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Brazilians' attitudes to meat consumption and production: Present and future challenges to the sustainability of the meat industry

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ABSTRACT

Brazil is a main global producer, exporter, and consumer of farm animal products. Information about the knowledge and attitudes of Brazilian citizens and consumers towards the different dimensions of meat production sustainability can support policy discussions and guide the industry to adopt production systems compatible with societal expectations. Here we provide a historical, social, and economic overview of meat production and consumption in Brazil, review the scientific literature on Brazilian public attitudes towards meat production and consumption, and discuss some actions Brazil is taking to develop more sustainable production systems. We show that Brazilians expect affordable meat products with high organoleptic, sanitary, nutritional qualities and produced under high ethical standards. The pace of discussions and changes in policies and in meat production systems needs to accelerate to follow domestic and international demands and the changes in ethical expectations of society. Constructive dialogue between all interested stakeholders, including citizens and consumers, needs to be fostered to design more sustainable meat production systems.

1. Introduction

Animal production in Brazil increased exponentially over the last decades, making the country a main actor in the global meat market (Fig. 1). Brazil's influence tends to expand, as production systems continue to evolve and adopt specialized technologies (von Keyserlingk & Hötzel, 2015). In order to guarantee long-term success of Brazil's influence on the global meat market, Brazilian meat production has to achieve sustainable systems. Moreover, the meat industry needs to pay attention to changing attitudes and consumption habits of the domestic consumers, given that Brazilians consume 76% of the pork, 74% of the beef, 70% of the turkey and 68% of the poultry produced in Brazil (ABIEC, 2022; ABPA, 2022).

A broad concept of agriculture sustainability takes into account economic, environmental and social aspects, with public attitudes towards the production systems being an essential component of the last dimension (von Keyserlingk & Hötzel, 2015). Besides these cultural and economic aspects that shape meat consumption, citizens' and consumers' concerns with the impacts of farm animal production are considered important drivers of industry change; therefore, meat production systems and practices that do not account for public attitudes prove to be socially unsustainable (Hötzel, 2014). Although this is often considered an issue for industrialized countries, recent history suggests that farm animal industries in emerging countries will increasingly face internal societal demands (von Keyserlingk & Hötzel, 2015). Society's permission for animal production systems to operate is referred to as social license (Hampton, Jones, & McGreevy, 2020). Erosion of the social license may occur when the public questions animal production systems or practices and is not listened to by industry and policy makers. Given the importance of the meat industry to the national economy, local and international demands regarding animal production systems may have direct consequences to meat production and consumption in Brazil.

In this context, information about Brazilian citizens' and consumers' attitudes towards the different dimensions of meat production sustainability can support policy discussions and guide the industry to adopt production systems compatible with societal expectations. In this review, we first provide an overview of farm animal production and consumption in Brazil, then we discuss the scientific literature on Brazilian public attitudes towards meat production and consumption. Next, we present the main actions Brazil is taking to respond to the need to develop more sustainable production systems.

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2. A brief historical, social and economic overview of farm animal production in Brazil

Brazil is a main global producer, exporter and consumer of farm animal products, ranking among the top world producers and exporters for poultry, beef and pork (USDA, 2022). Fig. 1 offers a brief overview of animal production in Brazil in the last decades. Fig. 1a shows the sharp increase in global farm animal production, which is associated with the growth in human population size and wealth, and many societal changes including industrialization, urbanization and increase in median income and education levels (von Keyserlingk & Hötzel, 2015). Fig. 1b shows the changes in production in Brazil during the same period, highlighting steeper curves in beef and poultry production. This is explained in Fig. 1c; while pig and sheep production in Brazil is stable, the proportion of the world's beef and broilers that is produced in Brazil is growing. Moreover, Brazil houses a relevant proportion of the billions of food producing animals reared every year throughout the world (Fig. 1d).

Today, about 100% of the commercially-raised pigs and poultry in Brazil are reared in intensive housing and feeding systems, with genetic lines selected for optimal growth and feed conversion, and high use of antimicrobials (von Keyserlingk & Hötzel, 2015). Cattle are mostly raised on pasture, but a growing proportion is moving to intensive housing and grain-based diets, especially dairy and finishing beef cattle, although data showing this trend are scarce. The use of growth promoter additives to raise these animals is another issue related to these types of production systems, and also a concern for the public (Behrens et al., 2010; Hötzel, Yunes, Vandresen, Albernaz-Gonçalves, & Woodroffe, 2020). Steroidal growth promoters are not permitted by legislation in Brazil, but beta agonists for pig finishing and bST to increase milk production in dairy cows are largely used. Other potential concerns are antibiotics, widely used as growth promoters and for disease prevention, mainly in poultry and pig production, as well as drugs used to control endo and ecto-parasites, mostly in cattle production. Brazil is the second top consumer of antibiotics, behind China, and is projected to continue to hold this position in 2030 (Tiseo, Huber, Gilbert, Robinson, & Van Boeckel, 2020).

