIPAS criteria.

To compare the energy content and other nutritional components means of plant-based and animal-origin products, a Two-Way ANOVA or Welch test (when there was no homogeneity of variances of the tested dependent variable among groups) were conducted. In all cases, values were considered statistically significantly different when $p < 0.001$. Post hoc comparisons using Sidak (in Two-Way ANOVA) or Games Howell (in Welch test) tests were carried out.

3. Results

A total of 452 plant-based foods and 958 animal-origin counterparts from the Portuguese market as well as 718 plant-based and 1494 animal-origin products from the UK market were collected, grouped into nine categories (Burgers; Sausages Chorizo & similar products; Nuggets & similar breaded foods; Meatballs; Meat & minced meat & meat strips; Ham & charcuterie products; Cheeses; Yogurts), and evaluated both by food type (Plant-based; Plant-based dairy alternatives; Animal-origin; Animal-origin dairy), and by categories.

3.1. Compliance with EIPAS sugars and salt reference values

In the Portuguese market, the results showed that 97.0 % (N = 292) of the plant-based meat and fish alternatives were in accordance with the EIPAS reference value for sugars, but only 1.3 % (n = 4) met the values defined for salt. Regarding the plant-based dairy alternatives, 52.3 % (N = 79) and 63.6 % (N = 96) were in accordance with EIPAS sugars and salt reference values, respectively. However, when the sugar and salt contents were jointly evaluated, the results indicated that 98.7 % (N = 297) of the plant-based meat and fish alternatives and 81.5 % (N = 123) of the plant-based dairy alternatives did not meet the EIPAS criteria, compared to 96.0 % (427) and 79.5 % (N = 408) of the animal-origin counterparts (Table 2).

For the UK market, the results were very similar for the plant-based meat and fish alternatives, with 95.5 % (N = 510) meeting the EIPAS reference value for sugars, and only 1.1 % (n = 6) in accordance with the values defined for salt. For the dairy alternatives, opposite results were obtained, with 77.2 % (N = 142) meeting the sugars reference values, but only 37.5 % (N = 69) meeting the reference values for salt. Considering the EIPAS sugars and salt reference values jointly, the results were even more unfavorable for the plant-based products in the UK than in PT market, with 99.4 % (N = 531) of the plant-based meat and fish alternatives, and 83.7 % (N = 154) of the plant-based dairy alternatives not meeting the EIPAS criteria. Additionally, in the UK market, regarding the animal-origin foods, 89.8 % (N = 827) of the meat and fish products and 88.3 % (N = 506) of the dairy products failed to meet these reference values (Table 2).

Overall, with the exception of the dairy alternatives from the UK market, the plant-based foods had a statistically significantly lower prevalence of products in accordance with the EIPAS reference values compared to animal-origin products, when sugars and salt were jointly evaluated, as verified also by the observed and expected counts. Simultaneously, plant-based products in the Portuguese market overall had a higher proportion of accordance with EIPAS reference values compared to plant-based products of the UK market (Table 2).

There were statistically significant differences ($p < 0.001$) between

Table 2
Prevalence of observed and expected products in accordance with EIPAS sugars and salt reference values jointly evaluated, by food type and country.

	Country:	PT			UK		
		Accordance with EIPAS reference values			Accordance with EIPAS reference values		
Food type:		**YES**	**NO**	N	**YES**	**NO**	N
Plant-based	Observed counts N (%)	4_a (1.3 %)	297_b (98.7 %)	301	3_a (0.6 %)	531_b (99.4 %)	534
	Expected counts N*	29.0	272.0		51.5	482.5	
Plant-based dairy alternatives	Observed counts N (%)	28_a (18.5 %)	123_b (81.5 %)	151	30_a (16.3 %)	154_b (83.7 %)	184
	Expected counts N*	14.5	136.5		17.7	166.3	
Total observed plant-based food products N (%)		32 (7.1 %)	420 (92.9 %)	452	33 (4.6)	685 (95.4 %)	718
Animal-origin	Observed counts N (%)	18_a (4.0 %)	427_b (96.0 %)	445	94_a (10.2 %)	827_a (89.8 %)	921
	Expected counts N*	42.9	402.1		88.7	832.3	
Animal-origin dairy	Observed counts N (%)	105_a (20.5 %)	408_b (79.5 %)	513	67_a (11.7 %)	506_a (88.3 %)	573
	Expected counts N*	49.4	463.6		55.2	517.8	
Total observed animal-origin food products N (%)		123 (12.8 %)	835 (87.2 %)	958	161 (10.8 %)	1333 (89.2 %)	1494
Pearson's chi-squared test =		185.74					
p-value =		1.2e−36					

The observed counts are the simple size of a category. The expected counts (N*) are the sample size that we would expect to belong to each category, on average, if the proportions of products that comply with EIPAS (Integrated Strategy for the Promotion of Healthy Eating) reference values were independent of the attributed food type (Plant- based PT, Plant based dairy alternatives PT, Animal-origin PT, Animal-origin dairy PT, Plant- based UK, Plant-based dairy alternatives UK, Animal-origin UK, Animal-origin dairy UK).
p-value < 0.001 means there is a significant relationship between the attributed food group and the compliance with EIPAS (Integrated Strategy for the Promotion of Healthy Eating) reference values.
[a - a or a - b] → Different letters means significantly statistically different proportions of products that comply / do not comply with EIPAS (Integrated Strategy for the Promotion of Healthy Eating) reference values inside each food type group (z test with adjusted $p < 0.05$).
PT - Portugal; UK - United Kingdom.

Table 3
Prevalence of compliance of the products with EIPAS reference values, by category and country.

Country:	PT			UK		
	Accordance with EIPAS reference values			Accordance with EIPAS reference values		
Food category*	**YES** N (%)	**NO** N (%)	N	**YES** N (%)	**NO** N (%)	N
BurgVeg	1 (0.7 %)	133 (99.3 %)	134	0 (0 %)	128 (100 %)	128
Burg	13 (14.4 %)	77 (85.6 %)	90	1 (1.0 %)	101 (99 %)	102
SausVeg	0 (0 %)	40 (100 %)	40	0 (0 %)	90 (100 %)	90
Saus	0 (0 %)	100 (100 %)	100	1 (0.5 %)	184 (99.5 %)	185
ChorzVeg	3 (7.5 %)	37 (92.5 %)	40	0 (0 %)	21 (100 %)	21
Chorz	0 (0 %)	67 (100 %)	67	0 (0 %)	72 (100 %)	72
NuggVeg	0 (0 %)	33 (100 %)	33	0 (0 %)	102 (100 %)	102
Nugg	0 (0 %)	63 (100 %)	63	0 (0 %)	177 (100 %)	177
MeatBVeg	0 (0 %)	23 (100 %)	23	0 (0 %)	26 (100 %)	26
MeatB	2 (9.5 %)	19 (90.5 %)	21	0 (0 %)	55 (100 %)	55
MeatMSVeg	0 (0 %)	13 (100 %)	13	3 (2.8 %)	106 (97.2 %)	109
MeatMS	3 (17.6 %)	14 (82.4 %)	17	92 (83.6 %)	18 (16.4 %)	110
CharcVeg	0 (0 %)	18 (100 %)	18	0 (0 %)	58 (100 %)	58
Charc	0 (0 %)	87 (100 %)	87	0 (0 %)	220 (100 %)	220
CheeseVeg	2 (3.9 %)	49 (96.1 %)	51	2 (1.8 %)	108 (98.2 %)	110
Cheese	1 (1.0 %)	99 (99 %)	100	0 (0 %)	230 (100 %)	230
YogVeg	26 (26 %)	74 (74 %)	100	28 (37.8 %)	46 (62.2 %)	74
Yog	104 (25.2 %)	309 (74.8 %)	413	67 (19.5 %)	276 (80.5 %)	343

*Food category nominations - Table 1; PT - Portugal; UK - United Kingdom.

the observed and the expected counts for the majority of the food types and in both countries concerning the EIPAS criteria, as demonstrated by the Z-test. Only the animal-origin products from the UK market exhibited no statistically significant differences (Table 2).

