



# David vs Goliath: The challenges for plant-based meat companies competing with animal-based meat producers

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## 1. Introduction

An extensive body of literature has recently discussed how the transition from animal-based meat to alternative sources of proteins could help to reduce the environmental impacts of livestock chains, such as greenhouse gas (GHG) emissions (Sinke et al., 2023; Smetana et al., 2015; Takacs et al., 2022; Tuomisto and Teixeira de Mattos, 2011; Tuomisto et al., 2022). Alternative proteins are broadly characterized as being made with ingredients that replace traditional protein sources and have a lower environmental impact (Grossmann and Weiss, 2021), while the terms “meat analogs” and “meat substitutes” refer more specifically to alternative protein products that incorporate the nutritional and sensory characteristics of meat (McClements and Grossmann, 2021; Smetana et al., 2023). Plant-based meats are produced with vegetable proteins such as soy, pea or wheat to mimic the characteristics of animal meat products (Choudhury et al., 2020; He et al., 2020). These plant-based products can have 50% less GHG emissions than animal-based food (Xu et al., 2021; Smetana et al., 2023). Moreover, the dietary, nutritional, and health benefits of plant-based meats have also drawn the interest of consumers seeking meat substitutes (Michel et al.,

2021; Rizzo et al., 2023). For instance, plant-based meat consumption may be associated with a lower risk of developing chronic diseases (e.g., heart diseases) and can contribute to greater general well-being among consumers (Fehér et al., 2020).

Despite the expected benefits, potential bottlenecks to the development and expansion of the meat analogs sector have been discussed in the literature. Plant-based meat is already available but has challenges regarding product cost, the need to develop novel vegetable protein sources, and improving the sensory attributes of products (Choudhury et al., 2020; He et al., 2020).

Driven by the alleged environmental benefits of plant-based meats, the mainstream animal-based meat companies - associated with high levels of GHG emissions, extensive land use, animal suffering, and other negative externalities - have invested in alternative proteins. These plant-based meat products complement their existing portfolios. Examples include Tyson Food's Raised & Rooted, Jimmy Dean plant-based brands and JBS's Seara Incrível plant-based products. Thus, while keeping and promoting their animal-based products they also have branches in plant-based meat segments.

Tyson Foods, a major global food company, reported that 81.13% of

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their sales in 2022 came from livestock products (beef 37.26%, pork 11.66%, chicken 31.83%). They experienced a significant sales increase for beef (10.31%) and chicken (23.51%) that year. Plant-based meat sales, although not explicitly disclosed, represent a small fraction of the company's overall business (Tyson Foods, 2023).

Companies producing exclusively plant-based meats have also flourished and grown worldwide (e.g., Beyond Meat, Impossible Foods, Future Farm). However, little attention has been given to the differences between these two types of companies producing plant-based meats: animal-based meat processors companies (MPCs) and plant-based exclusive (PBE) companies. The extant life cycle assessment (LCA) studies developed and systematized by Detzel et al. (2022), Saget et al. (2021) and Smetana et al. (2023) show that plant-based products have less environmental footprints, we infer that PBE companies are likely to have a significantly lower overall environmental footprint than firms that combine animal-based and plant-based products.

Despite the importance of the products marketed by PBEs for a reduced overall environmental footprint, it remains unclear how they compete with MPCs' products (Dueñas-Ocampo et al., 2023), especially in downstream chain stages (e.g., retailers), which are closer to end consumers. By addressing retail, we explore a crucial aspect that is often overlooked in the plant-based literature, namely the role that retail plays in promoting the plant-based meat industry (He et al., 2020; Mohorčič and Reese, 2019). According to the global value chain (GVC) theoretical framework, large retailers can play a key leadership role within their value chains, influencing suppliers' activities, products, and marketing strategies (Gereffi et al., 2005; Gereffi and Christian, 2009). They also influence food purchasing and the extent to which consumers adopt sustainable and healthier products (Haan et al., 2022; Martin et al., 2017). Food retailers can either enable or restrict the consumption of alternative proteins (Gravelly and Fraser, 2018).

In addition, it remains unclear whether meat substitutes will be indeed able to compete with animal-based products in the meat sector, or whether they will be limited to niche segmentation. Thus, our objective is to compare PBE companies' plant-based meat products and MPC companies' corresponding products in terms of the product price and availability by analyzing publicly available data from online Brazilian stores.

Brazil is an emerging market, one of the largest producers and consumers of industrial animal-based meat and a home to major meat processing multinationals such as JBS and BRF (ABIEC, 2021). Most of the meat consumption is based on *in-natura* products, especially beef and poultry; nonetheless, processed meat consumption has grown in importance and has increased in recent years by 23% (Hase Ueta et al., 2023). The country is a major source of GHG emissions from animal production (Xu et al., 2021) which urges the need to transition to alternative sources of protein production, such as plant-based meats.

## 2. Literature review

### 2.1. Plant-based meat: production chain and environmental impacts

The development of plant-based meat products needs to consider several factors such as nutrition, allergenicity, consumer perception, cost, flavor, and texture (Gómez-Luciano et al., 2019; The Good Food Institute, 2021). The ability of textured vegetable proteins to mimic meat has driven the industry's success in bringing a wide variety of plant-based meats to the market (Gravelly and Fraser, 2018; McClements and Grossmann, 2021).

The plant-based meat chain exerts significantly less pressure on the environment when compared to animal meat. Studies estimate that meat will be responsible for 37%–49% of the allowable carbon budget under the Paris Accords (Harwatt, 2019; Smetana et al., 2023). To remain within planetary boundaries, a 50% reduction in meat should be combined with a 100% increase of plant-based food (Willett et al., 2019). Plant-based meat products have the potential to accelerate the

sustainability transition of food systems with high-performing products acceptable by dedicated vegetarian and vegan user groups to appeal to an expanded market (Detzel et al., 2022).

In a recent review of the climate impacts of plant-based meat products, Shanmugam et al. (2023) estimated that the median carbon emission emitted by the production of 1 kg of plant-based meat is 1.8 kg of CO<sub>2eq</sub>, with a variation from 0.67 to 2.54 kg CO<sub>2eq</sub> per kg of product. For comparison, based on adjusted LCA results from Poore and Nemecek (2018), the mean values of carbon emissions per kg of animal-based products are 7.89 CO<sub>2eq</sub>/kg (fish, farmed), 7.52 CO<sub>2eq</sub>/kg (poultry), 10.57 CO<sub>2eq</sub>/kg (pork) and 60.36 CO<sub>2eq</sub>/kg (beef, world average). The climate impact per protein content of the final plant-based product has a median value of 0.94 kg CO<sub>2eq</sub> per 100 g of protein, with a variation from 0.63 to 1.50 kg CO<sub>2eq</sub> per 100 g of protein. The cultivation and preparation of raw materials and the manufacturing processes account for the most significant portions of greenhouse gas emissions in plant-based meat production (Shanmugam et al., 2023). To compare the climate impact per protein content, Shanmugam et al. (2023) adapted results from Poore and Nemecek (2018). The mean values of carbon emissions per protein content are 4.30 CO<sub>2eq</sub>/100 g of protein (poultry), 6.50 CO<sub>2eq</sub>/100 g of protein (pork), 20.00 CO<sub>2eq</sub>/100 g of protein (lamb and mutton), 30.00 CO<sub>2eq</sub>/100 g of protein (beef), 3.50 CO<sub>2eq</sub>/100 g of protein (fish), and 10.00 CO<sub>2eq</sub>/100 g of protein (crustaceans) (Poore and Nemecek, 2018; Shanmugam et al., 2023).

