SEMINA
Ciências Agrárias

DOI: 10.5433/1679-0359.2026v47n1p95

Availability, nutritional quality, and ecological labeling of animal-based products and plant-based analogues in Brazil

Disponibilidade, qualidade nutricional e rotulagem ecológica de carnes e análogos vegetais no Brasil

Eliana de Souza Marques dos Santos[1]*; Davy William Hidalgo Chávez[2]; Ellen Mayra Menezes Ayres[3]

Highlights

Large quantities of animal and plant-based products are found in high-altitude regions.
Plant-based products have more fiber and a high sodium content.

Abstract

This study assessed the availability, nutritional quality, and economic accessibility of eco-labeled animal-based products and plant-based analogues within the urban food environment. A cross-sectional audit of 149 retail establishments in the city of Rio de Janeiro, Brazil, was conducted between July 2022 and June 2023, stratified by the Social Progress Index (*Índice de Progresso Social* - IPS). In total, 1,643 eco-labeled protein-rich foods (animal-based products and plant-based analogues) were evaluated for availability, price, and macronutrient composition. Multivariate factor analysis (MFA) and principal component analysis (PCA) were used to examine the relationships between product availability, geographic regions, and IPS levels, while chi-square and G tests compared product categories ($p \leq 0.05$). The results indicated that IPS accounted for 86.8% of the variance in product availability, suggesting that socio-spatial segregation is strongly associated with differences in access to sustainable protein-rich foods. Plant-based products were on average 71% more expensive than their animal-based counterparts. Among plant-based products, burgers emerged as the most prevalent item in the segment, whereas certified chicken was the most prevalent within the animal-based category. The nutritional composition of plant-based products showed advantages, including higher dietary fiber content, absence of cholesterol, and a more favorable lipid profile, but also limitations, such as lower protein content and elevated sodium levels. The unequal concentration of eco-labeled protein-rich

[1] PhD student in the Food and Nutrition Graduate Program (PPGAN), Universidade Federal do Estado do Rio de Janeiro, UNIRIO, Rio de Janeiro, RJ, Brazil. E-mail: eliana.santos@ifrj.edu.br
[2] Professor, PhD, Department of Food Technology, Universidade Federal Rural do Rio de Janeiro, UFRRJ, Seropédica, RJ, Brazil. E-mail: davyhw76@gmail.com
[3] Professor, PhD, Food and Nutrition Graduate Program (PPGAN), UNIRIO, Rio de Janeiro, RJ, Brazil. E-mail: ellen.menezes@unirio.br
* Author for correspondence

Received: Ago. 20, 2025 Approved: Mar. 12, 2026

foods reinforces disparities in access to innovative and sustainable foods. The protein transition in Brazil is unlikely to occur solely through market forces; targeted public policies will be necessary to overcome structural barriers related to price, distribution, and consumer information within sustainable food systems.
Key words: Availability. Plant-based analogues. Protein-rich foods. Nutritional quality. Eco-labeling. Sustainability.

Resumo

Este estudo teve como objetivo avaliar a disponibilidade, a qualidade nutricional e a relação custo-benefício de produtos de origem animal e seus análogos de origem vegetal com rótulos ecológicos. Trata-se de um estudo transversal com auditoria de 149 estabelecimentos varejistas no Rio de Janeiro (julho/2022 a junho/2023), estratificados pelo Índice de Progresso Social (IPS). Foram analisados 1.643 produtos proteicos com rotulagem ecológica (animal-based certificados e *plant-based*) quanto à disponibilidade, ao preço e à composição nutricional dos macronutrientes. Análises multivariadas (MFA e PCA) foram utilizadas e mostraram a distribuição espacial de produtos, regiões e IPS, enquanto os testes qui-quadrado e G compararam as categorias ($p \leq 0,05$). Os resultados demonstraram que o IPS explica 86,8% da variância na disponibilidade, evidenciando que a segregação socioespacial é o principal determinante do acesso a proteínas sustentáveis. Os produtos plant-based apresentaram custo médio 71% superior ao dos produtos de origem animal. Entre os plant-based, o hambúrguer destacou-se como principal produto âncora do segmento; entre os produtos de origem animal, o frango foi o principal produto certificado da categoria. A composição nutricional dos plant-based revelou vantagens, como maior teor de fibras, ausência de colesterol e melhor perfil lipídico, mas também desvantagens, como menor densidade proteica e altos níveis de sódio. A concentração desigual de produtos proteicos com rotulagem ecológica reforça as desigualdades no acesso a alimentos inovadores e sustentáveis. A transição proteica sustentável no Brasil não ocorrerá espontaneamente por forças de mercado, sendo necessária intervenção pública diante de barreiras estruturais relacionadas a preço, distribuição e informação.
Palavras-chave: Disponibilidade. Análogos vegetais. Proteínas. Qualidade nutricional. Rotulagem ecológica. Sustentabilidade.

Introduction

Sustainable food production and consumption capable of nourishing a growing population while supporting environmental sustainability rely on several key pillars, including environmental ethics, reduced meat consumption, and greater consumption of plant-based foods (Willett et al., 2019). Plant-based foods can serve as sustainable and nutritionally adequate alternatives to animal-based foods (Song et al., 2016; Willett et al., 2019; Clark et al., 2022).

However, despite scientific advances and progress toward more sustainable food production systems capable of supporting the food supply of a growing population (Hasegawa et al., 2019; Summerhayes et al., 2024), questions remain regarding the nutritional quality of these foods and the extent to which sustainable consumption has been effectively prioritized, particularly in developing countries.

Food labeling is considered an important tool that enables consumers to identify information related to a product's environmental impact, certifications, or sustainability commitments (Grunert et al., 2018; Cook et al., 2023). The ISO 14020 (International Organization for Standardization [ISO], 2022) series of standards classifies environmental claims into three categories: Type I environmental labels (ISO 14024), which involve third-party certified eco-labeling; Type II labels (ISO 14021), defined as manufacturers' self-declared claims without third-party verification; and Type III declarations (ISO 14025), which provide quantified information based on Life Cycle Assessment (LCA).

The effectiveness of labeling in promoting consumer adherence depends on several variables, including product availability, nutritional quality, and price (Tiboni-Oschilewski et al., 2024). Food accessibility must meet essential requirements for sustainable consumption, such as ensuring basic human needs (Stoyanov, 2017), reducing social and territorial inequalities (Duran et al., 2013), and offering affordable prices so that consumers are not restricted in their choices, particularly regarding protein-rich foods (Hötzel & Vandresen, 2022).

Animal- and plant-based products carrying environmental labels tend to follow an unequal distribution pattern within the food supply, often concentrated in areas with higher purchasing power. Research indicates that these products are predominantly sold in high-income cities, both in developed and developing countries (Clark et al., 2019). This pattern highlights the challenge of democratizing access to sustainable foods within retail environments. Studies suggest that factors such as limited availability and higher prices hinder the purchase of sustainable foods (Kortetmäki & Oksanen, 2021; Berrebi et al., 2023).

The relationship between socioeconomic indicators and the availability and price of sustainable foods contributes to a better understanding of this market (de Carvalho et al., 2021). Food environment audits conducted across different economic contexts (Jiang et al., 2019) assess the availability of eco-labeled foods and may contribute to strengthening sustainable food systems by encouraging more responsible practices among industries and consumers (Engels et al., 2010). Checklist-based instruments are widely recommended in food environment audits because they allow standardized observation, improve inter-rater reliability, and facilitate comparisons across retail outlets (Glanz et al., 2007; Liu et al, 2019; Canto et al., 2020). Previous studies have validated the use of checklist-based instruments to investigate urban food environments, the availability of healthy foods, and labeling practices within nutritional transition contexts (Duran et al., 2013; Liu et al., 2019).

Rio de Janeiro city, Brazil, is characterized by substantial economic and social diversity, providing a relevant setting for examining access to and supply of sustainable foods. Moreover, regions within the city are classified according to the Social Progress Index for Rio de Janeiro (*Índice de Progresso Social* - IPS-Rio), an indicator that measures human development based on socio-environmental dimensions rather than relying solely on economic variables (Instituto Pereira Passos [IPP], 2023). The IPS-Rio is categorized as low (IPS < 50), medium (50 ≤ IPS < 60), high (60 ≤ IPS < 70), and very high (IPS ≥ 70) (Lenormand et al., 2020).

Understanding how the availability, variety, nutritional quality, and price of sustainable foods vary across socioeconomic contexts can help identify the opportunities and limitations of the current food environment. For the purposes of this study, eco-labeling refers to products that display environmental sustainability attributes on their labels, including environmental certifications, sustainable production seals, and self-declared environmental claims.

To address these issues, this study assessed the availability, nutritional quality, and economic accessibility of eco-labeled animal-based products and plant-based analogues.

Methodology

This cross-sectional quantitative study was conducted in three stages: (I) an audit involving the identification and characterization of eco-labeled products, followed by their classification, categorization, and nutritional evaluation; (II) neighborhood stratification and price standardization; and (III) statistical analysis.

Product identification and characterization

Data collection was conducted in two sequential stages. In the initial mapping stage, a researcher surveyed products available in five major supermarkets located across regions of Rio de Janeiro, identifying and classifying the products found. Subsequently, a trained team replicated the procedure in additional retail chains distributed in different areas of the city, including all previously identified products.