Although most of the meat consumed in the Brazilian market is produced under these systems, the country also produces special products, for example, free of antibiotics or beta-agonists, to attend specific demands of the domestic and export markets (CIDASC, 2021). Similarly, humane slaughter, including pre-slaughter stunning is mandated for all animals in Brazil, but the slaughter of animals according to religious precepts is allowed in federally certified abattoirs (Brasil, 2021a). It is estimated that Brazil supplies about 20% of the international Halal and Kosher meat market (Globo Rural, 2017).

Agriculture has an enormous importance for the Brazilian society, providing 27% of the GDP, 48% of the exports and approximately 30% of the jobs, including production, processing and trade, with approximately 30% related to the animal production sector (CNA, 2021). Although small family farms do not produce the majority of the food, they represent 85% of the farms in Brazil, which adds a relevant social component to this discussion. Family agriculture (which consists of

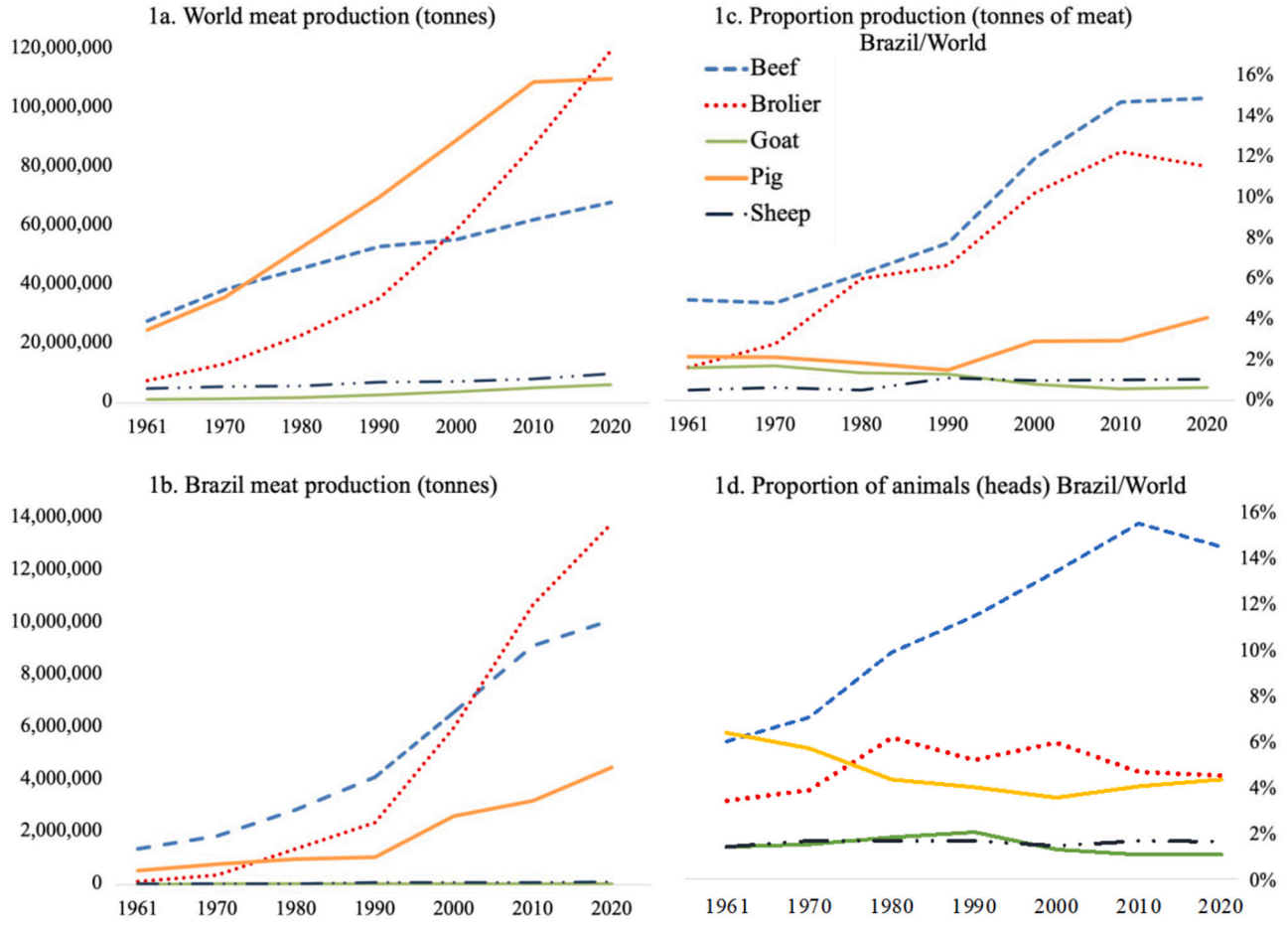

Fig. 1. Production of meat (tonnes) in the last six decades in the world (a) and in Brazil (b) according to meat type: beef (blue dashed line), broiler (red dotted line), pig (orange solid thick line), sheep (black dash-dotted line), and goat (green solid thin line). Proportion of the world's meat produced in Brazil (c) and proportion of the world's animals that are in Brazil (d). Source (FAO, 2022). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

small farmers, traditional peoples and communities, settlers of agrarian reform, foresters, fish farmers, extractivists and fishermen) is the main responsible for the production of foods that are made available to the Brazilian population; this sector stands out in the production of the main staple foods consumed in Brazil, including dairy, beef, pigs and poultry (IBGE, 2017).