The Pearson's chi-squared test results obtained suggest a highly statistically significant association between the compliance with EIPAS criteria (sugars and salt contents) and food types of country markets. The reported *p-value*, which is substantially less than 0.001 ($p = 1.2e\text{-}36$) (Table 2), indicates a significant difference between the subsets of EIPAS accordance proportions across the food types and country markets analysed, which is interpreted as evidence of a significant association between the variables. This means that the accordance with EIPAS reference values depends significantly on the considered food type (plant-based non-dairy and dairy alternatives and their animal-origin equivalents, for each country).

3.1.1. Compliance with EIPAS sugars and salt reference values by food category

Regarding the nine plant-based food categories evaluated, it was observed that only four categories in the PT market: BurgVeg (0.7 %), ChorzVeg (7.5 %), CheeseVeg (3.9 %), and YogVeg (26 %); and three categories in the UK market: MeatMSVeg (2.8 %), CheeseVeg (1.8 %), and YogVeg (37.8 %) had products meeting the EIPAS sugars and salt reference values, when both parameters were simultaneously evaluated. The prevalence of compliance did not exceed 26.0 % in the PT market and 37.8 % in the UK market, for the same food category (YogVeg) (Table 3).

In comparison, the corresponding animal-origin food categories showed somewhat better results, with five and four out of nine food categories with products meeting the EIPAS reference values in the PT and UK markets, respectively: PT market - Burg (14.4 %), MeatB (9.5 %), MeatMS (17.6 %), Cheese (1.0 %), and Yog (25.2 %); and UK market - Burg (1.0 %), Saus (0.5 %), MeatMS (83.6 %), and Yog (19.5 %). Thus, EIPAS compliance, by food category, reached a maximum of 25.2 % in the PT market for the Yog category, and 83.6 % and 19.5 % for the MeatMS and Yog categories, respectively, in the UK market (Table 3).

3.2. Evaluation of the nutritional composition of plant-based and animal-origin products

The statistical analysis of the key nutritional parameters for the overall plant-based and animal-origin processed foods (Table 4) highlights distinct differences between these product types, including subtypes of plant-based non-dairy and dairy alternatives, and animal-origin foods, within and between the two markets.

In the Portuguese market, non-dairy plant-based products exhibited higher average levels of energy, carbohydrates, sugars, and fibre than their animal-origin counterparts, while showing lower average levels of saturates and salt, potentially indicating a nutritional advantage. Conversely, dairy plant-based alternatives presented, on average, a less favorable nutritional profile, with higher average levels of energy, fat, saturates, carbohydrates, fibre, and salt, compared to the dairy animal-origin equivalents. For both subtypes of plant-based products a lower average protein content compared to their animal-origin counterparts was observed. Additionally, while the average sugar content in non-dairy and dairy plant-based alternatives was below the EIPAS reference value ($\leq$ 5 g/100 g), the average salt content was considerably higher than the corresponding EIPAS reference value ($\leq$ 0.3 g/100 g) (Table 4).

In the UK market, non-dairy plant-based alternatives exhibited lower average levels of energy, fat, saturates (less than half average content), proteins, and salt than their animal-origin counterparts, as well as higher average contents of carbohydrates, sugars (twice as much) and fibre. The dairy plant-based alternatives in the UK market exhibited higher average levels of energy, fat, saturates, carbohydrates, fibre, and salt than their animal-origin dairy equivalents, while showing lower average levels of sugars and protein (more than four times lower).

When comparing the two markets, non-dairy plant-based alternatives from the Portuguese market exhibited higher average energy value and higher contents of fat, carbohydrates, sugars and salt, indicating a worse nutritional profile. In contrast, the dairy plant-based alternatives from the Portuguese market showed lower average energy value and also lower contents of fat, saturates, carbohydrates, fibre and salt (Table 4).

In the UK market, non-dairy and dairy plant-based alternatives exhibited a similar trend in relation to the EIPAS reference values, with average sugars content below and salt content above the respective thresholds.

The ranges of energy values and nutrient contents are notably broad across food types, subtypes and markets, reflecting substantial variability (Table 4).

3.2.1. Nutritional composition of plant-based and animal-origin products by category across markets

The descriptive statistics of the energy content and nutritional parameters values for the different plant-based and animal-origin food categories in both countries (Table 5) reveals several insights:

- *Energy*: in the Portuguese market, plant-based products, compared to their animal-origin equivalents, had higher energy content in five out of nine categories. In the UK market, this trend was observed in four out of nine categories. There were no statistically significant differences between the average energy values for the two countries across all the plant-based categories. Statistically significant differences were just observed in the animal-origin categories Burg, Saus, Chorz, Cheese and Yog.
- *Fat*: plant-based products compared with their counterparts showed statistically significant differences between the average fat content in just three out of nine categories in each market. In the PT market NuggVeg and YogVeg had higher fat content than their animal-origin counterparts and ChorzVeg presented three times less fat content than Chorz. In the UK market statistically significant differences were observed in the BurgVeg, SausVeg, and ChorzVeg categories and their animal-origin equivalents, with BurgVeg presenting higher fat average content, while SausVeg and ChorzVeg displayed lower average fat content. Statistically significant differences between countries (PT vs UK) were observed for average fat values in the following categories: Burg (10.0 g/100 g vs 4.8 g/100 g), SausVeg (5.4 g/100 g vs 4.3 g/100 g), Saus (7.1 g/100 g vs 6.1 g/100 g), Chorz (10.9 g/100 g vs 8.2 g/100 g), and Yog (2.1 g/100 g vs 3.0 g/100 g).
- *Saturates*: plant-based alternatives consistently exhibited lower average saturates content in both markets, particularly in the BurgVeg, SausVeg, ChorzVeg, and MeatMSVeg categories. For example, the average saturates content in the ChorzVeg category was more than five times lower than in animal-origin Chorz in the Portuguese market, and more than three times lower in the UK market. Similarly, this lower average saturates level was also observed for the MeatBVeg and CharcVeg categories in the UK market. Exceptions to this trend were noted in NuggVeg, CharcVeg and YogVeg in the Portuguese market and in NuggVeg and YogVeg in the UK market. The CheeseVeg and Cheese categories exhibited parallel trends, with high average saturates level in both markets (> 5 g/100 g). Statistically significant differences between countries were observed exclusively for two animal-origin categories, with the Portuguese market presenting more favorable nutritional values.
- *Carbohydrates:* plant-based products exhibited considerably higher carbohydrate content compared to their animal-origin counterparts in both countries for all categories except YogVeg. This is attributed in part to the higher contents of sugars.
- *Sugars*: the non-dairy plant-based food categories across both markets exhibited higher average sugars values than their animal-origin counterparts, but statistically significant differences between categories were just observed in BurgVeg, ChorzVeg and MeatBVeg for the PT market; and BurgVeg, ChorzVeg, NuggVeg, MeatMSVeg and CharcVeg for UK market. For example, in the Portuguese market, the average sugars content in BurgVeg and MeatBVeg was three times higher than in their animal-origin equivalents. However, the YogVeg category in both markets presented lower average sugars levels compared to their counterparts. Despite this, the YogVeg category showed sugars values above the EIPAS reference threshold ($\leq$ 5 g/100 g). There were no statistically significant differences between the average sugars values for the two countries across all the plant-based categories.
- *Fibre*: plant-based products exhibited considerably higher fibre content compared to their animal-origin counterparts in both countries for the majority of the categories. Statistically, no significant differences were observed between countries for this parameter in the plant-based categories except for SausVeg.
- *Protein*: plant-based products exhibited lower average protein content than their animal-origin counterparts in four categories in the PT market and six categories in the UK market. This difference was most notable in categories such as CheeseVeg/ Cheese for both markets (by 100 g, PT: 3.9 $\pm$ 5.6 g vs 19.9 $\pm$ 7.3 g; UK: 3.1 $\pm$ 5.5 g vs 22.3 $\pm$ 6.4 g), as well as in YogVeg / Yog, BurgVeg / Burg and MeatBVeg / MeatB (UK market). However, the NuggVeg in the Portuguese market showed higher average protein values. There were no statistically significant differences between the average protein values for the two countries across all the plant-based categories.