This study focused on two main groups of protein-rich foods: a) animal-based products, including fresh and processed meats (beef, pork, poultry, fish, and seafood); and b) plant-based analogues formulated to mimic meat. Products were considered eligible if their labels displayed some form of eco-labeling, including certifications, sustainability seals, or environmental claims. Products were excluded if they were not intended to mimic animal-based meat, lacked explicit eco-labeling, were sold in bulk without labels, or had damaged or illegible packaging.

All identified products were cataloged and used to construct a standardized checklist (Borges & Jaime, 2022). A database was also created containing packaging information, including company name, brand, product description, weight, environmental and nutritional claims, ingredient list and nutritional information with respective serving sizes for both animal-based products and plant-based analogues.

Product classification and categorization

Based on the initial mapping, a systematic audit was conducted in 149 retail establishments stratified by geographic region (South, Southwest, North and West) and IPS (IPP, 2023) (Figure 1).

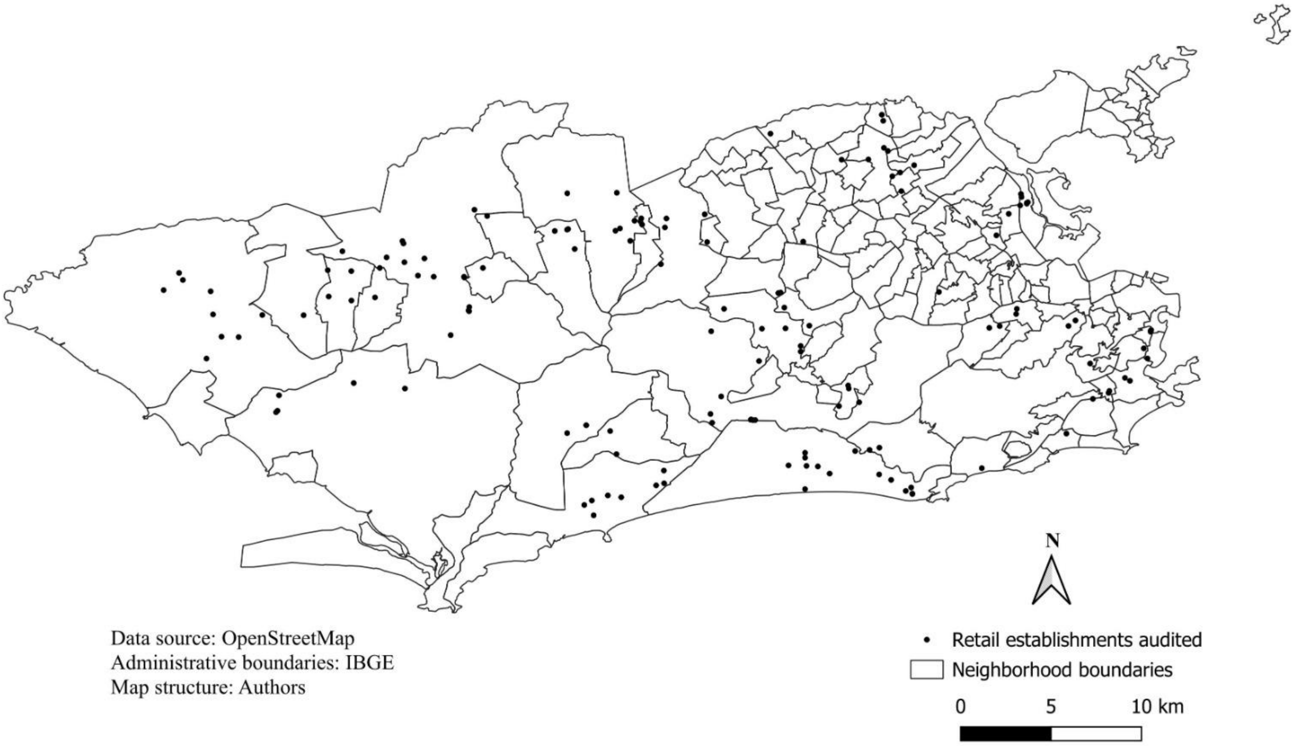

Figure 1. Geographic distribution of the retail establishments audited in the city of Rio de Janeiro, Brazil.
Note: Geographic coordinates of the establishments were obtained using the OpenStreetMap platform (OpenStreetMap Contributors, 2026). Coordinates were recorded in decimal degrees using the WGS 84 geodetic reference system (EPSG:4326) to ensure compatibility with geoprocessing and spatial analysis software. IBGE = Brazilian Institute of Geography and Statistics.

The audit was conducted between July 2022 and June 2023 by a trained research team, using a standardized checklist to record product availability, price, and location. In each establishment, all products meeting the inclusion criteria were recorded, resulting in a total of 1,643 eco-labeled products (animal-based products and plant-based analogues).

Considering the territorial extent of Rio de Janeiro city, and to reduce the influence of temporal price fluctuations, prices were collected at two time points in 2023 (January and June), with price collection concentrated within each respective month. For each product category, the lowest available retail price was recorded regardless of brand, and promotional prices were excluded.

Data from the audited products were entered into an Excel database and organized into two groups: animal-based products and plant-based products, which were further subdivided according to the classification proposed by Curtain and Grafenauer (2019). The plant-based product group was subdivided into the following subcategories: plant-based burgers, plant-based sausages, plant-based red meat, plant-based poultry, and plant-based seafood, representing products designed to mimic conventional meat products. Animal-based foods displaying sustainability claims on their labels were classified using the same subcategories. Product variety was assessed based on the number of product subcategories identified within each category of protein-rich foods. This classification strategy improved data standardization and facilitated subsequent analysis.

Nutritional evaluation

Nutritional information and ingredient lists were extracted from product labels and systematically compiled. The parameters used to evaluate nutritional labelling followed Brazilian regulatory standards, specifically Resolução da Diretoria Colegiada (RDC) nº 429, 2020 and Instrução Normativa (IN) nº 75/2020, issued by the Brazilian Health Regulatory Agency (Anvisa). Values reported in the nutrition facts panels were used for analysis, including: energy (kcal), carbohydrates (g), added sugars (g) (only for plant-based foods), protein (g), total fat (g), saturated fat (g), dietary fiber (g), and sodium (mg), standardized per 100g of product.

Neighborhood stratification and product price standardization

Product availability was analyzed in relation to the IPS of neighborhoods, a multidimensional measure of social conditions in the city based on 32 indicators. IPS data were calculated in 2022 and obtained from the open data portal of the City of Rio de Janeiro (available at: https://ips-rio-pcrj.hub.arcgis.com/). Retail establishments were stratified into three IPS categories - medium ($50 \leq IPS < 60$), high ($60 \leq IPS < 70$), and very high ($IPS \geq 70$) - following Lenormand et al. (2020).

To enable price comparisons across products with different package weights, prices were standardized per 100 g of product. This standardization allowed the calculation of the percentage price difference between plant-based analogues and animal-based products within each category, using the following formula:

$$ICC\ (\%) = \left(\frac{\bar{X}\ plant - based - \bar{X}\ anaimal - based}{\bar{X}\ animal - based}\right) x\ 100 \qquad (1)$$

Where ICC represents the Comparative Food Cost Index, and $\bar{X}$ the average price (R$), expressed in Brazilian reais, per 100g for each category.

Statistical analysis

Average product availability by IPS category was calculated, along with the relative proportions of each product category and subcategory. The association between product type and IPS category was then evaluated using the chi-square (χ^2) or G test, with a significance level of 5% ($p \leq 0.05$). Multiple Factor Analysis (MFA) and Principal Component Analysis (PCA) were applied to explore the relationships between product categories (animal-based products and plant-based analogues), IPS, and geographic regions. MFA enables the integration of different blocks of variables and projects them onto principal axes that maximize the variance explained between product groups and regions.

The nutritional profile of the products in each plant based subcategory was calculated using means, standard deviations, and medians for the following variables: energy value (kcal), total carbohydrates (g), added sugars (g), protein (g), total fat (g), saturated fat (g), dietary fiber (g), and sodium (mg). Nutritional values were standardized to 100 g of product. Data were analyzed separately for animal- and plant-based groups (e.g., plant-based burgers vs. beef burgers and plant-based sausages), and comparisons of the nutritional composition plant-based products and their available animal-based equivalents were conducted. Differences between subcategories were presented using means, standard deviations with their respective p-values using non-parametric Mann-Whitney test, with a significance level of $p \leq 0.05$. When nutritional information for certain meat products (beef and pork) was not available, reference values were obtained from the Brazilian Food Composition Table (Núcleo de Estudos e Pesquisas em Alimentação [NEPA], 2011).

A word cloud based on ingredient lists was generated to visualize the most frequently occurring ingredients. Statistical analyses were performed with R software (version 4.3.1), and the FactoMineR package was used for factor analysis and graphical visualization, while additional analyses were conducted in Microsoft Excel.

Results and Discussion

Retail food environment sampling and characterization

The audited establishments (n=149) were located across regions with marked social heterogeneity, as defined by the IPS (Table 1). The South was the only homogeneous region, with all establishments (10.07%; n=15) situated in areas classified as having very high IPS values. The remaining regions exhibited greater socioeconomic diversity. The North region was the most heterogeneous, with establishments distributed in areas with medium (2.7%; n=4), high (10.1%; n=15), and very high (6.0%; n=9) IPS values. The Southwest had establishments equally distributed between high and very high IPS areas (16.1%; n=24), while the West presented the lowest socioeconomic profile, with establishments located in medium (10.7%; n=16) and high (28.2%; n=42) IPS areas.