The development of Brazilian agriculture was accompanied by important demographic changes in the last decades, with a growing population becoming gradually more urban, educated and relatively wealthier. In the 1960s the majority of Brazilians (55%) lived in rural areas and 40% were illiterate. Today an estimated 85% of the 213 million Brazilian citizens live in urban areas and about 23% have post-secondary schooling (Brasil, 1997; IBGE, 2020). These changes have impacts on Brazilians' attitudes and behaviors as meat consumers that will be discussed in the following sections.

3. Meat consumption in Brazil

Meat consumption has roots in the Brazilian culture before the European colonization, as hunting was the main feeding source of the indigenous population and meat was an important component of their diet (Ribeiro & Corção, 2013). Animal farming was introduced by the European colonizers to attend the food needs of the increasing population. Meat consumption was associated with higher social standards, which was accentuated in 1808 by the arrival of the Portuguese royal family, which was followed by the presence of many court members that sought the European way of life (Ribeiro & Corção, 2013). Today meat is a staple food of Brazilians (Rodrigues et al., 2021) and an important part of the Brazilian culture (Happer & Wellesley, 2019; Ribeiro & Corção, 2013); for many, meat eating is a symbol of economic progress (Happer & Wellesley, 2019). According to different studies, between 57% and 71% of Brazilians consume meat three or more days a week (da Fonseca & Salay, 2008; GIF, 2021; Hötzel et al., 2020; Vandresen & Hötzel, 2021; WAP, 2016), with higher consumption among wealthier citizens (IBGE, 2019; Rodrigues et al., 2021).

Poultry is the most consumed meat in the country, followed by beef and pork (Fig. 2). Besides, fish consumption is approximately 9.5 kg/inhabitant/year, with a vast regional variation in the type available and consumed (Brasil, 2022). Other, less consumed meats are other birds, mostly turkey and duck (0.84 kg/inhabitant/year), sheep and goat meat

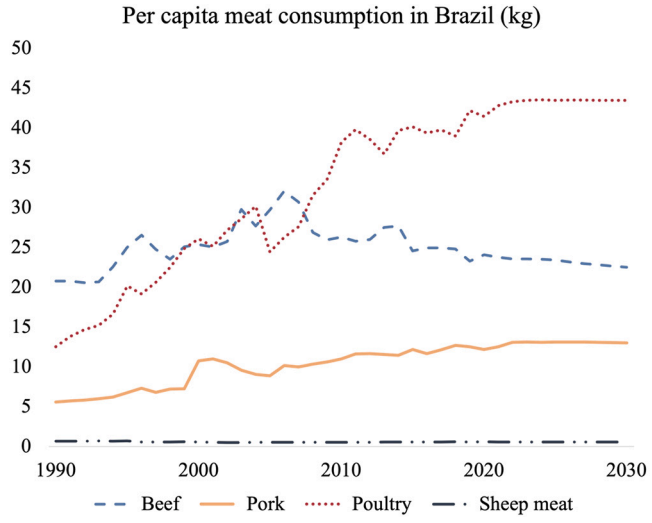

Fig. 2. Yearly per capita meat consumption (kg) in Brazil from 1990 to 2020 with a forecast for 2021 to 2030 (OECD-FAO, 2021). The data is shown according to meat type: beef (blue dashed line), pork (yellow solid line), poultry (red dotted line), and sheep meat (black dash-dotted line). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(0.52 kg/inhabitant/year) (ABPA, 2022; CompreRural, 2021) and rabbit meat (0.08 kg/inhabitant/year) (Szendro, Szabo-Szentgroti, & Szigeti, 2020). Additionally, wildlife hunting is cited as an important source of food for forest communities in Brazil (Nogueira & Nogueira-Filho, 2011). Total increases in per capita meat consumption in recent years are related to increased consumption of poultry and pork (Whitton, Bogueva, Marinova, & Phillips, 2021). There are some regional differences, considering the three main meats consumed in Brazil: the Northern region is the largest consumer of beef and chicken among all regions, while the consumption of pork is higher in the Southern region; these two regions are also the largest meat consumers in the country (Schlindwein & Kassouf, 2006). The data mentioned in that study also shows that meat consumption is slightly higher among rural consumers, which is explained by greater pork consumption, and that the main factor explaining variation in total consumption is family income, although urbanization, women's schooling and family composition also influence consumption and expenditure on meats.