However, the assessment of the production chain's climate impact of plant-based meat is hindered by the data limitations and lack of transparency of previous LCA studies regarding individual life cycle stages. This lack of transparency hinders the identification of emission hot spots and the extent of potential improvements in products and processes. Studies of the environmental impacts of different dietary patterns often compare the impact of meat to that of minimally processed plant-based foods, such as legumes, vegetables, nuts, and grains (Shanmugam et al., 2023). In addition, recent studies have shown that animal-based meat products have a greater climate impact than plant-based products even when considering the processing of plant-based meat and the comparison of meat protein and plant-based concentrates and isolates (Clune et al., 2017; Poore and Nemecek, 2018; Shanmugam et al., 2023). These findings have led to policy recommendations for promoting a shift towards more plant-based diets as a strategy for mitigating climate change (Shanmugam et al., 2023; Willett et al., 2019).

In addition to the significant environmental benefits, a growing body of literature has addressed the health advantages associated with plant-based diets. A study conducted by Rizzo et al. (2023) in Italy revealed a positive correlation between an individual's interest in their health and the choice to adopt plant-based diets. Fehér et al. (2020) highlighted that the primary benefit of consuming plant-based products lies in reducing the risk of developing chronic diseases, such as heart disease, followed by promoting overall well-being and contributing to environmental preservation. The literature further suggests that plant-based diets may lead to reductions in body fat and increased intake of vital nutrients (Fehér et al., 2020). Additionally, research by Martin et al. (2021) demonstrated that providing information about the health benefits of plant-based products positively influences potential consumers' preferences and willingness to pay for meat substitutes. Furthermore, after reviewing 43 studies on the health and environmental sustainability of plant-based meat, Bryant (2022) found that these products are more environmentally sustainable than conventional animal-based products in terms of environmental impact categories; they present benefits also in terms of individuals and public health.

### 2.2. Plant-based meat market: animal-based meat and plant-based exclusive companies

Conventional meat producers have been challenged by companies developing and commercializing plant-based meats to meet the growing global demand for proteins. This has presented an opportunity for food

startups and established producers to offer an array of new products and redefine concepts to address market needs (Choudhury et al., 2020). The startups in the plant-based meat sector or plant-based exclusive (PBE) companies are dedicated to a purpose-driven mission of reinventing the industry by removing animals from their supply chains. Conventional meat-processing companies (MPCs) add more plant-based offerings to their portfolio and brand themselves as “protein companies” as opposed to meat processors (Guthman et al., 2022). Questions on how both types of firms compare regarding environmental profiles still needs to be clarified.

The environmental profile of products and companies has become a critical driver in product communication and adoption (Bryant and Barnett, 2018; Collier et al., 2021), along with elements of trust in the firms operating in plant-based meat alternative market (Bryant and Sanctorem, 2021). MPCs tend to capitalize this opportunity, but it is uncertain how much plant-based meat products contribute to their product portfolio (e.g., sales revenue or production volume). Additionally, it is unclear how production volumes and the range of plant-based meat products offered by PBEs and MPCs affect the decisions, bargaining power and strategies of upstream actors, such as supermarket chains.

The largest Brazilian meat processors - JBS, BRF, and Marfrig - have entered the plant-based market. JBS claims to lead the plant-based meat market in Brazil and has invested over R\$ 43 million in research and development and facility adaptations. BRF offers 10 plant-based meat products and has invested US\$ 2.5 million in Aleph Farms. Marfrig focuses on ingredient development and acquired Sol Cuisine and Hilary's to strengthen their plant-based meat business. (JBS, 2021; 2022; BRF, 2022; Marfrig, 2022a). Although their reports follow international sustainability reporting guidelines and standards, it is not possible to determine the extent to which plant-based meat products make up their portfolios, as none of the companies disclose specific figures for their plant-meat-based products. Figures are lumped into generic categories such as “hamburgers” or “processed products” (BRF, 2022; JBS, 2022; Marfrig, 2022b). This lack of transparency is problematic for estimating the size of the market for plant-based meat products and the environmental and social impact of MPC and PBE companies. It is also problematic in terms of evaluating the consistent development of plant-based meat products in line with rigorous environmental criteria and meeting consumer expectations, which could prevent potential greenwashing and distortions in the market (de Moraes et al., 2023).

In this study, we examine the plant-based meat sector by comparing the products of PBE and MPC companies in large Brazilian supermarket chains. According to the GVC literature, large supermarket chains exert significant influence on various aspects of the production chain, pricing to product development and availability (Gereffi et al., 2005; Lowe and Gereffi, 2009). Notably, they have the ability to facilitate or hinder the entry of suppliers' products depending on their profit potential. Consequently, supermarkets play a central role in promoting wider acceptance of plant-based meat products. Specifically, they are able to overcome barriers that prevent consumers from adopting plant-based alternatives and can guide consumers toward sustainable choices (Helmefalk and Berndt, 2018; Coucke et al., 2022; Martin et al., 2017). The strategic importance of supermarkets in shifting the food system towards alternative proteins, therefore, stems from their considerable influence on both consumers and food production chains (Murray and Caraher, 2019).

### 3. Data and methods

We compared plant-based meat products marketed by PBEs with plant-based and animal-based products marketed by MPCs in the downstream production chain (retailers). We compared information about PBEs and MPCs regarding a set of aspects that can affect plant-based meat sales consumption: price (Apostolidis and McLeay, 2016; Nezek and Forestell, 2022; Trewern et al., 2022), product availability (Trewern et al., 2022), and promotions, i.e., discounts and multi-buy

offers (Haan et al., 2022).

#### 3.1. Data collection

We collected data about plant-based and animal-based meat products available in the online stores of major Brazilian supermarkets, following the approach used in the extant study about animal-based meat sales in the UK's retailers (Haan et al., 2022). Collecting plant-based meat product information online grants an access to a large amount of publicly available data and reflecting the focal information presented for plant-based meat consumers (e.g., price, available products). Moreover, it has an advantage of collecting up-to-date plant-based meat product offering and availability information. Thus, information from online stores is ideal for comparing the offerings and promotions of plant-based meat products from PBE and MPC companies.