Among the 1,643 eco-labeled protein-rich foods analyzed, the availability of animal-based products (57.5%; n=945) was significantly higher ($p \leq 0.05$) than that of plant-based analogues (42.5%; n=698) (Table 2). The Southwest region showed the highest absolute availability of both animal- (n=622) and plant-based (n=394) products. This pattern may be associated with the concentration of large supermarket chains, retail assortment strategies aligned with higher purchasing power, and the clustering of niche markets in high-income areas (Deggerone et al., 2023; McBey et al., 2024).

Table 1
Distribution of audited retail establishments by Social Progress Index (IPS) classification and region in Rio de Janeiro, Brazil

Region	IPS1			Total % (n)
	Medium	High	Very high	
	% (n)	% (n)	% (n)	
South	0	0	10.1 (15)	10.1 (15)
Southwest	0	16.1 (24)	16.1 (24)	32.2 (48)
North	2.7 (4)	10.1 (15)	6.0 (9)	18.8 (28)
West	10.7 (16)	28.2 (42)	0	38.9 (58)
Total	13.4 (20)	54.4 (81)	32.2 (48)	100.0 (149)

Note: IPS1 = Social Progress Index: medium (50 ≤ IPS < 60), high (60 ≤ IPS < 70), very high (IPS ≥ 70). Values are expressed as percentage (%) and number of establishments (n).

Table 2
Distribution of eco-labeled protein-rich foods and their subcategories across regions of Rio de Janeiro, Brazil (n = 1,643)

Products	Region				Total	p-value
	Southwest	South	West	North		
	% (n)	% (n)	% (n)	% (n)	1643	
Plant-based	**56.4^{aB} (394)**	**17.9^{bA} (125)**	**17.5^{bA} (122)**	**8.2^{cA} (57)**	**42.5^{B} (698)**	**0.0001**
Meatballs	6.9^{b} (27)	7.2^{b} (9)	20.5^{a} (25)	15.8^{a} (9)	10.0 (70)	0.0001
Burgers	49.7^{a} (196)	52.0^{a} (65)	51.6^{a} (63)	43.9^{a} (25)	50.0 (349)	0.7528
Sausage	4.8^{a} (19)	8.8^{a} (11)	3.3^{a} (4)	3.5^{a} (2)	5.2 (36)	0.1969
Poultry	22.1^{a} (87)	18.4^{a} (23)	15.6^{a} (19)	26.3^{a} (15)	20.6 (144)	0.2706
Beef	9.9^{a} (39)	9.6^{a} (12)	7.4^{a} (9)	8.8^{a} (5)	9.3 (65)	0.8653
Fish	5.3^{a} (21)	2.4^{a} (3)	1.6^{a} (2)	1.8^{a} (1)	3.9 (27)	0.1509
Hot dogs	1.3^{a} (5)	1.6^{a} (2)	0	0	1.0 (7)	0.8669
Pork	0	0	0	0	0	-
Animal-based	**65.8^{aA} (622)**	**19.1^{bA} (180)**	**7.9^{cB} (75)**	**7.2^{cA} (68)**	**57.5^{A} (945)**	**0.0001**
Meatballs	0.3^{a} (2)	1.1^{a} (2)	0	0	0.4 (4)	0.4960
Burgers	3.4^{a} (21)	2.8^{a} (5)	0	1.5^{a} (1)	2.9 (27)	0.6636
Sausage	1.6^{a} (10)	2.2^{b} (4)	0	1.5^{b} (1)	1.6 (15)	0.8440
Poultry	78.3^{b} (487)	78.9^{b} (142)	94.7^{a} (71)	80.9^{b} (55)	79.9 (755)	0.0101
Beef	0.2^{b} (1)	2.2^{a} (4)	0	0	0.5 (5)	0.0232
Fish	16.2^{a} (101)	12.8^{ab} (23)	5.3^{b} (4)	16.2^{a} (11)	14.7 (139)	0.0423
Total	**61.8^{a} (1.016)**	**18.6^{b} (305)**	**12.0^{c} (197)**	**7.6^{d} (125)**	**1,643**	**0.0001**

Note: n = number of products identified; values are presented as percentage (%) and number of products (n). Different lowercase letters within rows indicate significant differences between regions according to the chi-square or G-test (p ≤ 0.05). Different uppercase letters within columns indicate significant differences between product categories according to the chi-square test (χ^2) (p ≤ 0.05). Zero values were not included in the statistical comparisons.

When examining the relative frequency of plant- versus animal-based products across regions, establishments in the West region showed a significantly higher proportion of plant-based products (61.9%; n=122; p = 0.0001). No statistically significant differences were observed in the other regions, indicating that the imbalance between product types was specific to the West. Conversely, in the Southwest, South, and North regions, animal-based products were more prevalent (p = 0.0001). These findings are consistent with research showing that assortment patterns vary with levels of urbanization and may be differently associated with product outcomes across regional contexts (Caccialanza et al., 2026).

Among plant-based products, burgers were the most frequent subcategory (50.0%; n=349), followed by plant-based poultry analogues (20.6%; n=144), indicating that burgers represent the most prevalent product within the plant-based segment of the protein transition in the audited establishments. This finding aligns with previous research highlighting the rapid market diffusion of plant-based burgers due to sensory acceptance and convenience (Lou et al., 2024; Sogari et al., 2025). Plant-based meatballs were the only subcategory showing a significant regional difference (p = 0.0001), with higher availability in the West (20.5%; n=25) and North (15.8%; n=9).

Among animal-based products, certified poultry was the most frequent item (79.9%; n=755), with significantly greater availability in the West region (94.7%; n=71; p=0.0101), while no significant regional differences were observed elsewhere. The near absence of certified beef (<1%) suggests that the current configuration of eco-labeled protein-rich foods in the audited retail environment is concentrated in poultry and plant-based categories. The limited availability of certified red and pork meats may be related to structural characteristics of organic or regenerative livestock systems, including extensive land requirements (2-5 ha/head vs. 0.01 ha/bird), long production cycles (24-36 months vs. 45 days for poultry), and higher management intensity. These factors may increase production costs by 100-200% relative to conventional systems (Röös et al., 2017), potentially restricting retail supply and consumer access. Furthermore, the stringent environmental certification requirements for cattle production may limit the expansion of certified beef supply (Poore & Nemecek, 2018). Conversely, poultry production is associated with lower costs, higher feed efficiency, and lower greenhouse gas emissions compared with cattle production (Tetteh et al., 2022), although the environmental impact hierarchy within animal-based systems generally follows the sequence cattle > lamb > pork > poultry (Manian, 2023).

Overall, the findings indicate that the number of retail establishments was not directly associated with the diversity of eco-labeled products offered (Tables 1 and 2). For example, in the North region, 28 establishments accounted for only 7.6% (125/1643) of all products (4.5 products per establishment), whereas in the West, 58 establishments accounted for 12% (197/1643) (3.4 products per establishment). In contrast, the South, despite having only 15 establishments, accounted for 18.6% (305/1643) of products (20.3 products per establishment), a level similar to that observed in the Southwest (21.2 products per establishment). These differences appear to coincide with lower IPS levels in the North and West regions, although other contextual factors may also contribute.

Of the 1,643 products identified, only 2.8% (n=46) were located in areas classified as medium IPS, compared with 40.3% (n=662) in high IPS and 56.9% (n=935) in very high IPS areas (p=0.0001) (Table 3).

Table 3
Distribution of eco-labeled protein-rich foods and their subcategories across areas with different Social Progress Index (IPS) levels in Rio de Janeiro, Brazil

Products	IPS[1]			Total	p-value
	Medium	High	Very high		
	% (n)	% (n)	% (n)	1,643	
Plant-based	**4.3cA (30)**	**40.5bB (253)**	**59.5aA (415)**	**42.5B (698)**	**0.0003**
Meatballs	23.3a (7)	13.8a (35)	6.7b (28)	10.0 (70)	0.0006
Burgers	50.0a (15)	50.6a (128)	49.6a (206)	50.0 (349)	0.9718
Sausage	3.3ab (1)	2.4b (6)	7.0a (29)	5.2 (36)	0.0349
Poultry	16.7a (5)	17.8a (45)	22.7a (94)	20.6 (144)	0.0504
Beef	3.3a (1)	9.1a (23)	9.9a (41)	9.3a (65)	0.4861
Fish	3.3a (1)	5.5a (14)	2.9a (12)	3.9a (27)	0.2260
Hot dogs	0	0.8 (2)	1.2 (5)	1.0 (7)	0.9054
Pork	0	0	0	0	-
Animal-based	**1.7cB (16)**	**43.3bA (409)**	**55.0aA (520)**	**57.5A (945)**	**0.0003**
Meatballs	0	0.5a (2)	0.4a (2)	0.4 (4)	0.7908
Burgers	0	2.0a (8)	3.7a (19)	2.9 (27)	0.1827
Sausage	0	0.7a (3)	2.3a (12)	1.6 (15)	0.1036
Poultry	81.3a (13)	79.2a (324)	80.4a (418)	79.9 (755)	0.8991
Beef	0	0	1.0 (5)	0.5 (5)	-
Fish	18.8a (3)	17.2a (72)	12.3a (64)	14.7 (139)	0.0696
Total	**2.8c (46)**	**40.3b (662)**	**56.9a (935)**	**1,643**	**0.0001**

Note: IPS1 = Social Progress Index: medium ($50 \leq IPS < 60$), high ($60 \leq IPS < 70$), and very high ($IPS \geq 70$). Values are expressed as percentage (%) and number of products (n). Different lowercase letters in the rows indicate significant differences between IPS categories according to the chi-square or G test ($p \leq 0.05$). Differ uppercase letters within columns indicate significant differences between product groups according to the chi-square test (χ^2) ($p \leq 0.05$). Zero values were excluded from statistical comparisons.