Table 4
Descriptive statistics of nutritional parameters for the overall data of plant-based and animal-origin processed foods, by country.

	Energy (kcal) & Nutritional components (g) (per 100 g or 100 ml)															
	Energy		**Fat**		**Saturates**		**Carbohydrates**		**Sugars**		**Fibre**		**Protein**		**Salt**	
Country:	**PT**	**UK**	**PT**	**UK**	**PT**	**UK**	**PT**	**UK**	**PT**	**UK**	**PT**	**UK**	**PT**	**UK**	**PT**	**UK**
Food type	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)
Plant-based	216	209	11.1	10.2	2	2.1	13.2	11.2	2	1.8	4.5	4.7	13.7	16	1.42	1.30
	48	50	5.1	4.9	2.4	2.2	9	7	1.4	1.6	3	2	7	8	0.62	0.58
	104–358	84–444	0–31	0.3–38	0–19	0.1–18	0.5–47.1	0.2–33.7	0–5.8	0–12	0–23	0–19	0.7–35	2–52	0.03–3.60	0.01–5.10
	301	534	301	534	301	534	301	534	301	534	246	463	301	534	301	534
Plant-based dairy	160	220	10.7	16.9	6.6	11.7	12.7	13.7	4.8	2.6	1.2	1.4	3	2.8	0.64	1.06
	96	119	4.6	11.1	3.5	9.1	12	8	4.5	3.5	1	1	2	4	0.15	0.90
	35–648	42–545	1.3–56	1.7–46.5	0.2–26	0.2–30.7	0–45	0–40.4	0–14	0–12.5	0–8.6	0–5.6	0–20	0–26.1	0.01–3.50	0.00–3.60
	151	184	151	184	151	184	151	184	151	184	86	119	151	184	151	184
Total plant-based foods	197	212	11.0	11.9	3.6	4.5	13.0	11.9	2.9	2	3.6	4	10.1	12.6	1.16	1.24
	85	74	7.7	7.6	5.4	6.5	9	7	3	2.3	3	3	8	9	0.80	0.69
	35–648	42–545	0–56	0.3–46.5	0–26	0.1–30.7	0–47.1	0–40.4	0–14	0–12.5	0–23	0–19	0–35	0–52	0.01–3.60	0.00–5.10
	452	718	452	718	452	718	452	718	452	718	332	582	452	718	452	718
Animal-origin	208	231	13.4	14.4	4.9	5	5.9	5.8	0.9	0.9	0.9	0.9	15.6	19.2	1.8	1.51
	99	88	10.4	9.9	4.2	4.3	7.2	6.6	0.8	1	1	0.9	4.8	5.3	1.08	1.20
	67–629	87–506	0.6–65	0.7–48	0–20.3	0.1–43	0–34.5	0–26	0–5.1	0–10	0–7.8	0–11.4	5.7–38	8.3–51.2	0–6.50	0.1–12.00
	445	921	445	921	445	921	445	921	445	921	177	812	445	921	445	921
Animal-origin dairy	118	189	6.4	13	4.3	8.4	8.1	6.6	7.6	5.5	0.3	0.4	6.9	11.4	0.38	0.74
	101	137	9.6	13	6.5	8.5	5	5.3	5	4.9	0.5	0.5	7.3	9.9	0.57	0.85
	8–469	27–530	0–41	0–42	0–28	0–28	0–21.7	0–25.5	0–20.8	0–21.4	0–3.6	0–4.6	1.8–33	1.3–43.5	0.04–3.70	0–5.00
	513	573	513	573	513	573	513	573	513	573	234	406	513	573	513	573
Total animal-origin foods	160	215	9.7	13.9	4.6	6.4	7.1	6.1	4.5	2.7	0.5	0.7	10.9	16.2	1.04	1.22
	110	111	10.6	11.2	5.6	8.3	6.2	6.2	5	3.8	0.8	0.8	7.6	8.3	1.10	1.14
	8–629	27–530	0–65	0–48	0–28	0–43	0–34.5	0–26	0–20.8	0–21.4	0–7.8	0–11.4	1.8–38	1.3–51.2	0–6.50	0–12.00
	958	1494	958	1494	958	1494	958	1494	958	1494	411	1218	958	1494	958	1494

*The total number of products (N) for the fibre content is different from the number of products for the other nutritional components evaluated. This is due to the non-mandatory nature of this information on the label.
PT - Portugal; UK - United Kingdom.
SD - Standard deviation

Table 5
Descriptive statistics of nutritional parameters for the different plant-based and animal-origin food categories, by country.