In general, lower income Brazilians spend less money and a greater proportion of their income in food, whereas wealthier consumers spend a smaller proportion and a greater absolute amount in food; official census data shows that Brazilian families that make up the highest income class spend 7.6% on food, while families with lower incomes spend 22%; moreover, in absolute values, the wealthiest group spends more than six times in food products than the lowest income citizens (IBGE, 2019). In 2021 there was a sharp reduction in the consumption of many foods due to increases in price, most notably beef and other meats, and especially among the lower income citizens (G1, 2021). Moderate to severe food insecurity in Brazilian households decreased from 16.8% in 2003 to 11.5% in 2009 and 7.8% in 2013, but this trend reversed in 2017–2018, when 12.7% of the households were classified in the category; importantly, the proportion of moderate to severe food insecurity is greater in rural than urban households (which comprise 13.8% and 86.2% of the population in the country, respectively) (IBGE, 2019). Related to the type and quality of foods consumed, according to a survey carried out by the Ministry of Health in 2021, 57% of Brazilians were classified as overweight and 22% as obese; the document cited as reasons behind these figures the high consumption of ultra-processed foods and low consumption of vegetables (Vigitel, 2022).

Brazilians' consumption habits are changing though, with many adopting flexitarian diets. In parallel with the high consumption of meat, Brazil is the 16th largest alternative protein market, with plant-based substitutes moving USD 82.8 million in 2020, a 70% growth compared to 2015 (Estadão, 2021). According to a nationally representative survey carried out in 2018, 14% of Brazilians identify as vegetarians, a 75% growth compared to 2012 (SVB, 2018). The survey also showed that 63% of Brazilians would like to reduce their meat consumption in order to obtain a healthier diet. In another survey with 2000 Brazilians from all regions of the country (GFI, 2020), half of the participants declared to have reduced their consumption of meat – beef, poultry, pork and fish – and 39% consumed products of plant origin at least three times a week in place of products of animal origin. This and other studies (e.g., Gomez-Luciano, de Aguiar, Vriesekoop, & Urbano, 2019) indicate that the public with a greater predisposition to try alternative proteins, including plant-, cell- and insect-based proteins, are women and young consumers. Besides many sociocultural factors, these developments in consumption habits may be influenced by the Brazilian dietary guidelines, widely discussed in the media, which recommend diets with small quantities of foods of animal origin (Monteiro et al., 2015). Despite the current and historical high meat consumption and cultural value of meat consumption in Brazil, the social environment seems favorable to the shift to diets with less meat. For example, a study comparing four different countries found that most people did not find vegetarians particularly bothersome and Brazilians were the least bothered by vegetarians, with admiration of vegetarians being relatively high in the country (Ruby et al., 2016).

4. Brazilian citizens' and consumers' concerns regarding meat production systems

Like shown in many different countries (Hobbs, 2021), key criteria for choice of meat identified among Brazilian consumers are price, sensory characteristics, freshness, meat appearance, ease to prepare, healthiness and fat content (Battagin, Panea, & Trindade, 2021; Bonamigo, Bonamigo, & Molento, 2012; Cunha, Spers, & Zylbersztajn, 2011; de Andrade, Sobral, Ares, & Deliza, 2016; Hötzel et al., 2020; Teixeira, Larraín, & Hötzel, 2018; Viana, Silva, & Trindade, 2014). Importantly, and also comparable to other countries (Grunert, Sonntag, Glanz-Chanos, & Forum, 2018; Hobbs, 2021; Ortez, Widmar, Thompson, & Brad Kim, 2022), food safety and impacts on human health often rank as main concerns among Brazilians in studies about meat purchase and consumption (Cunha et al., 2011; Dill et al., 2021) and citizens' assessment of farm animal production (Teixeira et al., 2018). However, despite the interest in food safety, only 43% of Brazilians in a study with 2.949 consumers had knowledge about traceability schemes for meat products that would ensure these traits – though wealthier consumers were more aware and willing to pay more for labeled products (Brunoro et al., 2020).

The sociodemographic changes discussed earlier associated with the growth and industrialization of animal agriculture in Brazil have resulted in a growing distance between agri-food systems and consumers. Possibly as a consequence, Brazilians know little about how farm animals are reared (Hötzel et al., 2020; Queiroz, Delfino Barbosa Filho, Albiero, Brasil, & Melo, 2014; Schaly, de Oliveira, Salviano, & de Abreu, 2010; WAP, 2016; Yunes, Teixeira, von Keyserlingk, & Hötzel, 2019). This is not a particular characteristic of Brazilian citizens; the urbanization and distancing from the realities of farming is a globally described phenomenon (von Keyserlingk & Hötzel, 2015) and the same trend of consumers' low awareness has also been reported in several countries (e.g., Cornish, Raubenheimer, & McGreevy, 2016; Stampa, Schipmann-Schwarze, & Hamm, 2020; Tomasevic et al., 2020).