Consistent with the overall pattern, animal-based products (57.5%; n=945) were more available than their plant-based counterparts (42.5%; n=698; p≤0.05). A similar distribution was observed in areas with high IPS (43.3; n=409). However, plant-based meatballs (4.3%; n=30) were significantly more available in establishments located in medium IPS areas (p≤0.05), and no significant differences between product types were observed in very high IPS areas.

The frequency of plant-based meatballs (23.3%; n=7) was significantly higher (p=0.0006) in areas with medium IPS values, followed by high and very high IPS areas. In contrast, plant-based sausage (7.0%; n=29) was more widely available (p=0.0349) in establishments located in very high IPS areas. As shown in Table 2, poultry products were the most prevalent animal-based product in the West region (94.7%; n=71); however, no statistically significant difference (p=0.8991) was observed when stratified by IPS category.

The distribution of products according to IPS classification revealed that, although all regions exhibit IPS diversity, there was a higher concentration of eco-labeled products in areas with greater social development (Table 3). Notably, 13.4% of establishments were located in medium IPS areas (Table 1), whereas only 2.8% of products were identified in this stratum (Table 3), suggesting an association between IPS classification and product availability that appears stronger than regional location alone.

When comparing product variety between the South/Southwest (20-21 products per establishment) and North/West (3-4 products per establishment), a sixfold difference was observed, indicating that eco-labeled products were substantially less diverse in lower-IPS regions. The greater variety observed in higher-IPS regions may be related to differences in retail formats, consumer price sensitivity, and supply strategies (Clark et al., 2020; Willett et al., 2019).

Using IPS as an analytical criterion provided insight into how the socio-spatial context is associated with the availability of eco-labeled products and highlighted potential barriers and opportunities specific to each region. Poore and Nemecek (2018) highlighted that plant-based products are considered environmentally preferrable due to their lower greenhouse gas emissions, water use, and land use relative to most animal-based products.

Multiple factor analysis (MFA) explained 55.78% of the total variance, with 43.19% attributed to dimension 1 and 12.43% to dimension 2 (Figure 2). The factor loadings with longer vectors along dimension 1 were associated with very high and high IPS areas, located primarily in the South and Southwest, respectively. The inverse distribution of vectors indicates differentiation in product availability patterns across socioeconomic strata, rather than direct evidence of market specialization. Previous studies (Garnett, 2016; Alsubhi et al., 2023; He & Tsvetkova, 2025) indicate that economically privileged regions tend to place greater emphasis on technological innovation and ethical considerations in food choices. The present findings are consistent with this literature but reflect retail distribution patterns rather than direct measures of consumer preference and may also be influenced by higher product prices in these areas.

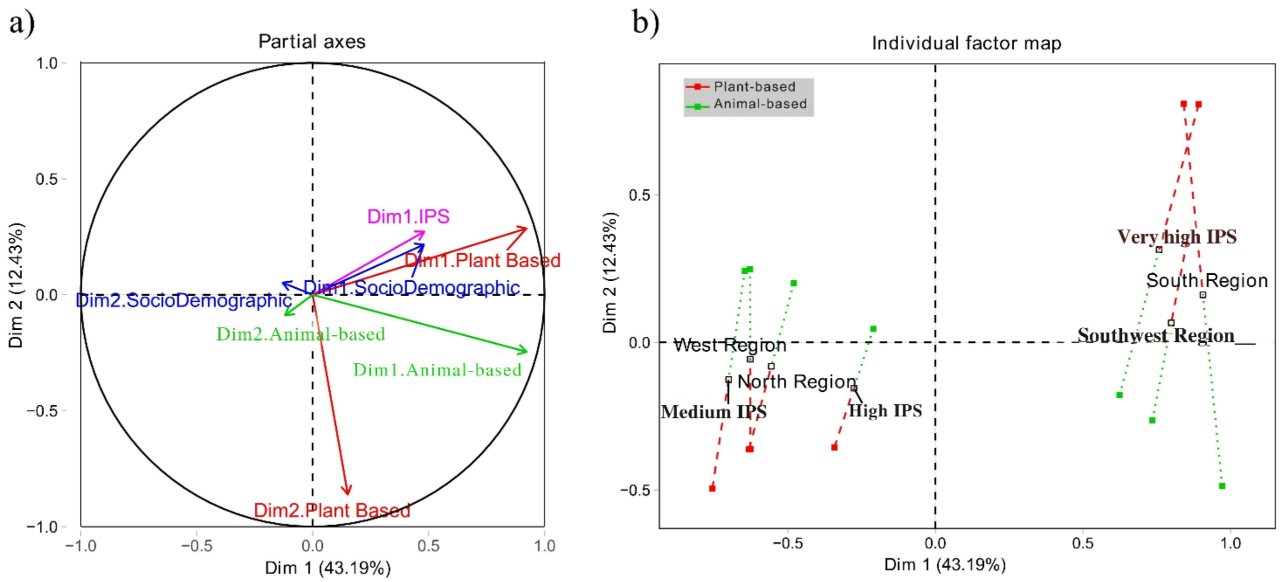

Figure 2. Multiple factor analysis (MFA) of the availability of plant- and animal-based products across regions and Social Progress Index (IPS) categories in Rio de Janeiro, Brazil.
a) Correlation circles showing the contribution of plant-based (red) and animal-based (green) product categories and IPS to the principle dimensions of the MFA (Dim 1 and Dim 2); b) Factor map showing the spatial distribution of product groups, regions, and IPS categories across the first two dimensions of the MFA.

Principal Component Analysis (PCA) explained 98.7% of the total variance (86.8% in dimension 1 and 11.9% in dimension 2) (Figure 3a). Animal- (beef, poultry, fish, and sausage) and plant-based products (meatballs, poultry analogues, and hot dogs) were positioned on opposite sides of the West and North regions, suggesting uneven distribution patterns across supermarkets. The positioning of high and medium-IPS regions at opposite ends of dimension 1 suggests that socioeconomic differences are associated with contrasting availability profiles. However, given the cross-sectional design, these spatial patterns should be interpreted as associations rather than causal relationships.

With respect to regional distribution, the products analyzed were more strongly clustered in the South and Southwest regions, where IPS levels are higher. Because IPS-Rio captures multiple social dimensions beyond income, it provides a framework for examining structural inequalities across regions. The findings indicate that areas with higher IPS values tend to show greater availability of eco-labeled products, supporting an observed correlation between social development indicators and product supply.

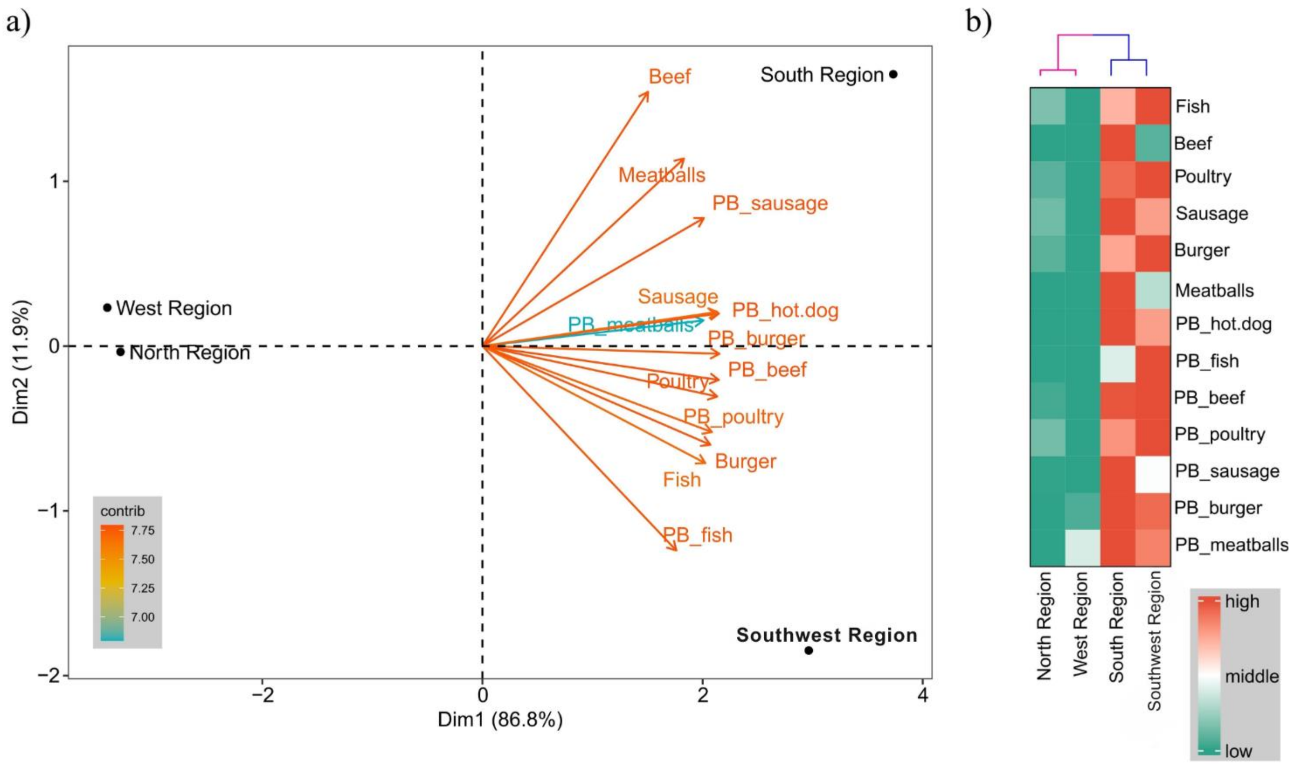

Figure 3. Principal component analysis (PCA) of the availability of animal- and plant-based product subcategories across regions of Rio de Janeiro, Brazil.
(a) PCA biplot showing the association between product subcategories and geographic regions based on availability. Arrows represent product subcategories, and points represent regions. (b) Heatmap with hierarchical clustering illustrating the availability patterns of animal- and plant-based product subcategories across regions.
Note: PB = plant-based.