Studying the Brazilian market is relevant because the country is globally a major producer and consumer of livestock meat (Statista, 2022). Considering that the Brazilian food industry has undergone a significant concentration process and a limited number of large corporations are responsible for 40% of the sector's turnover (Arkader and Ferreira, 2004), we initially selected four Brazilian supermarket chains with the largest sales that operate in regions with the largest gross domestic product (GDP) and number of inhabitants (São Paulo and Rio de Janeiro): Carrefour Brazil, Pão de Açúcar, Extra, and Big (ABRAS, 2022). The regions of São Paulo and Rio de Janeiro were selected due to their concentration the plant-based meat producers, brands, and sales (Lupetti and Casselli, 2022). The selection of major supermarket chains is consistent with our overarching theoretical framework, i.e., GVC theory, which assumes that prominent retailers play an influential role in the development of their chains (Gereffi and Christian, 2009).

The four supermarkets selected (Appendix A, supplementary materials) are controlled by two groups: Grupo Pão de Açúcar (GPA) and Carrefour Brazil. GPA is one of the largest food retail groups in South America (GPA, 2022) and is controlled by the Casino group, a major retailing organization from France; Carrefour Brazil is the largest food retail company in the country (ABRAS, 2022) and is controlled by the international Carrefour group. To compensate for this retail ownership concentration and increase the heterogeneity of the sample, we included a fifth supermarket chain: Muffato supermarkets, which is among the six largest Brazilian supermarket chains (ABRAS, 2022).

Carrefour Brazil follows a lower-price strategy whereas GPA does not explicitly compete with prices (Draska, 2022; Valor, 2022). Muffato has not released its pricing strategy. Moreover, all three groups claim that they have adopted sustainable and environmentally friendly initiatives such as GHG emissions reduction targets (Carrefour, 2021; GPA, 2022; Muffato, 2023).

We collected data from supermarkets three times a week for five weeks, from August 5 to September 8, 2022. The data collected included information about plant-based meat products offered by PBEs and MPCs such as hamburgers, sausages, minced meat, hot dogs (frankfurters), meatballs, kibbeh, and chicken nuggets.

To assess product availability in online stores, the data count corresponded to the total number of entries, consisting of 1191 data points from 117 distinct products. This indicates that, for each survey iteration, whenever a product was available, the researchers recorded it in the data table. See also Appendix B (supplementary materials). Thus, a total of 1191 plant-based meat data points (PBEs: N = 899; MPCs: N = 292) were included in the final dataset. Since we also collected data about the corresponding animal-based meat products of MPCs, the total number of cases (or observations) increased to 5697 data points (animal-based MPCs: N = 4506) (Companies and examples of their products are listed in Appendix B).

We included information about animal-based meat products in the data to allow comparisons between plant-based meat products. PBE companies' products are likely to compete with MPCs' plant and animal-based meat products as they target regular meat consumers and those

seeking to replace animal-based meat products with plant-based meat options (He et al., 2020).

The information collected included the price per kg of each product, type of product (e.g., hamburgers, meatballs), and the type of a food production company. We also collected information about promotions. Following Haan et al. (2022), data about promotions included (i) price discounts or the frequency of discounts (the number of occurrences) and the percentage of price discount offered, and (ii) the frequency of multi-buy offers, which consider the conditional purchase of more than one product or a range of products (e.g., buy two units, get the second unit 50% off).

Data were manually extracted on a product-by-product basis from the online stores of the supermarkets situated within the predetermined geographical region (namely, the cities of São Paulo or Rio de Janeiro). The extraction was carried out by two researchers: one was responsible for extracting the data from the supermarkets' websites, while the other checked the gathered data to prevent any inaccuracies during the data manipulation and entry phases. To enhance the consistency of data collection and recording, the researchers alternated their roles in each successive round of data collection. Data collection occurred between August 5th and September 8th, 2022, a timeframe less susceptible to seasonal oscillations. Consequently, most variations were related to discounts and marketing activities. The distribution of data collection across a span of five weeks allowed for minimizing potential biases stemming from particular campaigns or random events within the supermarkets under investigation.

### 3.2. Data analysis

We compared plant-based meat products marketed by PBEs with plant-based and animal-based products marketed by MPCs in online Brazilian supermarkets. The analysis covered a set of variables that tend to impact plant-based meat sales in supermarkets: price (Apostolidis and McLeay, 2016; Nezek and Forestell, 2022; Trewern et al., 2022), product availability (Trewern et al., 2022), and promotions or discounts and multi-buy offers (Haan et al., 2022).

We explored the data with descriptive and comparative analyses. Product availability was determined by counting all instances (data points) of the products offered during the data collection period in each of the online stores. Therefore, if a product was available at the online store at the time of data collection, it was included in the analysis. The prices were standardized per kg in US dollars (conversion rate - R\$5.25/US\$1.00), to increase the comparability of the products (they are in different pack sizes) and to ease communication with an international audience (in US dollars). Regarding promotions, we analyzed the frequencies of occurrence (discount or multibuy) and the percentage of discounts (price reductions) offered. In the analysis of the gathered data and comparison of PBEs' and MPCs' products, we utilized descriptive analysis, Student's t-test, and analysis of variance (ANOVA) tests to identify statistically significant differences between the groups. A confidence level 95%, risk level 5% was employed for the statistical tests. The post-hoc Bonferroni test was employed to adjust p-values, with the aim of managing the risk of type 1 error.

## 4. Results

As mentioned before, the data comprise 1191 individual plant-based meat product data points, from which 292 (24.5%) were produced by MPCs and 899 (75%) by PBEs. In addition, 4506 data points describe MPCs' animal-based meat products available during the data collection (Fig. 1).

Table 2 shows the availability of plant-based meat products divided by the MPC and PBE companies; it also shows the availability animal-based meat products from MPCs. The products of the MPCs were from two meat-processing companies, A (60% of all MPCs' plant-based meat products; 54% of MPCs' animal-based products) and B (40% of MPCs'

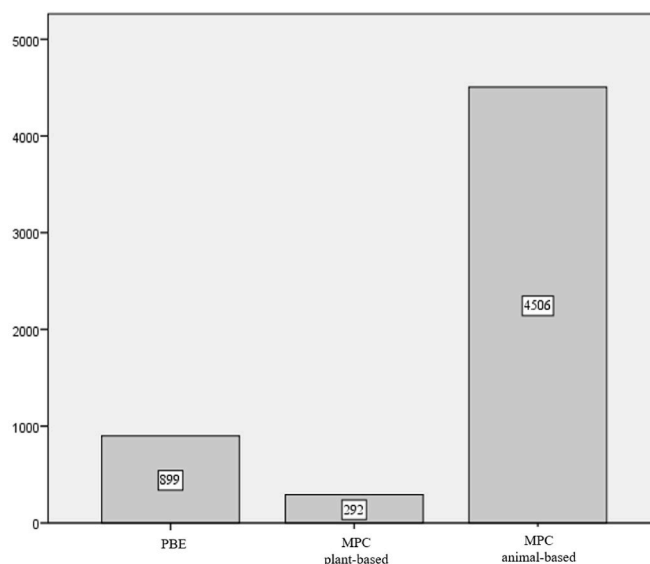


Fig. 1. Overall availability\* of PBE and MPC products in online supermarkets. Note: \*Based on the number of data points for each company type.