Nonetheless, 64% participants in a recent survey declared to be aware of the farm animal welfare issue (WAP, 2016); in a different survey, 50% of the participants said that they always or often thought about how animals were raised when they ate meat (Vandresen & Hötzel, 2021). Brazilians also express concerns with the level of animal welfare in Brazilian farms, and consider it especially low in species known to be reared in intensive confined systems (Comin et al., 2022; Queiroz et al., 2018; Yunes, von Keyserlingk, & Hötzel, 2017). Studies investigating Brazilian citizens' and consumers' knowledge and attitudes regarding animal production practices or systems indicate that Brazilians prefer or expect farm animal production systems that yield high quality products, allow animals to move freely and express natural behaviors, provide space and good/gentle treatment, and are free of stress (Behrens et al., 2010; da Rosa et al., 2021; Hötzel et al., 2020; Silva et al., 2021; Yunes, Osório-Santos, von Keyserlingk, & Hötzel, 2021). Humane slaughter is also a concern for Brazilian consumers cited in some studies (Rucinque, Souza, & Molento, 2017; Szendro et al., 2020; WAP, 2016). Many Brazilians believe that animal welfare is positively associated with product quality (Cardoso, von Keyserlingk, & Hötzel, 2019; WAP, 2016), which has also been described in studies in many different parts of the world (Clark, Stewart, Panzone, Kyriazakis, & Frewer, 2016). Finally, also consistent with the international literature (Clark et al., 2016), a greater level of concern is observed among urban and female citizens (e.g., Hötzel et al., 2020; Vandresen & Hötzel, 2021).

Several studies concluded that Brazilians associate conventional, intensive systems with poorer animal welfare; in contrast, organic, agroecological, free range, outdoor, or pasture-based systems are equated to high animal welfare and healthier, higher quality products (Bonamigo et al., 2012; Cardoso et al., 2019; da Rosa et al., 2021; Teixeira et al., 2018). Preference for these systems is often associated with perceptions that the resulting products are free of pesticides, hormones, antibiotics and other additives, a reason why many consider them more natural and healthier (Barone, Nogueira, Guimarães, & Behrens, 2018; Cardoso et al., 2019; Hötzel et al., 2020). Perceptions of the naturalness of the systems, a valued feature of the production and processing systems according to studies with Brazilian citizens (Szendro et al., 2020; Vandresen & Hötzel, 2021) may explain at least in part these preferences. Perception of naturalness is known to influence attitudes towards animal production systems, as many people see natural systems as healthier and capable of providing better welfare for animals (Clark et al., 2016). Corroborating these perceptions among the public, in a discussion of the dietary guidelines issued by the Brazilian government in 2014, Monteiro et al. (2015) mention that the basis of diets should be more natural and minimally processed foods, obtained directly from plants or animals. Perceived naturalness of animal proteins (Clark et al., 2016), as well as cellular alternatives (Bryant, Anderson, Asher, Green, & Gasteratos, 2019), are known to play an essential role in shaping acceptability and preferences for these products. The competition from alternative animal and non-animal protein sources (Chriki et al., 2021) highlights the relevance of promoting naturalness in the animal production systems. As discussed by Yunes et al. (2021), given the growing relevance of the issue for consumers, failure to consider the importance of naturalness of the meat production systems for consumers may undermine the sustainability of farm animal production.

In contrast, the few studies available suggest that Brazilian consumers' concerns with the environmental impacts of meat production may be relatively lower (Barone et al., 2018; Burnier, Spers, & de Barcellos, 2021; Happer & Wellesley, 2019; Teixeira et al., 2018), with female, urban and wealthier citizens being the most concerned (Chriki et al., 2021; de Barcellos, Krystallis, de Melo Saab, Kuegler, & Grunert, 2011). Also, consumers' concern with environmental impacts of meat production are weakly reflected in purchase behavior (de Barcellos et al., 2011; Krystallis, Grunert, de Barcellos, Perrea, & Verbeke, 2012). As discussed by Burnier et al. (2021), although the issue is debated in political spheres, it does not seem to have reached yet Brazilian consumers, who do not link it to sustainability as much as animal welfare and traceability of the production process.

Public acceptability of new technologies is another important issue in the discussion of the social dimension of agriculture sustainability. Brazilians are supportive of technologies (Castelfranchi, Vilela, Lima, Moreira, & Massarani, 2013), including their use in agriculture and animal food production (Cardoso, von Keyserlingk, & Hötzel, 2017; Valente, Fiedler, Sucha Heidemann, & Molento, 2019). Cell-based meat (also named cellular, cultivated, synthetic, artificial, in vitro, lab-grown meat) is a novel technology that may be used to produce muscular tissue from a sample of cells taken from a live animal and grown artificially. The product is in the initial steps of development and its success depends, among other factors, on consumers' acceptance. Some studies indicated that most Brazilians, especially women, young and highly educated citizens, would be willing to try cell-based meat, though fewer would be willing to consume it regularly or to replace conventionally-produced meat (Chriki et al., 2021; Oliveira, Domingues, & Borges, 2021; Fernandes et al., 2021; Valente et al., 2019). Gene editing is another example of an emerging technology relevant for this discussion. This biotechnology can be used to modify specific characteristics of interest in a shorter intergenerational interval than conventional genetic selection, and has been proposed that it can bring solutions for animal health and welfare issues in farm animal production systems (Menchaca, 2021). Brazilian consumers seem to support genetic engineering of vegetables and products of biochemical processes like fermentation, but not of food of animal origin, differences explained by perceived ethical and moral implications of the use of genetic engineering on animals (Ribeiro, Barone, & Behrens, 2016). Brazilian farmers and animal production stakeholders seem optimistic about the use of gene editing technologies to improve animal productivity, welfare and health (Yunes, 2021). In contrast, when asked about the possibility of gene editing of farm animals to improve animal welfare, health or productivity, Brazilian citizens showed less support, based on concerns with potential

downstream biological and societal risks of gene editing of farm animals (Yunes et al., 2019; Yunes et al., 2021). Yunes et al. (2021) concluded that, although the introduction of gene editing in farm production in Brazil may not face significant public resistance, it may further exacerbate already existing concerns of loss of naturalness in intensive farm animal production.