The lower differentiation and limited variation in product options are further illustrated in Figure 3b. According to Henchion et al. (2017), high prices and limited local availability may restrict consumer access to eco-labeled products, in addition to the absence of educational initiatives highlighting their benefits. These regional differences may have implications for the broader dynamics of sustainable food system expansion, since unequal distribution patterns could reinforce disparities in access to products produced under sustainability principles (Poore & Nemecek, 2018). Public policies aimed at reducing price barriers and expanding access to foods carrying sustainability-related labels, such as environmental seals and claims, may contribute to increasing their accessibility, particularly in low-IPS regions (Tilman & Clark, 2014).

Price comparison of animal- vs. plant-based products

When standardized prices per 100 g were compared, plant-based products (R$ 12.75 ± 2.10) were on average 71.08% more expensive than their animal-based counterparts (R$ 7.45 ± 1.65), according to the Comparative Food Cost Index (*Índice Comparativo de Custo do Alimento* – ICC), with a statistically significant difference ($p < 0.001$) (Figure 4). These findings are consistent with previous studies reporting price differentials ranging from 35% to 270% for plant-based products (LendingTree, 2024; Smoluk-Sikorska, 2024). The observed price gap suggests that economic accessibility may represent a barrier to the broader uptake of plant-based products, particularly in lower-income contexts (Neff et al., 2018).

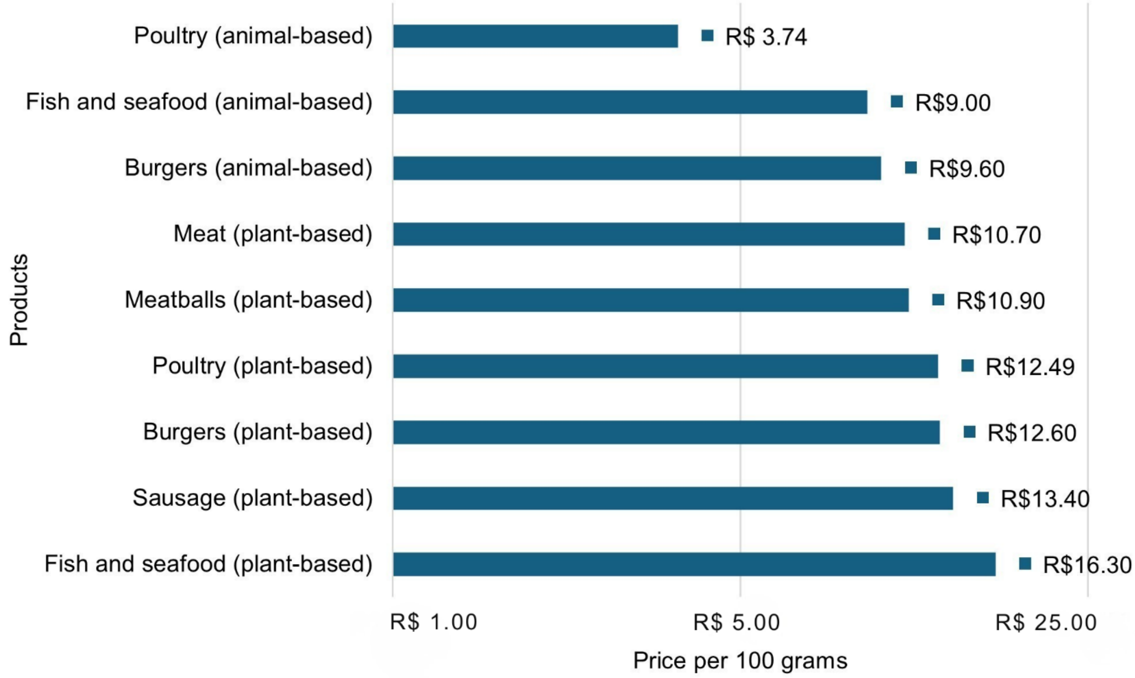

Figure 4. Average retail price per 100g of animal-based products and plant-based analogues in Rio de Janeiro, Brazil.
Note: Prices correspond to the average retail price per 100 g for products for which comparable animal-based and plant-based options were available between January and June 2023. R$ = Brazilian real (BRL).

Nutritional profile and ingredients of animal-based products and plant-based analogues

Analysis of the nutritional information of plant-based analogues revealed differences across subcategories (Table 4). In addition, comparison with animal-based products identified significant nutritional differences between these products and their plant-based counterparts, depending on the product subcategory. The energy value of plant-based burgers (166.2 kcal/100

g) and sausage analogues (190.5 kcal/100 g) fell within moderate energy ranges, while the remaining plant-based analogues presented the highest mean energy values, which may be related to the use of vegetable oils and structuring agents in these formulations.

Plant-based products equivalent to processed meats presented an average energy value of 186.1 kcal/100 g, which is higher than values reported for comparable products in other countries (Cutroneo et al., 2022; Costa-Catala et al., 2023). All plant-based products contained measurable amounts of carbohydrates, with significant differences observed among all plant-based products evaluated, particularly seafood analogues (16.9 g/100 g) and burgers (12.2 g/100 g), whereas animal-based equivalents showed values close to zero ($p \leq 0.05$). This pattern may reflect the addition of starches and flours commonly used to improve texture and structural stability in plant-based formulations. Total and added sugars were reported at negligible levels in label declarations for most categories.

Compared with animal-based products, plant-based burgers and plant-based pork showed lower energy values than their animal-based counterparts. In contrast, all other plant-based analogues presented higher energy values. These differences were not consistent across subcategories, suggesting that energy content varies according to product formulation and ingredient composition.

Regarding protein content, only plant-based sausages had higher values than their animal-based counterparts (17.3 g/100 g vs. 13.6 g/100 g, respectively). The remaining categories showed lower protein content compared with animal-based equivalents: processed meats (13.0 vs. 19.4 g/100 g), burgers (8.9 vs. 19.0 g/100 g), poultry (11.4 vs. 25.8 g/100 g), fish (12.4 vs. 15.8 g/100 g), and pork (10.1 vs. 22.6 g/100 g). These differences may be associated with the type and proportion of plant proteins used (e.g., soy, pea, wheat), as well as the degree of protein concentration or isolation applied during processing. Protein content is considered an important attribute in food choice for approximately 68% of consumers (Grasso et al., 2019), while 73% expect nutritional parity between plant- and animal-based products (Hartmann & Siegrist, 2017).

Across all plant-based categories, trans fats were absent. Total fat values varied among plant-based analogue subcategories, ranging from 8.7 g/100 g in burgers to 12.9 g/100 g in poultry analogues. Some products, such as plant-based burgers, showed significantly lower fat content than their animal-based equivalents (8.7 vs. 18.0 g/100 g; $p < 0.001$), while other categories presented comparable values. Saturated fat levels remained relatively low (overall average of 2.4–3.2 g/100 g) and, in several categories, were lower than those observed in animal-based items (except for fresh poultry and fish), indicating a comparably more favorable lipid profile, as also reported by Rizzolo-Brime et al. (2023).

With regard to dietary fiber, plant-based products showed substantial levels, ranging from 2.3 g/100 g (plant-based sausages) to 7.7 g/100 g (plant-based meat analogues). This component, absent in traditional animal-based products (Table 4; $p < 0.001$), may represent a potential nutritional advantage, since dietary fiber is associated with satiety and gastrointestinal health (Stanišić et al., 2025).