Table 2 Availability\* of MPC and PBE products per meat-producing company.

MPC companies	MPC availability	%**	%***
	Plant-based (animal-based)		
A	175 (1680)	60% (37%)	15%
B	117 (2826)	40% (63%)	10%
MPC total	292 (4506)	100% (100%)	
Mean	146 (2253)		
SD	41.01 (810.34)		
Variance	1682.00 (656.658)		
PBE companies	PBE availability	%**	%***
C	293	33%	25%
D	161	18%	14%
E	30	3%	3%
F	31	3%	3%
G	133	15%	11%
H	126	14%	11%
I	29	3%	2%
J	45	5%	4%
K	6	1%	1%
L	30	3%	3%
M	15	2%	1%
PBE total	899	100%	
Mean	81.73		
SD	88.18		
Variance	7775.01		
MPC plant-based + PBE total	1191	100%	

Note: \* Based on the number of data points for each meat-producing company. \*\*The % is in relation to the total of the company type: MPC plant-based (animal-based) or PBE. \*\*\*The % is in relation to the total of plant-based meat producers: MPCs + PBEs.

plant-based meat products; 46% of animal-based products). The exceptions among the PBEs were company C, which had the highest availability (33%), followed by D (18%) and G (15%). Overall, there was greater dispersion in the availability of plant-based meat products from the PBEs; the variance was almost five times higher than for the MPCs (Table 3).

The number of PBE companies is larger, but they exhibit greater heterogeneity in terms of plant-based meat product availability. Seven out of eleven PBEs offered only 1%–5% of the total PBE plant-based meat products. Products from these seven PBE companies consisted 20% of plant-based meat products in the data. Companies A, B, C, and D account for 62.64% of the plant-based meat availability in

**Table 3**  
Availability of plant-based meat product categories.

Products type	MPC Plant-based (animal-based)	%*	PBE	%*
Hamburgers	116 (1081)	40% (24%)	496	55%
Hotdogs	15 (466)	5% (10%)	30	3%
Minced Meat	12 (42)	4% (1%)	86	10%
Kibbehs	70 (69)	24% (2%)	60	7%
Meatballs	45 (35)	15% (1%)	144	16%
Nuggets	34 (772)	12% (17%)	30	3%
Sausages	0 (2041)	0% (45%)	53	6%
Total	292 (4506)	100% (100%)	899	100%

Note: \*Is in relation to the total.

supermarkets. The animal-based meat products had higher availability (79.09%) when compared to plant-based products.

Table 3 shows the availability of the plant-based meat product types produced by MPCs and PBEs. The most common plant-based meat products were hamburgers, which accounted for 40% of MPCs and 55% of PBEs. Kibbehs were the second most common for MPCs (24%) followed by meatballs (15%). For PBEs, the second was meatballs (16%) followed by minced meat (10%). The online stores offer least MPCs' hot dogs (5%) and minced meat (4%) whereas their plant-based sausages were not available at all during the data collection period. The least offered product categories from PBEs were hotdogs (3%) and nuggets (3%). Animal-based meat products had a significantly higher availability than plant-based meat products. Table 3 shows that animal meat-based sausages and hamburgers alone accounted for 54.8% of the observations in the data.

Supermarket 1 had a greater availability of plant-based meat products from both company types (PBEs: 72% of PBEs; MPCs: 28%). Supermarket 2 had a similar distribution (PBEs: 76%; MPCs: 24%), followed by Supermarket 4 (PBEs: 86%, MPCs: 14%). Supermarket 5 showed the lowest difference between plant-based meat product availability from PBEs and MPCs (PBEs: 62%; MPCs: 26%), and also the greatest availability of animal-based meat products among the five supermarkets.

Supermarket 3 had the lowest overall availability of plant-based meat products (PBEs: N = 81; MPCs = 15) whereas supermarkets 1 and 2 had comparatively fewer animal-based meat products (N = 813, N = 807, respectively) but the largest numbers of plant-based products available from PBEs (N = 250; N = 220). Supermarket 1 had the greatest number of plant-based meat products from MPCs (N = 95). It should be noted that these two supermarkets (1 and 2) are owned by the same retail group, which may explain the similar pattern. Fig. 2 also explicitly portrays that compared to PBEs, MPCs have a lower number of plant-based meat products, but they offer a multiple number of animal-based meat products in the studied supermarkets.

4.1. Comparison of plant-based meat product prices at PBEs and MPCs

Plant-based meat products from MPCs had lower average prices (M = \$14.59/kg, SD = 3.09) than those produced by the PBEs (M = \$16.54/kg, SD = 4.67); the difference is statistically significant (T test:  $t(1,189) = -6.69, p < .01$ ). On average, plant-based meat products from PBEs are 6% more expensive. The price difference is even greater for MPCs' animal-based meat products (M = \$9.41/kg, SD = 5,00). Hence, animal-based meat products exhibited the lowest prices, succeeded by plant-based products from MPCs, while offerings from PBE companies proved to be the costliest (Table 4).

A one-way ANOVA test revealed that there was a statistically significant difference between the average prices of PBEs' and MPCs' plant-based meat, and MPCs' animal-based meat products ( $F(2, 5694) = 2558.56, p < .01$ ). The Bonferroni post hoc test also confirmed these price differences ( $p < .01$ ). On average, MPC plant-based meat products were 91% more expensive than MPC animal meat products, while PBE

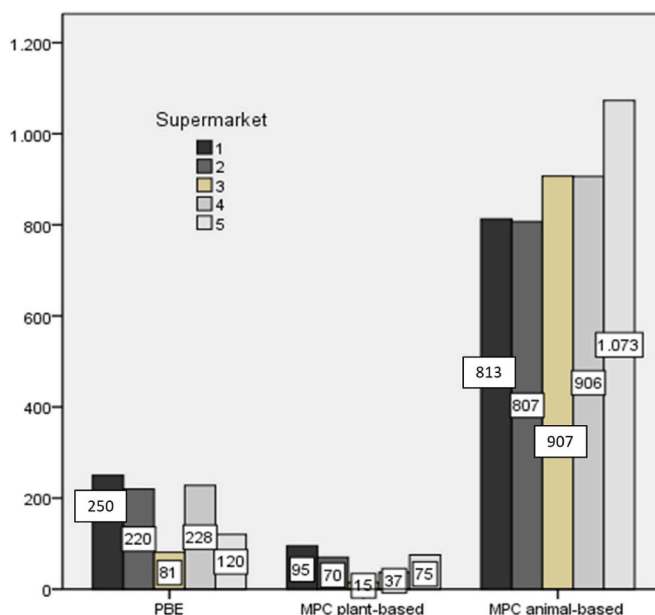


Fig. 2. Availability\* of plant-based meat products from MPCs and PBEs offered by online stores of the five Brazilian supermarket chains.