Precision livestock farming technologies are another example of emerging technologies that could potentially contribute to more sustainable systems (Schillings, Bennett, & Rose, 2021). These technologies can be used to monitor and control animal productivity, environmental impacts, health and welfare parameters in a continuous, real-time and automated manner. However, ethical concerns have been raised regarding these technologies, especially the consequences derived from increasing the distance between humans and the non-human animals under their care (Stevenson, 2017; Tuyttens, Molento, & Benaissa, 2022). Brazilian farmers' and consumers' ethical concerns about these technologies have not yet been investigated. Given their potential to generate ethical concerns, it is advisable to learn about public attitudes towards gene editing and precision technologies before their products become widespread in the production systems.

4.1. Willingness to pay for meat produced in alternative systems

Compared to other countries (Clark, Stewart, Panzone, Kyriazakis, & Frewer, 2017), relatively few studies have investigated Brazilians' willingness to pay for meat that attend their demands and aspirations (see e.g., Burnier et al., 2021). Brazilian consumers say that concern with food safety, price, animal welfare, and environmental impacts influence their purchasing decisions (Dill et al., 2021). Although when Brazilians buy food the main criteria are price and quality (Bonamigo et al., 2012; Brunoro et al., 2020; WAP, 2016), some Brazilians say that they would consider price increases to avoid painful procedures in pigs acceptable (Hötzel et al., 2020), or would pay for improved chicken welfare (da Rosa et al., 2021; Teixeira et al., 2018). However, in some studies consumers said that it is difficult to find animal welfare-friendly products (da Rosa et al., 2021; Franco, Souza, & Molento, 2018). Other Brazilian citizens have argued that meat is already expensive for many consumers and animal welfare is a public good that should be ensured by the government (Hötzel et al., 2020; Velho, Barcellos, Lengler, Elias, & Oliveira, 2009).

von Keyserlingk and Hötzel (2015) argued that using consumer purchasing behavior findings to justify inaction when faced with decisions regarding animal husbandry practices is not socially sustainable. The fact that attitudes towards production systems not always translate into purchasing behavior is widely recognized; it is also recognized that citizens' and consumers' attitudes towards animal welfare (Tonsor, Wolf, & Olynk, 2009), as well as environmental impacts of farm animal production (Krystallis et al., 2012), can influence policy formation at national and global levels. In Brazil this may happen through support of government and retailers' initiatives discussed below.

4.2. Gaps in knowledge

We have reviewed and discussed the literature on Brazilian consumers' knowledge, attitudes and behaviors regarding meat production and consumption. Given the large cultural and socio-economic heterogeneity and geographical amplitude of the country, and the extent and variety of animal production systems, this gives an initial picture that needs to be completed with further studies. Importantly, it is well established that consumers are heterogeneous regarding the relative importance they give to animal food production issues like naturalness, environmental impact, and animal welfare (Hobbs, 2021). This has been shown in some Brazilian studies (Barone et al., 2018; de Barcellos et al., 2011; Teixeira et al., 2018), but there is clearly a need to further expand investigation in this issue among Brazilian consumers.

We included consumers' attitudes to new and upcoming technologies used in farm animal production in our discussion. It is essential to know as early as possible the consumers' attitudes to issues that will continue to arise or gain prominence, to guide discussions, public policies and decisions made in the production chain. One example of an issue scarcely investigated among Brazilian citizens and consumers is the growing international concern with antimicrobial use in farm animal production, and the relationship with antimicrobial resistance and human health. Also, as recently discussed by Hobbs (2021), it is early to forecast how the COVID-19 pandemic will alter consumers' perceptions of the food systems. During the last two years, as pointed out by the authors, citizens have been made more aware of issues such as farm animal slaughter and the life of workers of abattoirs, the high level of concentration of animals in many farms, and the vulnerability of animals in intensive production farms in exceptional times. How this knowledge, new for many citizens and consumers, may impact attitudes to meat production and consumption, is an important topic to investigate.

5. Public and private actions in Brazil to adapt to sustainability demands

To achieve the growth and the intensification of the animal production systems described earlier, starting in the 60s and 70s the Brazilian government set in motion an aggressive program of modernization of agriculture. Extension and research centers and programs, animal science and technical agriculture schools were created to change and support more intensive systems and spread this new culture throughout the country (Caporal, 1991). In animal production, the term and meaning of efficiency became inseparable from productivity and profit (Domingues, 1960). Decades later, the meat industry needs to deal with society's new demands and needs. The definition of efficiency needs to be adjusted to pressing environmental challenges and the moral values of society regarding the impacts of animal production on the environment, humans and non-human animals. This requires policies and actions that drive the Brazilian meat industry to a sustainable path in upcoming years. In this section we review some recent actions adopted in Brazil that may contribute to achieving more sustainable animal production systems.