Table 4

Nutritional comparison of means and standard deviations between eco-labeled plant-based products and their animal-based counterparts by subcategory (per 100 g) in retail establishments in Rio de Janeiro, Brazil

Category	Subcategory	Nutrient											
		Energy value (kcal)	Carbo-hydrates (g)	Total sugars (g)	Added sugars (g)	Protein (g)	Total Fat (g)	Saturated fat (g)	Monounsa-turated fat (g)	Polyunsatu-rated fat (g)	Trans fat(g)	Dietary Fiber (g)	Sodium (mg)
Plant-based	**Sausages (n=10)**	$190.5^{aa} \pm 52.2$	$7.8^{a} \pm 3.6$	$0.8^{a} \pm 0.5$	$0.3^{aa} \pm 0.3$	$17.3^{a} \pm 9.0$	$9.9^{aa} \pm 3.2$	$2.6^{aa} \pm 2.2$	$0.4^{aa} \pm 1.4$	$0.8^{aa} \pm 2.7$	$0.0^{aa} \pm 0.0$	$2.3^{a} \pm 2.8$	$665.7^{aa} \pm 273.2$
Animal-based	**Sausages (n=12)**	$188^{aa} \pm 13.07$	$3.6^{b} \pm 0.15$	$0.0^{b} \pm 0.0$	$0.0^{aa} \pm 0.0$	$13.6^{b} \pm 0.1$	$13.2^{aa} \pm 0.23$	$5.6^{aa} \pm 0.21$	$0.0^{aa} \pm 0.0$	$0.0^{aa} \pm 0.0$	$0.0^{aa} \pm 0.0$	$0.0^{b} \pm 0.0$	$890^{aa} \pm 69.4$
Plant-based	**Burgers (n=29)**	$166.2^{aa} \pm 50.6$	$12.2^{a} \pm 10.0$	$0.2^{aa} \pm 0.7$	$0.0^{aa} \pm 0.0$	$8.9^{b} \pm 4.5$	$8.7^{aa} \pm 4.3$	$3.2^{b} \pm 3.1$	$0.7^{aa} \pm 1.6$	$0.6^{aa} \pm 1.5$	$0.0^{aa} \pm 0.0$	$4.1^{a} \pm 2.1$	$339.9^{a} \pm 156.6$
Animal-based	**Burgers (n=26)**	$240.8^{aa} \pm 125$	$0.5^{b} \pm 0.7$	$0.0^{aa} \pm 0.0$	$0.0^{aa} \pm 0.0$	$19.0^{a} \pm 6.8$	$18.0^{aa} \pm 11.1$	$8.6^{a} \pm 5.7$	$0.0^{aa} \pm 0.0$	$0.0^{aa} \pm 0.0$	$0.4^{aa} \pm 0.4$	$0.0^{b} \pm 0.0$	$172.3^{b} \pm 145.6$
Plant-based	**Poultry (n=11)**	$211,7^{a} \pm 90,9$	$11.0^{a} \pm 10$	$0.3^{aa} \pm 0.9$	$0.0^{aa} \pm 0.0$	$11.4^{b} \pm 4.9$	$12.9^{a} \pm 6.9$	$3.0^{a} \pm 2.1$	$1.7^{a} \pm 2.7$	$1.6^{aa} \pm 2.2$	$0.0^{aa} \pm 0.0$	$6.9^{a} \pm 3.9$	$468.6^{a} \pm 193.3$
Animal-based	**Poultry (n=11)**	$146,8^{b} \pm 96$	$0.0^{b} \pm 0.0$	$0.0^{aa} \pm 0.0$	$0.0^{aa} \pm 0.0$	$25.8^{a} \pm 3.4$	$1.0^{b} \pm 0.2$	$0.5^{b} \pm 0.14$	$0.0^{b} \pm 0.0$	$0.0^{aa} \pm 0.0$	$0.0^{aa} \pm 0.0$	$0.0^{b} \pm 0.0$	$60.6^{b} \pm 7.0$
Plant-based	**Seafood (n=6)**	$206.3^{a} \pm 53.3$	$16.9^{a} \pm 9.1$	$0.2^{aa} \pm 0.4$	$0.0^{aa} \pm 0.0$	$12.4^{aa} \pm 3.4$	$9.4^{aa} \pm 6.1$	$2.4^{aa} \pm 2.7$	$0.5^{aa} \pm 1.3$	$1.1^{aa} \pm 2.6$	$0.0^{aa} \pm 0.0$	$4.7^{a} \pm 2.5$	$447.2^{a} \pm 99.0$
Animal-based	**Seafood (n=6)**	$103.8^{b} \pm 36.3$	$0.0^{b} \pm 0.0$	$0.0^{aa} \pm 0.0$	$0.0^{aa} \pm 0.0$	$15.8^{aa} \pm 3.9$	$4.8^{aa} \pm 2.0$	$1.3^{aa} \pm 0.6$	$0.7^{aa} \pm 1.6$	$0.5^{aa} \pm 1.2$	$0.0^{aa} \pm 0.0$	$0.0^{b} \pm 0.0$	$32.7^{b} \pm 14.8$
Plant-based	**Pork (n=3)**	156.3 ± 65.9	12.3 ± 4.6	1.7 ± 2.9	1.2 ± 2.1	10.1 ± 3.8	7.1 ± 4.4	1.2 ± 0.8	1.6 ± 2.7	0.0 ± 0.0	0.0 ± 0.0	2.5 ± 1.5	545.3 ± 192.1
Animal-based	**Pork***	176	0.0	0.0	0.0	22.6	8.8	3.3	3.7	1.0	0.0	0.0	53
Plant-based	**Meat (n=8)**	186.1 ± 93.1	8.3 ± 6.5	0.0 ± 0.0	0.0 ± 0.0	13.0 ± 6.8	12.1 ± 9.7	3.0 ± 2.5	0.4 ± 0.9	0.2 ± 0.4	0.0 ± 0.0	7.7 ± 3.7	423.3 ± 187.4
Animal-based	**Meat***	137	0.0	0.0	0.0	19.4	5.9	4.5	5.5	0.0	0.0	0.0	49

Note: Values are expressed per 100 g of product. aDifferent lowercase letters indicate differences between plant-based and animal-based products within the same subcategory according to non-parametric Mann-Whitney test ($p \leq 0.05$); identical lowercase letters indicate no significant difference. *Reference values were obtained from the Brazilian Food Composition Table (TACO) (NEPA, 2011). Animal-based reference values corresponds to a single observation per category; therefore, statistical comparisons using non-parametric Mann-Whitney test were not performed.

All processed products plant-based showed elevated sodium levels. Among plant-based products, sausages exhibited the highest values (665.7 mg/100 g), followed by pork analogues (545.3 mg/100 g), poultry analogues (468.6 mg/100 g), processed meat analogues (423.3 mg/100 g), fish analogues (447.2 mg/100 g), and burgers (339.9 mg/100 g). Among processed animal-based products, sausages also showed the highest sodium content (890 mg/100 g), followed by burgers (172.3 mg/100 g). While fresh animal-based products present relatively low sodium values (32.7–60.6 mg/100 g), all processed products, including both animal-based items and their plant-based equivalents, showed higher levels (> 340 mg/100 g), suggesting that sodium may play an important functional role in flavor development, texture formation, and product preservation. These levels exceed half of the daily intake recommended by the World Health Organization [WHO] (2025), indicating that sodium reduction may be an important target for future product formulation.

Overall, plant-based products showed advantages in terms of dietary fiber content, and lipid profile, but disadvantages related to lower protein content and, in some cases, higher sodium levels. Energy values also varied across subcategories, indicating that formulation and processing strategies play an important role in determining nutritional composition.

Substantial nutritional variability was also observed among plant-based products themselves, which may be associated with the absence of specific regulatory standards or Identity and Quality Standards (*Padrões de Identidade e Qualidade* - PIQ) for these products. Protein content ranged from 8.9 g/100 g (burgers) to 17.3 g/100 g (sausages); fiber from 2.3 g/100 g (sausages) to 7.7 g/100 g (meat analogues); sodium from 339.9 mg/100 g (burgers) to 665.7 mg/100 g (sausages); and energy values from 156.3 kcal/100 g (pork analogues) to 211.7 kcal/100 g (poultry analogues) (Table 4). This heterogeneity complicates direct nutritional comparisons and highlights the potential need for clearer regulatory parameters. To ensure that the nutritional and environmental benefits communicated on product labels are substantiated, attention should be given to protein quality, sodium levels, and energy content, together with regulatory frameworks establishing minimum standards for this emerging product category.

The word cloud (Figure 5) illustrates the most frequently reported ingredients, including soy protein, pea protein, vegetable oils (canola and sunflower), and the additives guar gum and methylcellulose. Flavorings and colorants are commonly used to approximate the sensory characteristics of conventional meat products. Although these components are technologically functional, their presence may influence consumer perception, particularly among individuals who prefer minimally processed foods (Kyriakopoulou et al., 2021). In addition, fortification with B vitamins and iron was observed, likely intended to compensate for nutritional limitations of plant-derived ingredients (Hurrell & Egli, 2010; Watanabe et al., 2014).

According to Clark et al. (2022), plant-based products are often categorized as “win-win,” combining relatively high nutritional quality with lower environmental impact, whereas beef is considered “win-lose” because of their higher environmental footprint and variable nutritional profile. Although the nutritional patterns observed in the present study are broadly consistent with this classification, the relatively high sodium levels identified in several plant-based products suggest that nutritional advantages may vary depending on formulation.