Note: \*Based on the number of data points.

**Table 4**  
Average prices of PBE and MPC companies' products.

Products	N	M*	SD
PBE, plant-based meat	899	US\$16.54	4.67
MPC, plant-based meat	292	US\$14.59	3.09
MPC, animal-based meat	4506	US\$7.65	3.42
Total	5697	US\$9.41	5.00

Note: prices are in US dollars per kg.

plant-based meat products were 116% more expensive than MPC animal meat products (see Table 4).

In addition, there were statistically significant price differences when the company type (PBE, MPC) and plant-based meat product categories (hamburgers, meatballs, etc.) were analyzed with two-way ANOVA ( $F(5, 1178) = 30.99, p < .01, \text{partial } \eta^2 = 0.12$ ). Independent T-tests confirmed that price differences in each product category (Table 5) were statistically significant ( $p < .01$ ). The table also shows the most expensive product in a category. In four out of six product categories, prices were higher for plant-based meats produced by the PBEs; the exceptions were hot dogs and minced meat. Therefore, when the prices were

**Table 5**  
Price comparison per product category and company type (plant-based meat products).

Product	Type of company	N	M*	SD	More expensive
Hamburgers	MPC	116	15.06 US\$	3.23	
	PBE	496	17.31 US\$	5.23	X
Kibbehs	MPC	70	12.91 US\$	0.79	
	PBE	60	14.21 US\$	3.11	X
Meatballs	MPC	45	14.93 US\$	0.40	
	PBE	144	16.25 US\$	2.76	X
Nuggets	MPC	34	12.18 US\$	2.73	
	PBE	30	20.30 US\$	1.92	X
Hotdogs	MPC	15	21.23 US\$	2.95	X
	PBE	30	10.82 US\$	2.70	
Minced meat	MPC	12	17.05 US\$	0.00	X
	PBE	86	13.80 US\$	2.43	

Notes: Sausages were not included in the analysis because only plant-based meat products' prices from PBEs were available.

compared based on product categories, most products from PBE companies were found to be more expensive (Table 5).

We also compared PBE and MPC product prices charged by supermarkets (Fig. 3). A two-way ANOVA was performed to test the joint effect of plant-based meat exclusive companies (PBEs MPC plant-based meat, MPC animal-based meat) and supermarkets on average prices, which was statistically significant (two-way test ANOVA:  $F(8, 5682) = 108.95, p < .01$ , partial  $\eta^2 = 0.13$ ). The results show that average prices are related simultaneously to company type and supermarket. Subsequently, a post hoc test showed that the differences in average prices between company types were statistically significant ( $p < .01$ ). As for supermarkets, most price differences were significant ( $p < .05$ ), except for the difference between supermarkets 3 and 5 ( $p = .33$ ).

Animal-based meat products were the cheapest in all the supermarkets (Fig. 3). In most cases, plant-based meat products produced by the MPCs were cheaper than those produced by the PBEs. The only exception was supermarket 4, which also had the lowest price for plant-based meats produced by PBEs (Fig. 3). Average price of PBE plant-based meat products was statistically significantly lower than those produced by the MPCs in supermarket 4 (PBEs: 10.80 US\$/kg; MPCs: 12.61 dollars/kg (T-test:  $t(263) = 4.50, p < .01$ ). Supermarket 5 showed a more pronounced difference regarding average prices, with PBEs' products being on average 57% more expensive (PBEs: 19.24 US\$/kg; MPCs: 12.25 US\$/kg, T-test:  $t(193) = -22.47, p < .01$ ). Additionally, Table 6 compares the average price of both company types producing plant-based meat products. Prices are presented from the lowest to the highest.

The results support statistically the effect of companies on average prices (One-way ANOVA test:  $F(12, 1190) = 165.32, p < .01$ ). We also conducted Bonferroni's post hoc test. Companies J, K, L, and M have the cheapest prices, which show no statistically significant difference in their average prices ( $p > .05$ ). Their prices are in the lower range (US \$9.61-US\$10.95/kg) and differ from most of the other companies ( $p < .05$ ), with the exceptions of the differences between K and A, and K and D ( $p > .05$ ). As shown in Table 6, prices of MPCs' products (A, B) are in

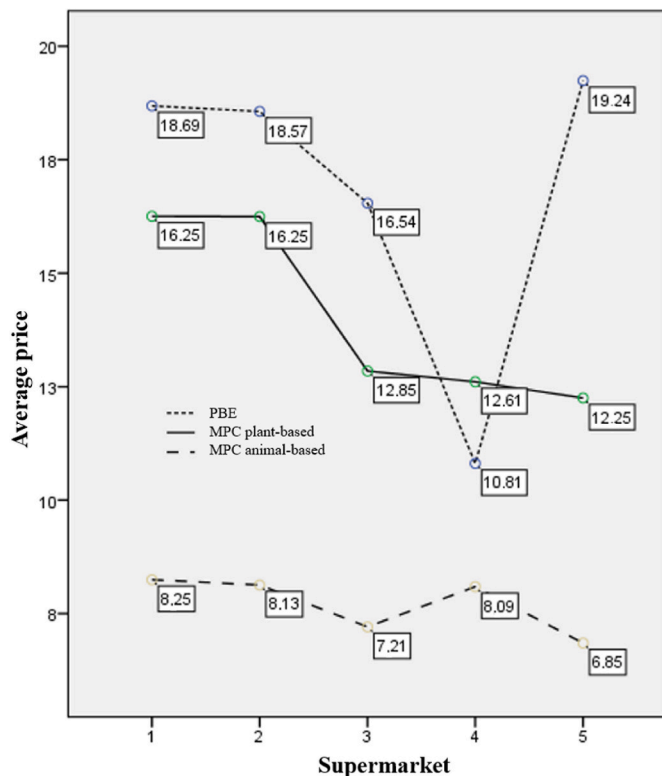


Fig. 3. Plant-based meat products' average price (US\$) comparisons by supermarket.

Table 6

Average prices of plant-based meat products by companies.