	Energy (kcal) & Nutritional components (g) (per 100 g or 100 ml)															
	Energy		Fat		Saturates		Carbohydrates		Sugars		Fibre		Protein		Salt	
Country:	PT	UK	PT	UK	PT	UK	PT	UK	PT	UK	PT	UK	PT	UK	PT	UK
Food category:	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)
BurgVeg (N * =262)	a 202 39.6 124–324 134	a 208 40.4 107–356 128	a 9.5 3.7 3.4–22 134	a 10.8 4.2 1.5–25 128	a 1.6 1.2 0.4–6.5 134	a 2.5 2.9 0.2–18 128	a 14.5 7.5 1.9–34.2 134	a 13.4 7.6 1.8–33.7 128	a 2.2 1.3 0–5.5 134	a 1.9 1.5 0–6.3 128	a 4.8 2.6 0–13.9 121	a 4.8 1.8 0.5–9.7 118	a 12.5 5.6 0.9–27 134	a 12.1 6.3 2.3–33 128	a 1.19 0.38 0.03–2.10 134	a 1.09 0.36 0.01–2.10 128
		c		c		c		c		c		c		c		c
Burg (N * =192)	b 175 49.3 76–307 90	b 233 45.8 109–364 102	b 10.0 5.7 0.7–24 90	b 14.8 5.7 1.6–33.7 102	b 4.1 2.8 0–12 90	b 6.3 2.7 0.5–14.7 102	b 3.7 3.6 0–19 90	b 4.0 3.2 0–20 102	b 0.7 0.6 0–3.9 90	b 0.8 1.0 0–6.6 102	b 1.0 0.9 0–4.9 39	b 0.7 0.6 0–5 97	b 17.2 3.2 10–29 90	b 20.8 3.4 11–28 102	a 0.96 0.48 0.00–2.10 90	b 0.86 0.28 0.10–2.30 102
		d		d		d		c		c		c		d		c
SausVeg (N * =130)	a 241 41.1 143–331 40	a 209 47.1 107–322 90	a 17.4 5.4 3.4–31 40	a 11.2 4.3 0.7–23 90	a 2.2 1.1 0.4–7 40	a 2.3 2.2 0.1–9.3 90	a 4.4 4.1 0.5–20 40	a 8.2 4.5 1.8–21 90	a 1.1 1.2 0–5.2 40	a 1.6 1.2 0–7.3 90	a 2.4 2.1 0–6.6 23	a 4.9 2.3 0–12 65	a 15.7 6.1 5.6–30.6 40	a 16.7 7.9 3.6–36.5 90	a 1.75 0.48 0.90–3.00 40	a 1.49 0.44 0.83–3.40 90
		c		d		c		d		c		d		c		c
Saus (N * =285)	b 191 65.1 67–384 100	b 253 49.3 109–378 185	a 14.7 7.1 0.6–37 100	b 18.4 6.1 2.5–32.5 185	b 5.6 3.3 0.3–20.3 100	b 6.6 2.3 0.8–11.6 185	a 2.2 1.6 0–10 100	a 6.4 4.4 0.2–18.3 185	a 0.6 0.4 0–2 100	a 1.5 1.6 0–9.5 185	b 0.3 0.4 0–2.2 41	b 1.2 0.7 0–3.5 163	a 12.6 2.3 8–19 100	a 15.0 2.9 8.3–24.2 185	a 1.86 0.43 0.80–3.60 100	b 1.40 0.34 0.30–2.90 185
		d		d		c		d		d		d		d		d
ChorzVeg (N * =61)	a 218 52.3 106–312 40	a 245 59.7 151–444 21	a 9.3 4.2 0.6–20 40	a 11.9 7.9 2.7–38 21	a 2.0 2.8 0–17 40	a 3.6 3.4 0.5–9.3 21	a 15.2 7.2 0.5–28 40	a 9.7 5.4 4.2–24.7 21	a 2.3 1.6 0.1–5.8 40	a 2.4 1.2 0.7–5.8 21	a 4.0 2.7 0–9 33	a 4.4 4.5 0–16.5 15	a 16.0 7.0 3–27 40	a 23.5 9.9 7.2–36 21	a 1.76 0.95 0.04–3.35 40	a 2.11 0.88 1.20–5.10 21
		c		c		c		c		c		c		c		c
Chorz (N * =139)	b 357 93.6 139–629 67	b 417 69.2 261–502 72	b 28.1 10.9 5.7–65 67	b 35.2 8.2 9.8–46 72	b 10.6 3.9 1.9–17.5 67	b 12.9 3.5 0.8–18 72	b 5.9 8.7 0–34.5 67	b 2.0 1.5 0.2–9.5 72	b 1.0 0.9 0–4.7 67	b 1.1 0.9 0–3.5 72	a 1.8 2.6 0–7.8 14	a 1.1 0. 8 0–4.4 54	a 19.3 6.2 6.1–37 67	a 22.6 3.7 14–30.4 72	b 2.95 0.94 0.90–4.90 67	b 3.52 0.67 1.10–5.40 72
		d		d		c		c		c		c		c		d
Food category:	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)
NuggVeg (N * =135)	a 260 47.7 177–358 33	a 234 40.3 118–330 102	a 13.1 4.1 6–21.4 33	a 12.0 4.0 4.9–21.1 102	a 3.6 4.0 0.6–13.3 33	a 1.6 0.9 0.4–5.7 102	a 22.1 11.5 1.2–47.1 33	a 19.6 4.8 6.8–32 102	a 1.8 1.1 0.5–4.3 33	a 1.8 1.6 0.1–9.6 102	a 4. 1 2.4 0.5–9.1 29	a 4.2 1.7 0.4–11 99	a 12.3 6.2 2.4–24 33	a 10.3 4.2 2–21.5 102	a 1.33 0.42 0.64–2.20 33	a 1.08 0.34 0.36–2.00 102

(*continued on next page*)

Table 5 (*continued*)

		c		c		c		c		c		c		c		c
Nugg	b	a	b	a	a	a	a	b	a	b	b	b	b	b	a	b
(N * =240)	212	224	9.6	10.5	1.6	1.5	19.1	17.1	1.3	0.9	1.3	1.4	11.8	14.6	1.00	0.79
	38.7	31.0	3.3	3.3	0.8	1.0	4.9	4.2	1.0	0.5	0.6	1.1	2.9	2.8	0.33	0.32
	138–291	150–324	1.2–17.1	2.5–21.8	0.3–4.4	0.4–8.6	7.8–28	2.4–26	0–5.1	0–4.4	0–3	0.4–11.4	5.7–18	9–23.3	0.50–2.20	0.38–2.80
	63	177	63	177	63	177	63	177	63	177	46	163	63	177	63	177
		c		c		c		c		c		c		d		d
MeatBVeg	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
(N * =49)	206	190	11.0	10.5	1.5	2. 5	12.8	8.0	2.1	1. 6	6.0	5.2	10.9	13.5	1.07	1.10
	40.1	38.3	3.8	4.5	1.0	2.4	6.8	3.5	1.2	1.6	3.2	2.3	5.8	3.1	0.27	0.27
	131–269	107–251	2.8–18	4.6–21	0.3–5.2	0.5–10	2–24	0.8–20	0.1–4.2	0.1–7.3	2.4–14	0.8–11	4–22	5.8–18	0.50–1.70	0.61–1.80
	23	26	23	26	23	26	23	26	23	26	17	24	23	26	23	26
		c		c		c		c		c		c		c		c
MeatB	a	a	a	a	a	b	a	a	b	a	b	b	a	b	a	a
(N * =76)	191	211	11.2	12.4	4.4	4.9	6.7	4.7	0.7	0.9	1.1	0.9	15.6	19.9	0.95	1.12
	54.7	46.4	6.3	5.5	3.2	2.5	5.8	3.2	0.7	1.4	1.0	1.2	2.0	3.6	0.42	1.53
	107–301	110–325	2.1–25.7	2.4–25.6	0–10.5	0.1–11	0–23	0–16.1	0–3.1	0–10	0.5–3.3	0–6	12.6–18	12–25.3	0.00–1.70	0.39–12.00
	21	55	21	55	21	55	21	55	21	55	8	49	21	55	21	55
		c		c		c		c		c		c		d		c
MeatMSVeg	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
(N * =122)	168	190	6.6	7.5	1. 3	1.6	4.3	7.0	1.2	1.9	5.3	5. 1	19.8	20.9	1.15	1.16
	40.8	55.5	4.6	4.8	1.5	1.9	2.9	4.6	1.3	2.1	1.8	2.9	2.6	7.8	0.33	0.54
	104–246	84–354	0–17	0.3–18	0–5.7	0.1–13	1.5–11.7	0.2–21	0–4.1	0–12	1.5–8	0.6–19	15–24.5	5.1–52	0.70–1.80	0.05–3.70
	13	109	13	109	13	109	13	109	13	109	11	95	13	109	13	109
		c		c		c		c		c		c		c		c
MeatMS	a	a	a	a	b	b	a	b	a	b	b	b	a	a	a	b
(N * =127)	180	178	10.8	9.5	5.0	4.3	3.5	0.7	0.5	0.4	0.8	0.4	17.3	22.5	0.69	0.28
	43.1	51.7	4.9	6.3	2.6	4.8	3.6	1.2	0.5	0.4	0.3	0.6	1.6	4.3	0.47	0.24
	106–239	102–377	2.9–17.5	1.1–31	1.4–9.2	0.3–43	0–16	0–7.1	0–1.5	0–3	0.5–1.1	0–5.8	14.7–21	13.3–36	0.00–1.70	0.10–1.50
	17	110	17	110	17	110	17	110	17	110	4	104	17	110	17	110
		c		c		c		c		c		c		d		c
Food category:	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)	(Mean) (SD) (Range) (N)
CharcVeg	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
(N * =76)	218	200	12.7	8.7	3.4	1.7	8.8	6.4	1.9	1.5	5.1	3.9	16.0	22.4	2.39	1.95
	46.4	55.1	5.9	5.3	5.5	1.6	6.2	2.9	1.3	1.0	5.8	2.3	12. 0	7.7	0.68	0.76
	143–296	87–399	2.6–21	0.6–29.4	0.4–19	0.1–6	1–22	1.3–14	0.4–4.3	0.3–4.2	1.6–23	0–8.5	0.7–35	7.1–35	1.50–3.60	0.80–3.80
	18	58	18	58	18	58	18	58	18	58	12	47	18	58	18	58
		c		c		c		c		c		c		c		c
Charc	b	a	a	a	a	b	a	b	a	b	a	b	a	b	a	b
(N * =307)	152	187	8.0	10.2	3.0	3. 7	3.0	1.2	1. 0	0.8	0.4	0.5	17.0	22.6	2.72	2.54
	108.1	98.1	11.2	10.2	4.2	4.0	2.3	0.9	0.7	0.8	0.4	0.4	5.3	5.3	1.11	1.10
	76–473	87–506	0.6–42	0.7–48	0.1–17	0.2–18	0–11	0–5.7	0–3.6	0–4.5	0–1	0–3	9.5–38	11.5–51.2	1.10–6.50	0.84–5.40
	87	220	87	220	87	220	87	220	87	220	25	182	87	220	87	220
		c		c		c		d		c		c		d		c
CheeseVeg	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
(N * =161)	312	305	24.4	24.9	15.4	17.6	19.1	16. 9	0.7	0. 5	1.4	1.8	3.9	3.1	1.63	1.68
	89.1	70.0	8.5	6.0	7.1	6.6	9.7	7.6	1.3	0.8	1.9	1.6	5.6	5.5	0.79	0.63
	179–648	150–545	7.2–56	13–46.5	1.3–26	1–30.7	3–45	0.1–40.4	0–5	0–5	0–8.6	0–5.6	0–20	0–26.1	0.01–3.50	0.05–3.60
	51	110	51	110	51	110	51	110	51	110	28	72	51	110	51	110
		c		c		c		c		c		c		c		c
Cheese	a	b	a	a	a	a	b	b	a	a	a	b	b	b	a	a
(N * =330)	308	342	24.6	27.4	16.7	18. 6	1. 8	1.6	1.1	0.8	0.2	0.3	19.9	22.3	1.43	1.66
	68.8	78.1	6.4	7.8	4.5	13.5	1.6	2.0	1.6	1.4	0.2	0.5	7.3	6.4	0.52	0.60