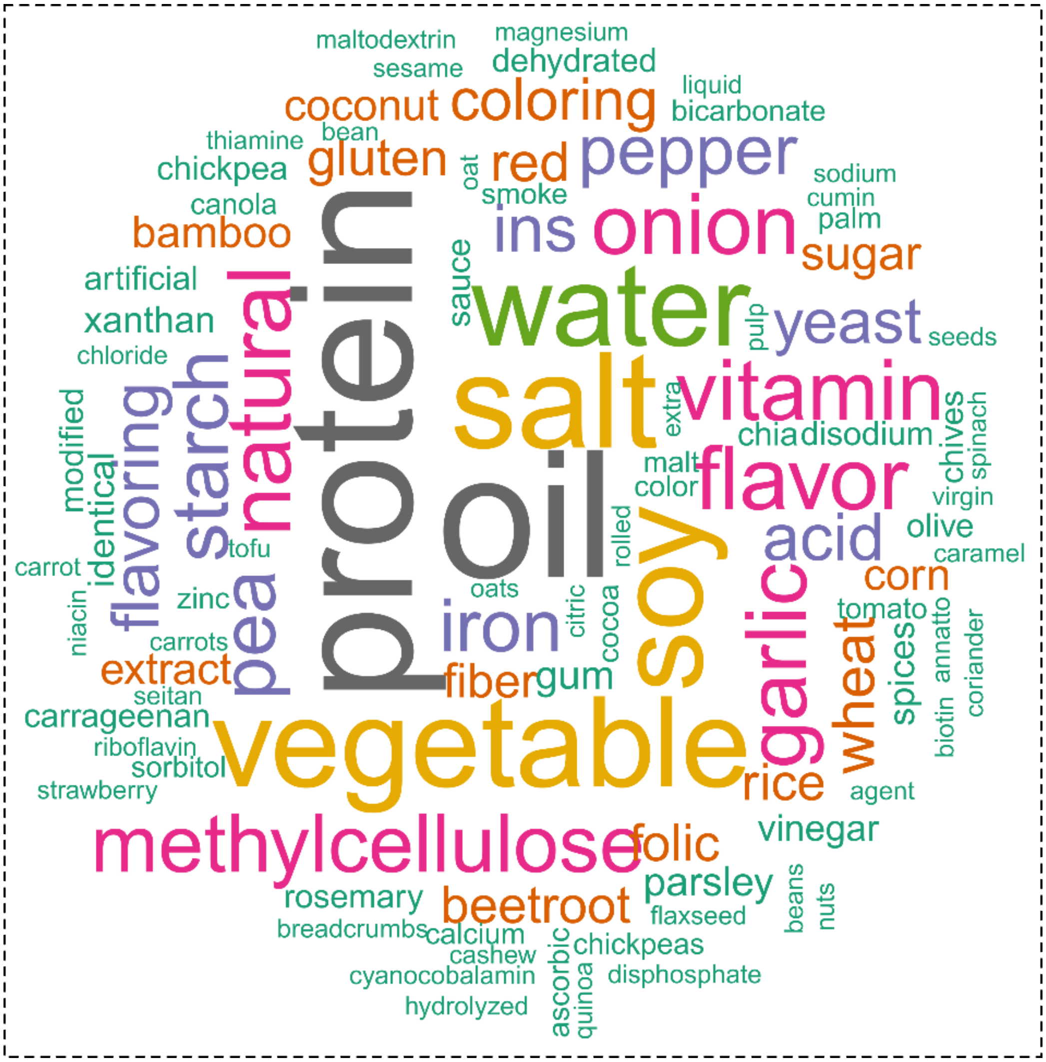

Figure 5. Word cloud representing the most frequently listed ingredients in plant-based products identified in retail establishments in Rio de Janeiro, Brazil. Word size is proportional to the frequency of occurrence in product ingredient lists. Words were extracted from ingredient lists on product labels and may represent components of multi-word ingredients (e.g., vegetable oil, vegetable protein).

Conclusion

The study indicates that, although eco-labeled animal-based products and plant-based analogues are available in the Brazilian market, their distribution appears uneven, with availability and variety associated with differences in IPS levels. The most prevalent products in the analyzed categories were plant-based burgers and poultry among animal-based products. Plant-based products identified in this study showed favorable nutritional characteristics in several aspects, particularly dietary fiber, lipid profile, and absence of cholesterol. However, the relatively low protein content observed in several subcategories suggests that reformulation or the establishment of minimum protein standards may be important to ensure nutritional equivalence with animal-based products.

The transition toward more sustainable protein sources in Brazil may depend on public policies aimed at reducing structural barriers related to price, distribution, and information, as well as improved consumer awareness regarding these products and their sustainability attributes. At present, eco-labeled protein-rich foods appear to remain concentrated in socioeconomically advantaged areas, suggesting that environmental and nutritional benefits associated with these products may not yet be equitably distributed across the population.

References

Alsubhi, M., Blake, M., Nguyen, T., Majmudar, I., Moodie, M., & Ananthapavan, J. (2023). Consumer willingness to pay for healthier food products: a systematic review. *Obesity Reviews, 24*(1), e13525. doi: 10.1111/obr.13525

Berrebi, L., Turquier, L., Kurth, T., & Taylor, L. (2023). *Whetting consumers' appetite for sustainable foods.* Boston Consulting Group. https://www.bcg.com/publications/2023/whetting-consumers-appetite-for-sustainable-foods

Borges, C. A., & Jaime, P. C. (2022). Ambiente alimentar do consumidor: definição, características, indicadores e instrumentos de auditoria. In L. L. Mendes, M. C. Pessoa, & B. V. de L. Costa (Orgs.), *Ambiente alimentar: saúde e nutrição* (pp. 87-97). Rio de Janeiro: Rubio.

Caccialanza A , Casati M , Muzzillo M , Iuffmann Ghezzi A (2026). How retail marketing levers influence demand for plant-based products: a revealed preference analysis across food categories and urbanization levels. *Revista Britânica de Alimentos, 128* (3), 1209–1234. doi: 10.1108/bfj-10-2024-1093

Canto, N. M., Jaime, P. C., & Monteiro, C. A. (2020). Instrumentos para avaliação do ambiente alimentar em estabelecimentos comerciais de alimentos no Brasil: revisão sistemática. *Cadernos de Saúde Pública, 36*(8), e00097819. doi: 10.1590/0102-311x00097819

Carvalho, A. M. de, Verly, E., Jr., Marchioni, D. M., & Jones, A. D. (2021). Measuring sustainable food systems in Brazil: a framework and multidimensional index to evaluate socioeconomic, nutritional, and environmental aspects. *World Development, 143*(1), 105470. doi: 10.1016/j.worlddev.2021.105470

Clark, M. A., Domingo, N. G. G., Colgan, K., Thakrar, S. K., Tilman, D., Lynch, J., Azevedo, I. L., & Hill, J. D. (2020). Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets. *Science, 370*(6517), 705-708. doi: 10.1126/science.aba7357

Clark, M. A., Springmann, M., Hill, J., & Tilman, D. (2019). Multiple health and environmental impacts of foods. *Proceedings of the National Academy of Sciences, 116*(46), 23357-23362. doi: 10.1073/pnas.1906908116

Clark, M. A., Springmann, M., Rayner, M., Scarborough, P., Hill, J., Tilman, D., Macdiarmid, J. I., Fanzo, J., Bandy, L., & Harrington, R. A. (2022). Estimating the environmental impacts of 57,000 food products. *Proceedings of the National Academy of Sciences, 119*(33), e2120584119. doi: 10.1073/pnas.2120584119

Cook, B., Costa Leite, J., Rayner, M., Stoffel, S., van Rijn, E., & Wollgast, J. (2023). Interação do consumidor com a rotulagem de sustentabilidade em produtos alimentícios: uma revisão narrativa da literatura. *Nutrients, 15*(17), 3837. doi: 10.3390/nu15173837

Costa-Catala, J., Toro-Funes, N., Comas-Basté, O., Hernández-Macias, S., Sánchez-Pérez, S., Latorre-Moratalla, M. L., Veciana-Nogués, M. T., Castell-Garralda, V., & Vidal-Carou, M. C. (2023). Comparative assessment of the nutritional profile of meat products and their plant-based analogues. *Nutrients, 15*(12), 2807. doi: 10.3390/nu15122807

Curtain, F., & Grafenauer, S. (2019). Plant-based meat substitutes in the flexitarian age: an audit of products on supermarket shelves. *Nutrients, 11*(11), 2603. doi: 10.3390/nu11112603

Cutroneo, S., Angelino, D., Tedeschi, T., Pellegrini, N., & Martini, D. (2022). Nutritional quality of meat analogues: results from the Food Labelling of Italian Products (FLIP) project. *Frontiers in Nutrition, 9*(1), 852831. doi: 10.3389/fnut.2022.852831

Deggerone, Z. A., Wiederkehr, F., & Bombardelli, C. L. (2023). Características do acesso aos alimentos em Erechim, Rio Grande do Sul, Brasil. *Confins, 57*(1), Article e52555. doi: 10.4000/confins.52555

Duran, A. C., Roux, A. V. D., Latorre, M. D. R. D., & Jaime, P. C. (2013). Neighborhood socioeconomic characteristics and differences in the availability of healthy food stores and restaurants in Sao Paulo, Brazil. *Health & Place, 23*(1), 39-47. doi: 10.1016/j.healthplace.2013.05.001

Engels, S., Hansmann, R., & Scholz, R. (2010). Toward a sustainability label for food products: an analysis of experts' and consumers' acceptance. *Ecology of Food and Nutrition, 49*(1), 30-60. doi: 10.1080/03670240903433154

Garnett, T. (2016). Plating up solutions. *Science, 353*(6305), 1202-1204. doi: 10.1126/science.aah4765

Glanz, K., Sallis, J. F., Saelens, B. E., & Frank, L. D. (2007). Nutrition environment measures survey in stores (NEMS-S): development and evaluation. *American Journal of Preventive Medicine, 32*(4), 282-289. doi: 10.1016/j.amepre.2006.12.019

Grasso, A. C., Hung, Y., Olthof, M. R., Verbeke, W., & Brouwer, I. A. (2019). Understanding meat consumption: attitudes, motives and dietary transitions. *Food Quality and Preference, 73*(1), 82-93. doi: 10.1016/j.foodqual.2018.11.011