Reducing environmental impacts is key to maintaining the economic and social sustainability of Brazilian animal production in the local and global scenarios. Analysts warn that international investors are likely to attribute a greater environmental, social and corporate governance risk to Brazilian agribusiness companies if the sector remains connected to environmental degradation (Malafaia, Mores, Casagranda, Barcellos, & Costa, 2021). Meat production is considered a cause of Amazon deforestation, which may impact the industry's reputation and international animal products' market (Ferrante & Fearnside, 2022; Malafaia et al., 2021). Brazil has two greenhouse gas mandatory reduction targets: one established in 2009 in the National Climate Change Policy (PNMC); and the emission reduction target for 2025 entered in the NDC (Nationally Determined Contribution) that commits to a reduction of net emissions by 37% by 2025 compared to 2005 and brings an indicative target for 2030 of 43% reduction. However, since 2010, the year of regulation of the PNMC, the amount of greenhouse gases released into the atmosphere every year in Brazil has increased by 28.2% (Albuquerque et al., 2020).

Growing global concerns regarding the role of animal production on antimicrobial resistance and residues in the products and the environment may force the Brazilian meat industry to change its relationship with antibiotics. The FAO/WHO/OIE collaboration on antimicrobial resistance (FAO and WHO, 2019) brought the One Health approach to the national sphere (Brasil, 2019). The international call by world health agencies to combat the antimicrobial resistance problem seeks to establish programs to monitor and foster the rational use of antibiotics. As a signatory member of the OIE, Brazil has undertaken to establish guidelines for the use of antibiotics in food-producing animals through the PAN-BR AGRO Program (Brasil, 2019), with several actions such as

increasing the awareness of stakeholders about the rational use of antibiotics, monitoring resistant bacteria strains, and promoting legislative changes in the use of veterinary antibiotics. Improving farm animal welfare is seen as essential to support the reduction in antibiotic use (Albernaz-Gonçalves, Olmos Antillón, & Hötzel, 2022).

Following the international trend, national and multinational food corporations started in the mid 2010s to announce commitments to force a change in their suppliers' production practices (Maciel, Mol, & Bock, 2015). International agreements are also main drivers for change regarding farm animal welfare in Brazil. The World Organization for Animal Health, WOAH, incorporated the promotion of animal welfare among its missions in the early 2000s (Bayvel, Diesch, & Cross, 2012). To adjust to international demands regarding farm animal welfare (von Keyserlingk & Hötzel, 2015), a regulation was introduced by the Ministry of Agriculture, Livestock and Food Supply in 2008 (MAPA, 2008). This regulation treats the issue of farm animals in all the production phases, stating basic requirements based on the FAWC Five Freedoms (FAWC, 2012) and referring to specific guidelines to be published for specific cases. One recent example of a regulation seeking to adjust the animal industries to international standards is the normative on pig production published in 2020 (Brasil, 2020), to be implemented between 2030 and 2045. The most complete normative covering animal welfare during the whole life of animals is the one regulating organic production systems (Brasil, 2021a). Humane slaughter in Brazil regulation is periodically updated to follow scientific and technological advancements (Brasil, 2021).

In response to WOAH initiatives regarding farm animal welfare, several outreach, education and training activities began to be carried out in partnerships involving the Ministry of Agriculture, universities, research centers and NGOs, to disseminate animal welfare initiatives in Brazil (Maciel et al., 2015; Paranhos da Costa, Huertas, Gallo, & Dalla Costa, 2012). Actions were seen related to slaughter and transport of animals (e.g., Hötzel, Mota, Ludtke, & Poletto, 2018; Paranhos da Costa et al., 2012; Sato et al., 2015), and on farm (Ceballos et al., 2018). Another result was the growth in interest in animal welfare, observed in university and technical agriculture colleges, with growing numbers of programs and faculties including animal welfare in their curricula, and especially great interest from students and continued education of professionals. For example, in a poll published by Brazilian Federal Council of Veterinary Medicine (CFMV), animal welfare was the theme chosen by the greatest proportion (64%) among 4068 veterinarians and 401 animal scientists that responded the survey asking in what areas they would like to increase their knowledge (CFMV, 2012). Animal welfare courses within veterinary programs were first offered in Europe in the mid-80's, with Brazil following some years later, in the beginning of the 90's. However, widespread animal welfare teaching is a challenge in Brazil, as well as leveling up the course contents, considering the excessive number of veterinary schools in the country. Nonetheless, some teaching and research centers are increasingly prominent, which relates to the increasing numbers of Brazilian scientific publications (Phillips & Molento, 2020), as illustrated in Fig. 3.