(*continued on next page*)

Table 5 (*continued*)

	142–469	85–530	10–41	2.5–42	6.7–28	1.3–207	0–6.5	0–10.7	0–6.5	0–6.8	0–1	0–2.7	4.1–33	3.8–43.5	0.10–3.70	0.20–5.00
	100	230	100	230	100	230	100	230	100	230	35	188	100	230	100	230
		d		c		c		c		c		c		c		c
YogVeg	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
(N * =174)	83	95	3.7	5.0	2.2	3.0	9.4	9.1	6. 9	5.8	1.1	1.0	2.5	2.4	0. 13	0.14
	22.8	37.4	2.4	3.8	2.8	4.0	4.5	4.8	3.8	3.6	0.8	0.6	1. 7	1.6	0.12	0.11
	35–134	42–219	1.3–11.9	1.7–19	0.2–10.5	0.2–16	0–19	0–17	0–14	0–12.5	0.1–4.5	0.1–2.5	0.2–6.4	0.2–5.8	0.01–0.60	0.00–0.43
	100	74	100	74	100	74	100	74	100	74	58	47	100	74	100	74
		c		c		c		c		c		c		c		c
Yog	a	a	b	a	a	a	a	a	b	b	b	b	b	b	a	a
(N * =756)	72	87	2.0	3.3	1. 4	2.1	9.7	9.9	9.2	8.7	0.3	0.5	3.7	4.2	0. 12	0.13
	28.6	34.2	2.1	3.0	1.5	2.0	4.3	4.2	4.2	3.7	0.5	0.5	1.5	1.9	0.03	0.08
	8–157	27–193	0–10	0–11.4	0–13	0–7.6	0.5–21.7	1.1–25.5	0.2–20.8	1.6–21.4	0–3.6	0–4.6	1.8–10	1.3–12.2	0.04–0.35	0.00–1.12
	413	343	413	343	413	343	413	343	413	343	199	218	413	343	413	343
		d		d		d		c		c		d		d		c

			Energy (kcal) & Nutritional components (g) (per 100 g or 100 ml)							
			Energy	**Fat**	**Saturates**	**Carbohydrates**	**Sugars**	**Fibre**	**Protein**	**Salt**
	Food category:	**Country:**	**PT UK**	**PT UK**	**PT UK**	**PT UK**	**PT UK**	**PT UK**	**PT UK**	**PT UK**
Sidak (in Two-Way ANOVA)[1]	Burg	BurgVeg	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]
or	Saus	SausVeg	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]
Sidak (in Two-Way ANOVA)[1] & Games Howell (in Welch)[2]	Chorz	ChorzVeg	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]
	Nugg	NuggVeg	**< 0.001**[2]	**< 0.001**[2]	0.044[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]
	MeatB	MeatBVeg	0.089[1]	0.299[1]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	0.927[1]
	MeatMS	MeatMSVeg	0.199[1]	0.011[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]
	Charc	CharcVeg	**< 0.001**[2]	0.037[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]
	Cheese	CheesVeg	**< 0.001**[2]	0.002[2]	0.562[1]	**< 0.001**[2]	0.002[2]	**< 0.001**[2]	**< 0.001**[2]	0.002[2]
	Yog	YogVeg	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	0.326[1]	**< 0.001**[2]	**< 0.001**[2]	**< 0.001**[2]	0.416[2]

*The total number of products (N) for the fibre content, by category, is different from the number of products for the other nutritional components evaluated. This is due to the non-mandatory nature of this information on the label

Sidak's multiple comparison test was used for comparing plant-based and animal-origin means. Values were considered statistically significant different when $p < 0.001$.

Comparison: 1) between categories [a - a or a - b] → different letters indicates statistically significant differences; 2) between countries [c or d] → c - indicates no statistically significant differences; d - indicates statistically significant differences.

PT - Portugal; UK - United Kingdom. SD - Standard deviation.

Table 6
Percentages of overall plant-based and animal-origin products, as well as by subtype (Non-dairy and Dairy) classified as having "High," "Medium," and "Low" levels for the different assessed nutritional parameters, based on the reference values of the DGS label decoder, by country.

Country market		PT		UK		PT				UK			
Food type/ Subtype		Total plant-based (N = 452) N (%)	Total animal-origin (N = 958) N (%)	Total plant-based (N = 718) N (%)	Total animal-origin (N = 1494) N (%)	Plant-based (N = 301) N (%)	Plant-based dairy alternatives (N = 151) N (%)	Animal-origin non-dairy (N = 445) N (%)	Animal-origin dairy (N = 513) N (%)	Plant-based (N = 534) N (%)	Plant-based dairy alternatives (N = 184) N (%)	Animal-origin non-dairy (N = 921) N (%)	Animal-origin dairy (N = 573) N (%)
Fat	High (>17.5 g)	80 (17.7)	198 (20.7)	132 (18.4)	498 (33.3)	38 (12.6)	42 (27.8)	114 (25.6)	84 (16.4)	30 (5.6)	102 (55.4)	297 (32.2)	201 (35.1)
	Medium (>3 - ≤17.5 g)	304 (67.3)	367 (38.3)	513 (71.4)	690 (46.2)	257 (85.4)	47 (31.1)	259 (58.2)	108 (21.1)	461 (86.3)	52 (28.3)	525 (57.0)	165 (28.8)
	Low (≤3 g)	68 (15.0)	393 (41.0)	73 (10.2)	306 (20.5)	6 (2.0)	62 (41.1)	72 (16.2)	321 (62.6)	43 (8.1)	30 (16.3)	99 (10.7)	207 (36.1)
Saturates	High (>5 g)	82 (18.1)	297 (31.0)	162 (22.6)	683 (45.7)	20 (6.6)	62 (41.1)	181 (40.7)	116 (22.6)	43 (8.1)	119 (64.7)	420 (45.6)	263 (45.9)
	Medium (>1.5 - ≤5 g)	128 (28.3)	235 (24.5)	181 (25.2)	367 (24.6)	104 (34.6)	24 (15.9)	130 (29.2)	105 (20.5)	160 (30.0)	21 (11.4)	238 (25.8)	129 (22.5)
	Low (≤1.5 g)	242 (53.5)	426 (44.5)	375 (52.2)	444 (29.7)	177 (58.8)	65 (43.0)	134 (30.1)	292 (56.9)	331 (62.0)	44 (23.9)	263 (28.6)	181 (31.6)
Sugars	High (>22.5 g)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Medium (>5 - ≤22.5 g)	81 (17.9)	313 (32.7)	66 (9.2)	295 (19.7)	9 (3.0)	72 (47.7)	1 (0.2)	312 (60.8)	24 (4.5)	42 (22.8)	12 (1.3)	283 (49.4)
	Low (≤5 g)	371 (82.1)	645 (67.3)	652 (90.8)	1199 (80.3)	292 (97.0)	79 (52.3)	444 (99.8)	201 (39.2)	510 (95.5)	142 (77.2)	909 (98.7)	290 (50.6)
Salt	High (>1.5 g)	131 (29.0)	272 (28.4)	192 (26.7)	465 (31.1)	100 (33.2)	31 (20.5)	243 (54.6)	29 (5.7)	132 (24.7)	60 (32.6)	319 (34.6)	146 (25.5)
	Medium (>0.3 - ≤1.5 g)	221 (48.9)	255 (26.6)	451 (62.8)	594 (39.8)	197 (65.4)	24 (15.9)	184 (41.3)	71 (13.8)	396 (74.2)	55 (29.9)	508 (55.2)	86 (15.0)
	Low (≤0.3 g)	100 (22.1)	431 (45.0)	75 (10.4)	435 (29.1)	4 (1.3)	96 (63.6)	18 (4.0)	413 (80.5)	6 (1.1)	69 (37.5)	94 (10.2)	341 (59.9)