Company	N	Mean	SD	Type of company
M	15	US\$9.61	0.00	PBE
L	30	US\$9.63	0.00	PBE
J	45	US\$10.29	2.32	PBE
K	6	US\$10.95	0.28	PBE
D	161	US\$12.76	3.28	PBE
A	175	US\$14.08	3.65	MPC
B	117	US\$15.34	1.73	MPC
C	293	US\$15.83	2.97	PBE
F	31	US\$18.54	1.64	PBE
I	29	US\$19.64	0.76	PBE
G	133	US\$19.87	1.89	PBE
H	126	US\$21.02	2.51	PBE
E	30	US\$25.92	1.61	PBE

the middle (from US\$12.76–US\$15.83/kg), which also includes PBE company C, the company of plant-based products with higher availability. All other average price differences were statistically significant ( $p < .05$ ) except for the difference between B and C, D and K, F and G, and I, H and I, and I and F ( $p > .05$ ).

Thus, upon exclusively evaluating the prices of plant-based meat products within each company, variations in pricing emerged based on the respective company (Table 6). The products from MPCs occupied an intermediate price tier, with the majority of prices from PBE companies falling either above or below this level, indicating that PBE companies have greater price variations.

#### 4.2. PBE and MPC plant-based meat product promotions

We compared the frequencies of promotions or discounts and multi-buy offers provided by PBE and MPC companies. We found that plant-based meat products manufactured by PBEs and MPCs had similar promotion frequencies when the number of promotion cases is considered (PBE: 11.01%,  $N = 899$ ; MPC plant-based meat products: 11.3%,  $N = 292$ ). However, MPC animal-based meat products showed twice the number of promotions (22.4%) (Table 7).

We also analyzed the number of price reductions offered by PBEs and MPCs in their discount promotions; the differences by company type (Table 8) were statistically significant according to the ANOVA test ( $F(2, 639) = 20.69, p < .01$ ). Subsequently, a Bonferroni post-hoc test confirmed the statistically significant differences in company types ( $p < .01$ ).

Thus, MPCs' animal-based meat products had a lower average discount than the others, 17.43%. MPCs offered an average of a 30.50% price reduction for their plant-based meat products compared to 21.65% for those produced by PBEs. MPCs' plant-based meat products were subject to bigger discounts than PBEs, representing an 8.85% average difference.

Table 7

Frequencies of promotions per company type.

Company type	N	Promotions* frequencies	%**
PBE	899	99	11.01
MPC plant-based meat	292	33	11.30
MPC animal-based meat	4506	1011	22.44
Total	5697	1143	20.06

Notes: \*Promotions include discounts and multi-buys; \*\* In relation to each company type frequency (PBE:  $N = 899$ ; MPC plant-based:  $N = 292$ ; MPC animal-based:  $N = 4506$ ).

**Table 8**  
Average price reduction in discount promotions, per company type.

Company type	N*	Average price reduction (%)	SD
PBE	56	21.65	8.50
MPC plant-based meat	13	30.50	12.75
MPC animal-based meat	573	17.43	8.34
Total	642	16.06	8.71

Note: \*N refers to the number of discounts for each company type's products.

## 5. Discussion

### 5.1. The role of plant-based exclusive companies

The prevalence of animal-based meat in Brazilian supermarkets represents a response of the meat industry to the escalating demands for animal meat both within the country and worldwide (Statista, 2022; Smetana et al., 2023) while animal meat substitutes are in the initial stages of entering the market.

Novel plant-based meat products exemplify healthier and sustainable foods without changing current eating habits and diets (Xu et al., 2021; Tuomisto et al., 2022; Smetana et al., 2023). Plant-based meat products are already on the market and have the potential to change the course of the food system (He et al., 2020; Boukid, 2021; Bryant, 2022).

Plant-based exclusive suppliers drive the sustainability transition of the food system, pressuring conventional animal-based meat companies to develop sustainable alternatives. However, our findings reveal that Brazilian online supermarkets primarily feature products from conventional animal-based meat companies, which contribute to GHG emissions, overuse of land and non-renewable energy, high water footprint, and animal ethics concerns (Xu et al., 2021; Smetana et al., 2023; Heidemann et al., 2020).

Moreover, our results demonstrate that plant-based meat products from plant-based exclusive (PBE) companies tend to be more expensive than those from conventional animal-based meat companies. PBE products are, on average, 13.39% pricier than plant-based meat products from conventional companies and 116% more expensive than animal-based counterparts from conventional companies. Although PBE companies' products exhibited the highest pricing, two product categories represented exceptions to this pattern: hotdogs and minced meat. These products also represented the least offered product categories within the PBE segment (refer to Table 3). This observation implies that the relatively lower prices of these specific products could be attributed to marketing strategies due to their positioning within an entry-level market stage. However, the confirmation of this aspect requires confirmation of future research.

PBEs also offer fewer promotions and discounts, potentially impacting consumer purchase intentions (Apostolidis and McLeay, 2016; Gravely and Fraser, 2018; Trewern et al., 2022). PBE products populate the markets in five Brazilian online supermarkets in terms of brands and product variety. However, the development and production of their plant-based meat products are mostly dispersed among several smaller companies, with considerable variations in product availability. In addition, these online supermarkets offer a much larger selection of animal-based products from MPCs. These observations indicate that it may be difficult for PBEs to expand in the meat alternative sector. In particular, price can be a major obstacle in emerging markets such as Brazil, where consumers are price-sensitive and animal meat (e.g., chicken) is a low-cost commodity (Selina Wamucii, 2023).

The higher prices of plant-based meat products may also be explained by the costs of the production chain, such as product development, vegetable protein sourcing, extrusion technologies, ingredients acquisition, packaging, and distribution (He et al., 2020; Boukid, 2021). PBEs' products are often produced by smaller companies and startups, which may have higher development, production, and distribution costs, less access to financial resources, and lower bargaining power

than large MPCs (de Moraes et al., 2023). An increase in sales, greater availability in supermarkets and, consequently, in the scale of production is expected to reduce the price of plant-based meat products over time (Bryant, 2019). These developments potentially benefit PBEs.

MPCs have also advantages in supplying plant-based meat products to supermarkets. They can rely on already existing relationships with retailers, while PBE companies are new entrants. As Mohorčič and Reese (2019) pointed out, developing consistent relationships with retailers is key for plant-based meat companies to thrive. Thus, access to supermarkets may also be an issue for the PBEs.

Despite these potential barriers and the lower availability of plant-based meat products compared to animal-based equivalents, our results show a positive side: several plant-based meat products are already available in the studies online supermarkets, with a wide variety of products and brands. Given that Brazil is one of the largest producers and consumers of animal meat globally, one could expect to see a lower availability of alternative products in supermarkets. However, the penetration of plant-based meat products is also happening in countries with a strong culture of meat consumption (Chiles and Fitzgerald, 2018).