Grunert, K., Sonntag, W., Glanz-Chanos, V., & Forum, S. (2018). Consumer interest in environmental impact, safety, health and animal welfare aspects of modern pig production: results of a cross-national choice experiment. *Meat Science, 137*(1), 123-129. doi: 10.1016/j.meatsci.2017.11.022

Hartmann, C., & Siegrist, M. (2017). Consumer perception and behaviour regarding sustainable protein consumption: a systematic review. *Trends in Food Science & Technology, 61*(1), 11-25. doi: 10.1016/j.tifs.2016.12.006

Hasegawa, T., Havlík, P., Frank, S., Palazzo, A., & Valin, H. (2019). Tackling food consumption inequality to fight hunger without pressuring the environment. *Nature Sustainability, 2*(9), 826-833. doi: 10.1038/s41893-019-0371-6

He, Y., & Tsvetkova, M. (2025). *High socioeconomic status is associated with diverse consumption across brands and price levels.* https://arxiv.org/abs/2506.13840

Henchion, M., Hayes, M., Mullen, A. M., Fenelon, M., & Tiwari, B. (2017). Future protein supply and demand: Strategies and factors influencing a sustainable equilibrium. *Foods, 6*(7), Article 53. https://doi.org/10.3390/foods6070053

Hötzel, M. J., & Vandresen, B. (2022). Brazilians' attitudes to meat consumption and production: present and future challenges to the sustainability of the meat industry. *Meat Science, 192*(1), 108893. doi: 10.1016/j.meatsci.2022.108893

Hurrell, R., & Egli, I. (2010). Iron bioavailability and dietary reference values. *American Journal of Clinical Nutrition, 91*(5), 1461S-1467S. doi: 10.3945/ajcn.2010.28674F

Instituto Pereira Passos (2023). *Índice de progresso social da cidade do Rio de Janeiro.* https://ips-rio-pcrj.hub.arcgis.com/

Instrução Normativa nº 75, de 08 de outubro de 2020 (2020). *Agência Nacional de Vigilância Sanitária (ANVISA).* https://anvisalegis.datalegis.net/action/ActionDatalegis.php?acao=abrirTextoAto&link=S&tipo=INM&numeroAto=00000075&seqAto=000&valorAno=2020&orgao=DC/ANVISA/MS&codTipo=&desItem=&desItemFim=&cod_modulo=134&cod_menu=1696

International Organization for Standardization (2022). *ISO 14020: environmental statements and programmes for products — principles and general requirements* (3nd ed.). ISO.

Jiang, Y., Wang, H., Jin, S., & Delgado, M. S. (2019). The promising effect of a green food label in the new online market. *Sustainability, 11*(3), 796. doi: 10.3390/su11030796

Kortetmäki, T., & Oksanen, M. (2021). Is there a convincing case for climate veganism? *Agriculture and Human Values, 38*(3), 729-740. doi: 10.1007/s10460-020-10182-x

Kyriakopoulou, K., Keppler, J. K., & van der Goot, A. J. (2021). Functionality of ingredients and additives in plant-based meat analogues. *Foods, 10*(3), 600. doi: 10.3390/foods10030600

LendingTree (2024). *Organic vs. conventional produce study: organic produce costs 52.6% more on average.* https://www.lendingtree.com/debt-consolidation/organic-vs-conventional-study/

Lenormand, M., Samaniego, H., Chaves, J. C., Fonseca Vieira, V. da, Silva, M. A. H. B. da, & Evsukoff, A. G. (2020). Entropy as a measure of attractiveness and socioeconomic complexity in Rio de Janeiro Metropolitan Area. *Entropy, 22*(3), 368. doi: 10.3390/e22030368

Liu, Y., Song, S., Gittelsohn, J., Jiang, N., Hu, J., Ma, Y., & Wen, D. (2019). Adaptation and validation of the Chinese version of the nutrition environment measurement tool for stores. *International Journal of Environmental Research and Public Health, 16*(5), 782. doi: 10.3390/ijerph16050782

Lou, K. J. Q., Rajaram, N. N., & Say, Y. H. (2024). Availability, price and nutritional assessment of plant-based meat alternatives in hypermarkets and supermarkets in Petaling, the most populated district in Malaysia. *Plos One, 19*(12), e0309507. doi: 10.1371/journal.pone.0309507

Manian, C. (2023). *What's the environmental impact of your favorite protein choices?* Real Simple. https://www.realsimple.com/environmental-impact-different-proteins-7375705

McBey, D., McCormick, B. J. J., Hussain, M., & Macdiarmid, J. I. (2024). Does sociodemographic strata determine local access to plant-based meat alternatives? *Proceedings of the Nutrition Society, 83*(OCE4), E350. doi: 10.1017/S0029665124005883

Neff, R. A., Edwards, D., Palmer, A., Ramsing, R., Righter, A., & Wolfson, J. (2018). Reducing meat consumption in the USA: a nationally representative survey of attitudes and behaviours. *Public Health Nutrition, 21*(10), 1835-1844. doi: 10.1017/S1368980017004190

Núcleo de Estudos e Pesquisas em Alimentação (2011). *Tabela brasileira de composição de alimentos* (4a ed., rev. e exp.). NEPA-UNICAMP. http://www.nepa.unicamp.br/taco/

OpenStreetMap Contributors (2026). *Map of Rio de Janeiro, Brazil.* OpenStreetMap. https://www.openstreetmap.org

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science, 360*(6392), 987-992. doi: 10.1126/science.aaq0216

Resolução da Diretoria Colegiada (RDC) nº 429, de 08 de outubro de 2020. (2020). *Agência Nacional de Vigilância Sanitária.* https://anvisalegis.datalegis.net/action/ActionDatalegis.php?acao=abrirTextoAto&tipo=RDC&numeroAto=00000429&seqAto=000&valorAno=2020&orgao=RDC/DC/ANVISA/MS&codTipo=&desItem=&desItemFim=&cod_menu=1696&cod_modulo=134&pesquisa=true

Rizzolo-Brime, L., Orta-Ramirez, A., Puyol Martin, Y., & Jakszyn, P. (2023). Nutritional assessment of plant-based meat alternatives: a comparison of nutritional information of plant-based meat alternatives in Spanish supermarkets. *Nutrients, 15*(6), 1325. doi: 10.3390/nu15061325

Röös, E., Bajželj, B., Smith, P., Patel, M., Little, D., & Garnett, T. (2017). Greedy or needy? Land use and climate impacts of food in 2050 under different livestock futures. *Global Environmental Change, 47*, 1–12. https://doi.org/10.1016/j.gloenvcha.2017.09.001

Smoluk-Sikorska, J. (2024). Differences between prices of organic and conventional food in Poland. *Agriculture, 14*(12), 2308. doi: 10.3390/agriculture14122308

Sogari, G., Andreani, G., Livat, F., Lefebvre, M., Menozzi, D., & Mora, C. (2025). Understanding young consumers' motivations for purchasing plant-based burgers: insights from the means-end chain theory. *Agricultural Economics, 13*(37), 1-31. doi: 10.1186/s40100-025-00372-8

Song, M., Fung, T. T., Hu, F. B., Willett, W. C., Longo, V. D., Chan, A. T., & Giovannucci, E. L. (2016). Association of animal and plant protein intake with all-cause and cause-specific mortality. *JAMA Internal Medicine, 176*(10), 1453-1463. doi: 10.1001/jamainternmed.2016.4182

Stanišić, N., Kurćubić, V. S., Stajić, S. B., Tomasevic, I. D., & Tomasevic, I. (2025). Integration of dietary fibre for health benefits, improved structure, and nutritional value of meat products and plant-based meat alternatives. *Foods, 14*(12), 2090. doi: 10.3390/foods14122090

Stoyanov, S. (2017). An Analysis of Abraham H. Maslow's A Theory of Human Motivation. (1st ed.) Taylor & Francis. https://doi.org/10.4324/9781912282517

Summerhayes, L., Baker, D., & Vella, K. (2024). Food diversity and accessibility enabled urban environments for sustainable food consumption: a case study of Brisbane, Australia. *Humanities and Social Sciences Communications, 11*(1), 1386. doi: 10.1057/s41599-024-03724-9

Tetteh, H., Bala, A., Fullana-i-Palmer, P., Balcells, M., Margallo, M., Aldaco, R., & Puig, R. (2022). Carbon footprint: the case of four chicken meat products sold on the Spanish market. *Foods, 11*(22), 3712. doi: 10.3390/foods11223712

Tiboni-Oschilewski, O., Abarca, M., Santa Rosa Pierre, F., Rosi, A., Biasini, B., Menozzi, D., & Scazzina, F. (2024). Strengths and weaknesses of food eco-labeling: a review. *Frontiers in Nutrition, 11*(1), 1381135. doi: 10.3389/fnut.2024.1381135

Tilman, D., & Clark, M. (2014). Global diets link environmental sustainability and human health. *Nature, 515*(7528), 518-522. doi: 10.1038/nature13959

Watanabe, F., Yabuta, Y., Bito, T., & Teng, F. (2014). Vitamin B12-containing plant food sources for vegetarians. *Nutrients, 6*(5), 1861-1873. doi: 10.3390/nu6051861

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L. J., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J. A., Vries, W. de, Majele Sibanda, L., … Murray, C. J. L. (2019). Food in the anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet, 393*(10170), 447-492. doi: 10.1016/S0140-6736(18)31788-4

World Health Organization (2025). *Sodium reduction.* WHO. https://www.who.int/news-room/fact-sheets/detail/sodium-reduction