DGS - Directorate-General for Health
PT - Portugal; UK - United Kingdom.

- *Salt*: the average salt content in plant-based products was higher than in their animal-origin equivalents just in one category in the Portuguese market and in six categories in the UK market. The SausVeg category, in the Portuguese market, as well as the ChorzVeg, CharcVeg and CheeseVeg categories in both markets exhibited high average salt contents (> 1.5 g/100 g). The CharcVeg category in the Portuguese market and the ChorzVeg in the UK market exhibited the highest salt levels, with 2.39 g/ 100 g and 2.11 g/100 g, respectively.

  Statistically, no significant differences were observed between countries for salt content in the plant-based categories. With the exception for YogVeg / Yog categories, all plant-based and animal-origin categories showed average salt levels exceeding the EIPAS reference threshold (≤ 0.3 g/100 g) in both markets.
- None of the eighteen food categories complied with the EIPAS reference values when the average levels of sugars and salt were evaluated together, despite some of the products included in these categories meeting the reference values, as previously showed (Section 3.1.1).
- Considerable variation in energy values and nutrient contents per 100 g was observed within the same category for both plant-based processed foods and animal-origin products across the two markets, as evidenced by the broad ranges presented in Table 5.

Statistically significant differences in the evaluated nutritional parameters between plant-based and animal-origin food categories across the two markets were observed in the majority of the cases. No significant differences were observed in just 18.1 % of the cases, across six food categories (NuggVeg /Nugg, MeatBVeg /MeatB, MeatMSVeg /MeatMS, CharcVeg /Charc, CheeseVeg /Cheese, YogVeg /Yog) and nutrient components (energy, fat, saturates, carbohydrates, sugars, and salt). Regarding fibre and protein, statistically significant differences were exhibited for all food categories across the markets. This suggests that, while food type is the primary driver of nutritional differences, the specific characteristics of these products also exhibit significant variability between countries for most evaluated parameters.

3.3. Classification of the food products based on the DGS label decoder reference values, by country

The use of the DGS label decoder thresholds (Fig. 1) yielded the percentages of plant-based and animal-origin products classified as low, medium and high in fat, saturates, sugars and salt for both countries (Table 6). Although in previous analyses non-dairy and dairy alternatives were considered in separate, they were grouped here (Table 6) to provide a more comprehensive overview of the totality of products under each nutritional parameter classification.

The percentage of the overall plant-based products classified as having high content in fat, saturates and salt was generally lower compared to their animal-origin counterparts. The only exception to this trend was observed in the Portuguese market, where the percentage of products with high salt content was similar (29.0 % vs 28.4 %). The plant-based non-dairy alternatives exhibited a higher percentage of products with high salt content than the dairy alternatives (33.2 % vs 20.5 %).

Regarding fat content in the Portuguese market, although overall plant-based products had a slightly lower percentage of foods classified as “High” in fat content compared to animal-origin equivalents (17.7 % vs 20.7 %), overall animal-origin products had a considerably higher proportion of "Low" fat content products (41.0 % vs 15.0 %). The plant-based dairy alternatives contributed with 27.8 % of the products with high fat content. The percentage of the overall plant-based products classified as having high fat content is almost similar in both countries. However, the Portuguese market showed a slightly higher percentage of products with low fat content compared to the UK market (15.0 % vs 10.2 %).

The percentage of products classified as "High" in saturates was notably higher for the animal-origin products across both markets (PT: 31.0 % vs 18.1 %; UK: 45.7 % vs 22.6 %). Simultaneously, compared to their animal-origin counterparts, the majority of plant-based products were classified as "Low" in saturates, with similar percentages across both markets (PT: 53.5 % vs 44.5 %; UK: 52.2 % vs 29.7 %). It is important to highlight that 41.1 % and 64.7 % of plant-based dairy alternatives in the PT and UK market, respectively, had high saturates levels.

In relation to sugars, both markets showed no overall plant-based or animal-origin products classified as "High" in sugars (0.0 %). However, a higher percentage of plant-based products were classified as "Low" in sugars content compared to their animal-origin counterparts. This percentage was more pronounced in the UK market (PT: 82.1 % vs UK: 90.8 %), particularly in plant-based dairy alternatives (PT: 52.3 % vs UK: 77.2 %).

The percentage of plant-based products classified as "High" in salt was the most notable among the four nutritional parameters evaluated, reaching nearly 30 % in both markets, and closely aligned with the percentages observed for the animal-origin counterparts. As previously mentioned, in the Portuguese market, this percentage was slightly higher for the overall plant-based products, contrary to the results observed in the UK market, as well as exceeding the percentage registered by the UK plant-based products. Simultaneously, overall plant-based products showed a considerably lower percentage of products classified as "Low" in salt content compared to animal-origin products across both markets (PT: 22.1 % vs 45.0 %; UK: 10.4 % vs 29.1 %). The Portuguese market had almost more 12 % of plant-based products with low salt than the UK market. Last, 33.2 % and 20.5 % of the plant-based and plant-based dairy imitates respectively exhibited high salt content in PT market, which was the opposite trend than in the UK market, with the plant-based dairy imitates presenting higher percentages (24.7 % vs 32.6 %, respectively).

4. Discussion

Due to the increasing availability and consumption of ultra-processed plant-based foods worldwide, together with ongoing concerns regarding their overall healthiness and potential impacts on non-communicable diseases, there has been a significant rise in the number of published studies focusing the nutritional characteristics, comprehensive evaluation, and comparison of these products with their animal-origin counterparts, across different countries and markets, and even comparing them directly (Alessandrini et al., 2021; Petersen & Hirsch, 2023; Bryant, 2022; Vellinga et al., 2024; Curtain et al., 2019; Lisa et al. 2021; Costa-Catala et al., 2023). However, studies addressing the Portuguese reality regarding plant-based products, their nutritional characteristics, and consumer behavior remain scarce. This gap underscores the pertinence and relevance of this study, which provides valuable insights about the intrinsic nutritional characteristics and healthiness of plant-based ultra-processed foods available in the Portuguese market, while also comparing them with animal-origin products and with food products from the UK market.