In addition, we found that some PBEs can compete side-by-side with plant-based meat products from MPCs from the perspective of price and availability. For example, plant-based meat producer 'C' was superior to MPCs (A and B) in terms of product availability and average product price. The supply of plant-based meat products tends to be concentrated. Four plant-based meat producers – A, B, C, and D (two MPCs and two PBEs) accounted for 62.64% of the supply of plant-based meat products in the studied Brazilian online supermarkets. These results suggest that the plant-based meat sector risks following the competitive pattern of the Brazilian market for animal-based products, which is dominated by a small number of large multinational companies (Casanova and Kassum, 2014). MPCs have logistical advantages, established relationships with retailers and stable communication channels for reaching consumers, which can be barriers for new PBE companies to enter the market.

Our results also portrayed the pronounced price variations that exist among online supermarkets. Brazilian supermarkets adopt different pricing strategies (Drška, 2022; Valor, 2022). Some of them use a low-price approach whereas other retailers manage their margins and buying conditions.

Moreover, product availability follows similar trends in the stores owned by the same retail chains (Fig. 2). Our results thus suggest that retailers' strategies regarding plant-based meat products have an impact on how these products are marketed to end consumers in terms of price and availability. This aspect goes beyond the already explored upstream chain factors, such as the cost of plant protein, which have been discussed in prior literature (Ambiel et al., 2021). It sheds light on the crucial role that retailers play in the marketing dynamics of plant-based meat and allows for a deeper understanding of the broader implications of their decisions. In line with the GVC literature, we therefore argue that supermarkets potentially hold a dominant position that enables to impose incremental price requirements on suppliers across the global food value chain (Lowe and Gereffi, 2009). This dominant role is also exercised through the strategic selection of product types they choose to market (Humphrey & Schmitz, 2001). Thus, supermarkets exert a significant influence on the supply of food to consumers (Fuchs et al., 2009) and play a pivotal role in facilitating or delaying the transition to alternative proteins (Gravely and Fraser, 2018). Furthermore, MPC companies have greater bargaining power based on volume, size and consumer brand awareness. Due to these characteristics, MPC have also better access to resources that could potentially give them better bargaining terms with supermarkets (e.g., prices, availability, visibility). This can lead to lower power asymmetries compared to PBEs.

When analyzing the variety of plant-based meat products offered by PBEs in Brazilian online supermarkets, we identified several options for plant-based hamburgers and meatballs (71%), to the detriment of limited offerings of sausages, hot dogs, nuggets, and minced meat. Although plant-based burgers are technologically less demanding to

produce and thus represent entry-level products for businesses (Boukid, 2021), there may already be an oversupply from this product category. PBEs should look for product segments that are underexplored by the plant-based meat product market.

The expansion of the plant-based meat sector will require efforts in terms of increasing product diversity, improving sensory characteristics (texture, meat-like taste), nutritional attributes, product quality, and reducing costs (He et al., 2020; McClements and Grossmann, 2022). It is recommended that alternative and less expensive vegetable protein sources (e.g., aquatic plants, agricultural residues, and regional crop sources) should be developed to manage costs (McClements and Grossmann, 2022).

Although the development and production of plant-based burgers and meatballs is less technologically demanding, making them entry-level products for companies (Boukid, 2021), there may already be an oversupply in these product categories. The characteristics of animal-based products such as minced meat and nuggets are more difficult to mimic in terms of taste, appearance, texture, and cooking properties. However, PBEs should look for product segments that are under-explored in the plant-based meat market to increase product variety and address the needs of a wider range of consumers, thereby increasing consumer acceptance and market growth. The expansion of the plant-based meat sector requires efforts to increase product diversity, improve sensory characteristics, nutritional properties, product quality, and reduce costs (He et al., 2020; McClements and Grossmann, 2022).

Our results also reveal a paradox in the way supermarkets operate: they claim to support sustainability initiatives (Carrefour, 2021; GPA, 2022; Muffato, 2023), but at the same time promote products from intensive animal agriculture to defend their market position or increase sales. Despite their contribution to the development of the plant-based meat industry, it is important to acknowledge that they also perpetuate the harmful impacts of livestock production. In particular, there is an overarching lack of transparency in retail companies' annual reports and corporate communications regarding the promotion of animal products in supermarkets. This aspect is consistent with the literature on the decoupling between sustainability reporting and practice that has been observed in organizations and may have negative effects, such as corporate social and environmental irresponsibility (Conrad and Holtbrügge, 2021). Not only does this choice directly contribute to the negative environmental and social impacts of supermarkets, but it also hinders the development of a broader awareness of their role among consumers and other value chain partners.

## 5.2. Implications

Several implications derive from our results. Policymakers and government bodies should stimulate the development and expansion of PBEs through three main lines of action, that focus on reducing product price and increasing product availability and diversification: investing in research, providing sources of funding and capital, investing in capacity building, and cooperative initiatives (Lazaro-Mojica and Fernandez, 2021; Paiva et al., 2022). Investments in research involve supporting the development of novel and less costly vegetable protein sources and innovative products. As an illustrative example, the Brazilian Agricultural Research Organization (Embrapa) has studied new vegetable ingredients such as cashew fiber (Embrapa, 2023). These public efforts could also focus on sensory and quality attribute enhancement (He et al., 2020; McClements and Grossmann, 2022). In addition, investments in research could also address the comprehension of consumers' expectations and acceptance of plant-based meats, along with their anticipations concerning retailers.

Moreover, given the relevance of PBEs in reducing environmental footprints, start-ups could have priority access to subsidies, financial resources, and specific credit options. These initiatives may help PBE companies to reduce production costs, enter distribution channels and

be available and price competitive in supermarkets.

PBEs may also benefit from capacity-building initiatives aimed at developing the use of less technology-driven skills such as business and supply chain management, distribution and sales management, business-to-business (B2B) management, product branding, and marketing.

Furthermore, government agencies could support the creation of associations and cooperative initiatives involving PBE companies and other stakeholders (e.g., research institutions, suppliers) in the development of new products, purchasing raw materials, and conjointly developing a differentiated plant-based exclusive identity associated with fewer environmental and animal ethics concerns. Moreover, following Haan et al. (2022) we argue that MPCs' promotions in supermarkets should be inhibited through specific regulations to contribute to reductions in GHG emissions. Singapore's initiatives aimed at consolidating the meat alternatives industry within the country serve as an illustrative case of how governments can effectively establish supportive mechanisms for the sector. These mechanisms encompass facilitating access to funding, research opportunities, startup incubators, universities, and networks, among others, while also formulating regulatory frameworks conducive to stimulating the sector's growth (Reis et al., 2022).