These plant-based products are often regarded as healthy foods and are as well perceived to have superior nutritional, environmental and sustainability characteristics compared to their animal-origin counterparts. This perception is supported by the findings of the majority of published studies (Alessandrini et al., 2021; Poore et al., 2018; Springmann et al., 2018; Sultan et al., 2024; Willett, 2019; Rizzolo-Brime el al., 2023). However, despite this widespread belief, the ultra-processed nature of most plant-based foods (Alessandrini et al., 2021; Monteiro et al., 2019; Ketelings et al. 2023; Maganinho et al., 2024; Petersen et al., 2023; Rizzolo-Brime el al., 2023) and emerging evidence from more recent, in-depth studies indicates that the health halo and nutritional profiles often attributed to these products may not fully correspond to the reality and align with healthy eating patterns (Petersen et al., 2023;

Ketelings, et al., 2023; Maganinho et al., 2024; Pointke et al., 2022). The results and insights provided by this study offer a degree of corroboration for this perspective.

The results revealed that the majority of the plant-based products were not in accordance with EIPAS reference values for sugars and salt when jointly evaluated in both markets (PT: 98.7 % (N = 297) of plant-based meat and fish alternatives and 81.5 % (N = 123) of the dairy alternatives exceeded the thresholds; UK: 99.4 % (N = 531) of plant-based meat and fish alternatives and 83.7 % (N = 154) of dairy alternatives failed to meet the thresholds. When compared to animal-origin products, the non-compliance with EIPAS was generally higher for plant-based equivalents, except for dairy alternatives in the UK market. These findings suggest that the plant-based products may present some unfavorable nutritional characteristics and do not always possess superior nutritional quality compared to their animal origin counterparts. The results also indicated that the compliance with EIPAS criteria (sugars and salt contents) by the plant-based non-dairy and dairy alternatives, as well as their animal-origin equivalents, is closely related to the food category they belong to, and depends significantly on the country market in which they are sold.

The prevalence of plant-based products meeting EIPAS criteria by category was in general very low, not exceeding 26 % in the Portuguese market and 37.8 % in the UK market. Moreover, the majority of plant-based categories did not include any products meeting the EIPAS reference values for sugars and salt jointly evaluated. These discrepancies between both markets point to potential differences in products formulation, ingredient choices/availability and consumer preferences adaptations that may influence the nutritional content of plant-based foods in these countries.

Inadequate dietary habits are the leading risk factor contributing to the total years of healthy life lost by the Portuguese population (15.8 %) and a significant determinant of chronic diseases, which account for over 86 % of the disease burden in the Portuguese health system (Diário da República, 2017). To reverse this reality and improve health outcomes, it is essential to promote changes in consumption/dietary patterns. This should include reducing the intake of certain food products, particularly those with high sugar, salt, and fat content and promoting the increased consumption of healthier alternatives, with plant-based products potentially having a significant role in this shift. Substantially reducing animal-origins foods intake with increasing consumption of plant-based alternatives will also reduce environmental effects, enhance the overall environmental sustainability and improve animal welfare, by reducing dependence on livestock (Willett et al., 2019).

A more detailed evaluation of the nutritional composition of both plant-based and animal-origin products revealed distinct trends between these product types. Plant-based alternatives from some categories across both markets had higher energy, carbohydrates, and fibre content and lower levels of saturates compared to their animal-origin counterparts, potentially offering a nutritional advantage to those specific categories.

Regarding fat content, statistically significant differences were observed in only three plant-based categories across each market. Two of those categories in the PT market (NuggVeg and YogVeg) and one in the UK market (BurgVeg) exhibited higher levels than their animal-origin counterparts. Also, some plant-based categories from both markets consistently exhibited lower protein content than their animal-origin counterparts, particularly obvious in plant-based dairy alternatives. This finding may be of significant concern for consumers seeking complete sources of protein from plant-based diets.

Additionally, in the PT market just one of the analysed food categories showed significant difference in the salt content between plant-based and animal-origin products, with ChorzVeg exhibiting lower level than Chorz (1.76 g/100 g vs 2.95 g/100 g). The UK market had several plant-based categories with higher salt contents than their animal-origin equivalents. The highest salt level recorded in the UK market was 2.11°g/100°g (ChorzVeg) in the Portuguese market it reached 2.39 g/100 g (CharVeg).

The obtained results suggest that, despite the perceived health benefits of plant-based products consumption, not all of these foods meet the expectations for a balanced and healthy nutritional profile, especially concerning fat, saturates and salt intake. This is consistent with the study by Maganinho et al. (2024), which observed a range of Portuguese plant-based foods with high energy, fat, sugars, salt, as well as low protein content.

Similarly, the findings of Brime at al. (2023), Costa-Catala et al. (2023), Ketelings et al. (2023), and Pointke et al. (2022) which focused on the Spanish, Dutch and German markets, respectively, indicated that the fat, saturates and salt content in plant-based alternatives varied considerably, due to the wide range of ingredients used in their formulation. The Spanish markets studies also found that majority of the plant-based products analysed were low in sugars but moderate in carbohydrates, total and saturated fat, and high in salt (Brime et al., 2023). Additionally, plant-based meat analogues had low protein content and lower levels of fat and saturates that their animal-origin counterparts, while containing higher amounts of fiber and complex carbohydrates (Costa-Catala et al. 2023). In the Dutch study, plant-based meat analogues had less protein and saturates but more fiber and salt than their meat counterparts. Meanwhile, the German study found that all plant-based meat analogues exhibited lower energy density, fat and saturates content but significantly higher sugars and salt levels compared to real meat.

Studies in the Swedish (Bryngelsson, et al., 2022) and in the Norwegian (Tonheim, et al., 2022) markets found that the plant-based foods generally had lower saturates and higher fibre contents compared to animal-origin products. However, their contribution to salt intake was substantial from both plant-based foods and their counterparts. Additionally, the study conducted in the Norwegian market found that plant-based dairy alternatives contained considerable lower protein levels compared with their animal-origin equivalents.

Recent findings in the Portuguese market by Sultan et al. (2024) reported that, in general, plant-based foods had lower levels of energy, fat, saturates, and salt compared with their animal-origin counterparts, while presenting higher fiber, carbohydrate, and sugars content. The results regarding salt diverged from most other studies referenced here, as well as from the findings of the present study, by showing lower salt levels in plant-based products.

In light of the overall findings of the referenced studies, their authors concluded that plant-based products have potential limitations in terms of their ability to contribute to a healthy diet and serve as a nutritious alternative to animal-origin products, aligning with the present study.

The findings for the UK market are, to some extent, similar to those reported by Alessandrini et al. (2021), not only in the observed wide variation in energy density and nutrient content across both plant-based and animal-origin categories, but also particularly in the comparison of fat, saturates, protein, fibre and salt contents between these two product types. The lower protein content and the high salt levels observed in some plant-based categories were also highlighted in that study, suggesting that manufacturers could improve the nutritional products composition of the products.

Some results obtained in this study for the UK market differed from those observed in the Portuguese market, stressing the discrepancies between both markets. A main difference was observed for the energy value. A previous study conducted in Sidney, Australia, in 2019, was generally consistent with these findings, showing that plant-based products were lower in energy, and in total and saturated fat, while being higher in carbohydrate, sugars, and dietary fibre compared with animal-origin foods. Additionally, only 4 % of the products were low in salt (Curtain et al., 2019).

Despite the absence of a well-defined and consistent nutritional profile for plant-based products compared to their animal-origin counterparts across both markets, the findings from this evaluation, particularly related with the lower fat, saturates, and salt content observed in plant-based non-dairy alternatives, suggest a generally more favorable nutritional profile. Consequently, replacing animal-origin products with plant-based foods has the potential to promote healthier dietary patterns and improve the nutritional status of the population. This shift may help reduce the incidence of overweight and obesity and also have a direct impact on the prevention and management of other chronic diseases. Evidence from various studies underscores these benefits, highlighting the positive effects of the adoption of plant-based dietary patterns on weight and obesity prevalence and also prevention or reduction of cardiovascular diseases and other non-communicable diseases (Hemler et al., 2019; Satija and Hu, 2018; Turner-McGrievy et al., 2017; Baden et al., 2019). Additionally, numerous studies indicate that, compared to animal-origin foods, plant-based alternatives provide healthy protein and contain more fiber, vitamins, and bioactive compounds, as well as generally lower level of fat and saturates (Wang et al., 2023; Zhao et al., 2022).