Most importantly, our work emphasizes the importance of PBEs as a group of companies that have a significantly lower environmental footprint than MPCs. However, consumers in general may not be aware of the differences between PBEs and MPCs due to a systemic lack of transparency. Improving consumer awareness in this regard should also be the subject of policy initiatives to enable consumers to make more informed purchasing decisions. Educating consumers about the importance of sustainability and the environmental impact of their food choices can increase demand for transparency and accountability from conventional meat producers. This can be done through public campaigns and labeling requirements that provide clear and concise information on the sustainability of a range of products.

The pronounced lack of transparency in MPCs' annual reports regarding sales volumes, the proportion of plant-based meat products in the current portfolio and specific environmental impacts should also be addressed. Governments and regulators around the world, such as the UK's Financial Conduct Authority, are attempting to curb misleading corporate practices through measures and restrictions on the use of "green" claims and labels. Similarly, policy instruments could be used to require MPCs to report sales of plant-based products separately from animal-based products, enhancing sustainability transparency.

To promote greater transparency and sustainability in the plant-based meat industry, conventional meat producers could be encouraged to undergo independent audits conducted by third-party organizations with expertise in sustainability and environmental impact assessment. Furthermore, these companies could establish partnerships with sustainability-focused organizations to collaboratively improve their sustainability practices. Through collaboration, these organizations could share best practices, develop new products prioritizing environmental sustainability, and participate in sustainability research aimed at advancing the industry. Such measures could help create a more sustainable and transparent food industry, benefiting both consumers and the environment.

There are limitations due to the exploratory nature of our study. The sales volumes of PBEs and MPCs could be investigated by using cash-registered data. Other studies could explore how information about the differences between PBEs and MPCs might influence purchasing decisions. Other product attributes that we could not capture with our method also influence sales (e.g. sensory characteristics of the product) and other promotional strategies (e.g., signaling, placement) should also be investigated. Moreover, our results predominantly relate to the context of major Brazilian retail chains and urban centers (Rio de Janeiro and São Paulo), where plant-based products have the highest penetration; they also show product prices related to these regions and specific points in time. Our primary objective was to study specific



aspects of the market rather than generalizable results for the whole country. Although the chains studied provide a comprehensive view of the region and the role of prominent retailers in line with the GVC literature, the vast size and diversity of Brazil require caution when extrapolating our findings to other regions and supermarket chains. As meat substitutes continue to gain ground in other regions, future studies should be conducted to provide a detailed, country-wide perspective on this burgeoning segment.

Despite the importance of large chains in the Brazilian food retailing sector, small and medium-sized stores are also important and may have unique characteristics that can provide valuable insights for comparing PBE and MPC products and understanding consumer behavior towards plant-based meat. Thus, we suggest the inclusion of smaller retailers in future studies addressing these issues. To better capture medium and long-term variations, future research may also consider adopting an extended time frame in data collection or longitudinal research design. Studies could also analyze consumer attitudes, preferences, and perceptions about plant-based meats in retail settings or how the availability, promotions, and pricing of meat substitutes might influence consumer perceptions of retail chains. On the other hand, considering the Brazilian habit toward consuming *in-natura* meat, a future study could broaden our current analysis by exploring the impacts of those products on plant-based meats price and availability.

In addition, informing potential consumers about health benefits of plant-based product may stimulate purchases (Martin et al., 2021). Studies could explore how supermarkets and companies can promote the expansion of plant-based meat products through in-store marketing strategies and labels. Additionally, comparisons between PBEs and MPCs regarding product health and nutritional aspects could offer valuable insights. Future research could also explore the extent to which plant-based meats are considered unhealthy by consumers and retailers and how such perceptions impact prices and availability.

Food retail sector is concentrated in Brazil, five retail chains cover 47.1% of the Brazilian food market (ABRAS, 2022). While this aspect falls outside the scope of our research, it is worth noting that the concentration of retailers may lead to increased power asymmetries (Dallas et al., 2019). Also, bigger retail units or supermarkets are likely to dominate along the supply chain, as pointed out by the GVC literature (Gereffi, G., & Fernandez-Stark, 2016; Lowe and Gereffi, 2009). Concentrated food markets impact product prices, availability, and competitiveness of plant-based meat compared to animal-based products. This subject warrants further investigation, as it could also impact the expansion of plant-based meat companies. In our study, we mitigated the potential impact of this food retail sector concentration by analyzing also a smaller food retail chain (Muffato).

Future research could also delve into supermarket consumer attitudes and preferences, specifically examining their perceptions regarding plant-based meats (e.g., whether they view them as more sustainable than animal-based meats) and how the availability, promotions, and pricing of meat substitutes might influence their perceptions toward retailers.

Furthermore, in light of this, several initiatives may be proposed to ensure enhanced alignment between sustainability claims or reporting and actual practices. Retailers and producers could undertake efforts to inform consumers about the adverse environmental impacts of animal-based meat and the advantages of plant-based alternatives. This could entail reducing the promotion of animal meat and increasing the visibility and promotion of meat substitutes in retail stores to stimulate sales (Gravelly and Fraser, 2018; Trewern et al., 2022; Piernas et al., 2021). Particularly, products from PBE companies could be highlighted as having potentially lower environmental and animal welfare impacts.

This study contributes to the literature on sustainable food systems by examining the availability of plant-based portfolios of MPCs and PBEs in downstream production chains, providing insights into how policy-makers, industry stakeholders, and consumers can advance sustainable food systems. The study highlights the potential for MPCs to improve

their sustainability practices and transparency, and the crucial role of PBEs in driving the much-needed sustainability transition of food systems. The findings can support the effective design of various food policies aimed at increasing sustainability in the food industry, and highlight the challenges and opportunities associated with their implementation, including issues of transparency among producers and supermarkets.

Our study also reveals the importance of understanding the impact of downstream value chain activities, including distribution, marketing, and retailer relationships, for the successful market penetration of plant-based meats. Furthermore, investigating the implications of power asymmetries (Dallas et al., 2019) existing between major retailers and plant-based meat suppliers presents a promising avenue for future research. Finally, our study has brought to light a paradox within supermarkets, where they concurrently champion sustainability initiatives while escalating the promotion of animal-based products. The ramifications of this apparent incongruity also present a significant area for future exploration, aiming to gain a deeper understanding of its repercussions on environmental concerns, consumer behaviors within supermarkets, and the broader shift toward more sustainable food systems.

#### CRediT authorship contribution statement

**Germano Glufke Reis:** Conceptualization, Funding acquisition, Methodology, Formal analysis, Project administration, Writing – original draft, Writing – review & editing. **Eduardo Guedes Villar:** Data curation, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Toni Ryyänen:** Investigation, Validation, Writing – original draft, Writing – review & editing. **Vinicius Picanço Rodrigues:** Investigation, Validation, Writing – original draft, Writing – review & editing.

#### 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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#### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jclepro.2023.138705>.

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