The WHO and also the EIPAS aim to encourage adequate food consumption and consequently improve the overall nutritional status of the population, with particular emphasis on children (WHO, 2023; Diário da República, 2017). Both initiatives highlight the importance of implementing nutritional interventions to prevent overweight and obesity and promote long-term health outcomes. Key strategies include decreasing the availability of certain foods high in fat, sugar, and salt contents, and replacing them with healthier alternatives; encouraging the nutritional reformulation of food products; and empowering citizens and professionals to make and promote healthier food choices.

The overconsumption of energy-dense foods is associated with a higher risk of obesity, which in turn is a risk factor for several non-communicable diseases, while excessive intake of salt is associated with higher blood pressure and consequently a greater risk for cardiovascular disease. The World Health Organization (WHO) recommends an intake of under 30 % of the total energy supply from fats and under 10 % from saturated fats, and a maximum for salt intake of 5 g/day for adults to prevent and reduce these chronic health issues. However, the actual intake of energy, from fat and saturates, as well as of salt in Europe exceeds the amounts recommended (Petersen and Hirsch, 2023). As previously mentioned, the consumption of plant-based foods could potentially be used as a strategy to achieve some of these goals. Their intrinsic nutritional benefits, such as the lower fat, saturates and higher fibre content, can assist consumers in meeting recommended intake levels.

The evaluation of the statistics of the nutritional parameters values revealed that some of the plant-based food categories had lower fat and saturates content than their counterparts in both markets, aligning with the general perception of plant-based foods as being healthier alternatives in these nutritional aspect. However, plant-based categories consistently exhibited higher carbohydrate contents, due mainly to greater sugars levels. This trend was particularly pronounced for BurgVeg, ChorzVeg, NuggVeg, andMeatBVeg categories, where sugars contents were significantly higher than those of animal-origin equivalents.

Additionally, a great number of plant-based categories exhibited lower protein contents compared to their equivalent animal-origin categories as well as very concerning contents of salt for both countries. In the Portuguese market, the averages of four plant-based categories exceeded 1.5 g of salt per 100 g, while the averages of three categories in the UK market crossed this threshold used to classify the foods as high in salt content. With the exception for the YogVeg / Yog categories, all plant-based and animal-origin categories showed average salt levels exceeding the EIPAS reference thresholds that would allow the nutritional claim "low in salt" ($\leq$ 0.3 g/100 g). The high salt content in some plant-based products is particularly alarming and is a recurrent subject in several published studies (Alessandrini et al., 2021; Bryant et al., 2022, Curtain and Grafenauer, 2019; Pointke et al., 2022; Bryngelsson et al., 2022; and Tonheim et al., 2022). It diminishes the perceived health benefits of plant-based food consumption and also highlights the urgent need for food reformulation, to lower their salt content without compromising taste or preservation.

The broader ranges observed across all plant-based and animal-origin food categories in both markets and between them reflect significant variability in the nutritional characteristics of these foods. This variability highlights substantial differences in product formulation, production processes, and potentially market-driven preferences. Importantly, this variability also underscores the potential for producers to improve the nutritional profiles of their products, aligning them more closely with healthy nutritional patterns and recommendations. Despite plant-based categories exhibiting in general a more favorable nutrient profile compared to their animal-origin counterparts, these findings reveal that manufacturers have the opportunity to further improve the nutritional characteristics of their products, enhancing their health benefits and meeting consumer expectations for healthier options. The decision to evaluate both markets together was intentionally designed to identify potential differences between them and, where such differences exist, to confirm opportunities for improved formulation or reformulation of plant-based products.

The classification of plant-based and animal-origin foods based on the DGS label decoder provided an additional mean of assessment of their nutritional characteristics and also variability. Although plant-based products were generally classified as having lower fat, saturates, and salt compared to animal-origin foods, there were still considerable proportions of plant-based products that were classified as high in fat, saturates and particularly in salt. This underscores the importance of the food reformulation, to improve the nutritional quality of both plant-based alternatives and animal-origin products across both markets, especially in terms of salt and saturates reduction. Furthermore, it also highlights the importance of the label and labelling systems in helping consumers make more informed and healthier choices (Jones et al., 2019; Cecchini et al., 2015), as well as in incentivising manufacturers to reformulate their products, particularly in cases where labelling systems indicate to consumer whether certain sugars, fat, or salt content is high or unfavorable.

5. Limitations of the study

An important limitation of this study was the lack of nutritional information regarding the micronutrient content of the evaluated food products. It is well established that animal-origin products are significant sources of essential micronutrients, such as vitamin B12, iron, zinc, and calcium. Assessing these micronutrients and bioacessibility in plant-based products and comparing them with their animal-origin counterparts would provide valuable insights. However, this evaluation was not possible due to current European labeling legislation, which does not mandate the reporting of micronutrient content on food packaging. As previously mentioned, this limitation also extends to fibre content, as the available data for this nutritional parameter did not account for all evaluated products in both categories and markets.

Another limitation of our study was that the nutritional data for all the products were collected online from the websites of retailers and food distributors in Portugal and the UK. Consequently, we could not guarantee that the information is fully updated or reflects the most recent product formulations.

6. Conclusion

The results obtained showed that plant-based substitutes of meat, fish and dairy products offer certain nutritional advantages compared to their animal-origin counterparts, particularly in terms of lower fat and saturates, and higher fibre levels. However, these products also present significant challenges with regard to sugar, protein and especially salt contents. The vast majority of the plant-based meat and fish alternatives (98.7 %) and plant-based dairy alternatives (81.5 %) did not meet EIPAS sugars and salt reference values when jointly evaluated. These results were even less favorable in the UK market, with 99.4 % and 83.7 %

falling outside these reference values, respectively. For both types of products and markets only very small percentages of foods within the nine evaluated categories met the reference values for sugars and salt simultaneously. However, when considering the combined average contents for sugars and salt, by category, none of the eighteen categories complied with the EIPAS reference values.

The classification using the DGS label decoder demonstrated that fewer plant-based products were classified as high in fat and saturates compared to animal-origin products in both markets. However, a difference in salt content was observed between the markets of the two countries. In the Portuguese market, the percentage of plant-based and animal-origin products with high salt content was similar (29.0 % vs 28.4 %, respectively). Conversely, the opposite results were observed in the UK market (31.1 % vs 26.7 %, respectively).

The findings of this study highlight the need for plant-based product reformulation, to align these foods with healthier nutritional profiles, ensuring that their perceived health benefits are substantiated by their actual composition. The significant variability observed across various nutritional parameters within the same food categories for both product types and markets underscores a substantial opportunity for food manufacturers to adjust or reformulate their products to achieve healthier and more balanced nutritional profiles. Additionally, these findings emphasize the importance of improving labelling and food literacy, helping consumers make more informed choices by better understanding the nutritional quality of the products they purchase.

In this context, the purchase of processed plant-based meat, fish and dairy alternatives, as well as the partial or complete substitution of animal-origin products with these products, often perceived as healthier and nutritionally superior, should be carefully considered. Public health actions to address the nutritional quality of plant-based foods and to promote healthier and more sustainable food choices are also needed, namely food literacy initiatives and legislative measures concerning the labeling, food reformulation and eventually advertising restrictions.

CRediT authorship contribution statement

Fernandes Paulo: Writing – review & editing, Data curation. **Batista Rita:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation. **Lopes Andreia:** Writing – review & editing, Data curation. **Brazão Roberto:** Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Dias M. Graça:** Writing – review & editing, Validation, Supervision, Formal analysis.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Data availability

Data will be made available on request.

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