6. Implications and conclusions

Meat production, trade and consumption are highly relevant to Brazil for economic, nutritional, and cultural reasons. Additionally, the livelihoods of a considerable proportion of the population are related to this sector. Pressure from international markets is recognized by many as a key mechanism to change practices to achieve sustainability goals. Yet, as issues related to sustainable farm animal production gain social prominence in the country, the meat industry needs to consider the demands and expectations from local consumers. Brazilian citizens and consumers have little knowledge about many issues relevant for the sustainability of the sector but, when asked, express similar views as reported among citizens from industrialized countries; overall, consumers expect affordable products with high organoleptic, sanitary, nutritional and ethical standards of production. Also, a majority of consumers associate animal welfare with product quality and many believe outdoor and pasture-based systems can offer both. Environmental issues rank lower among Brazilian consumers' concerns, but this may change with growing public awareness. The international and domestic markets of the Brazilian meat industry may be undermined if it

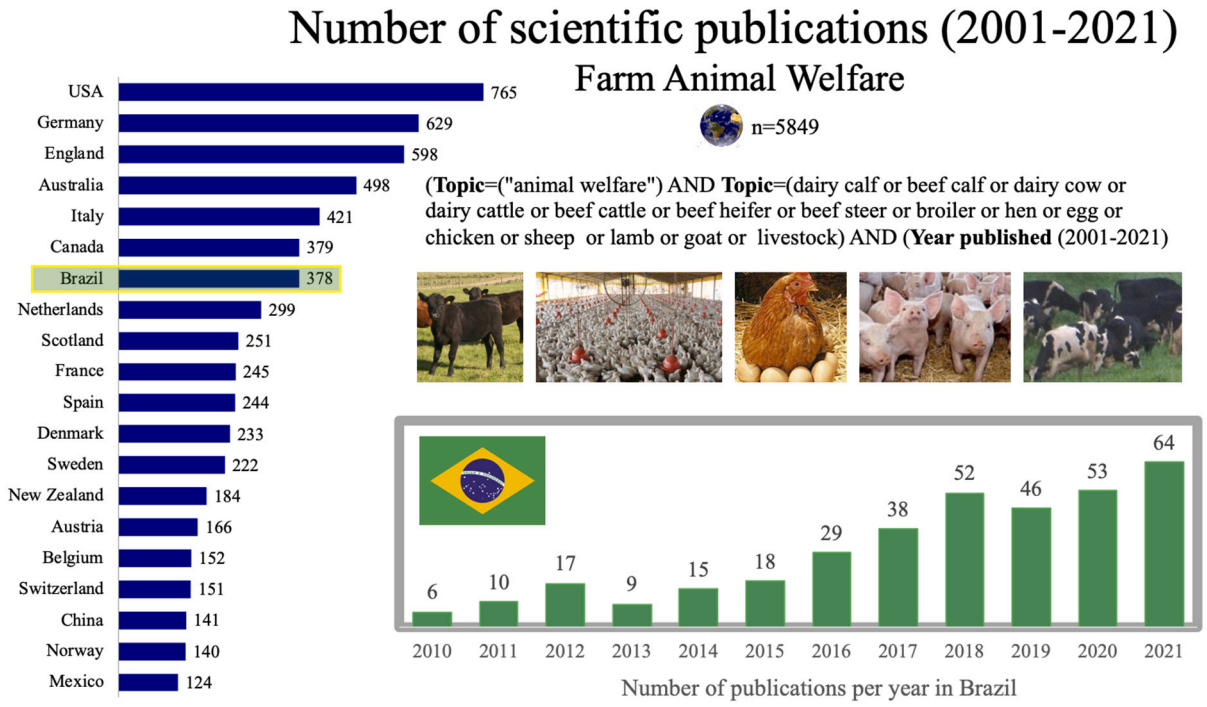

Fig. 3. Results of a simple search in the Web of Science platform spanning from 2001 to 2021. Blue bars display the 20 top countries in terms of numbers of articles published in the past 20 years. The green bars illustrate the steady growth in the scientific production of Brazil in the issue between 2010 and 2021. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

does not address environmental and animal welfare issues. Some discussions and changes in policies and in the production systems are already in place that may help the sector face sustainability challenges and respond to global demands regarding animal welfare, antibiotic use and environmental impacts of production. However, it is becoming increasingly clear that the pace of these changes needs to accelerate to follow the international demands and changes in ethical expectations of society. Constructive dialogue between all stakeholders of the meat production chain, including all types of producers and the local consumers, needs to be fostered to design more sustainable meat production systems. Without dialogue involving all stakeholders, changes may be forced top-down and fail to consider the interests of local consumers and producers.

CRediT authorship contribution statement

Maria José Hötzel: Conceptualization, Writing – original draft, Writing – review & editing. **Bianca Vandresen:** Writing – original draft.

Declaration of Competing Interest

The authors declare that there is no conflict of interest.

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References

ABIEC. (2022). *Brazilian Beef Exporters Association: Numbers of the sector*. Retrieved 9 May 2022, 2022, from http://abiec.com.br/en/.

ABPA. (2022). *Brazilian Association of animal protein - Annual report* (p. 144). São Paulo, SP: Brazilian Association of Animal Protein.

Albernaz-Gonçalves, R., Olmos Antillón, G., & Hötzel, M. J. (2022). Linking animal welfare and antibiotic use in pig farming: A review. *Animals, 12*(2), 216. https://doi.org/10.3390/ani12020216

Albuquerque, I., Alencar, A., Angelo, C., Azevedo, T., Barcellos, F., Coluna, I., … Zimbres, B. (2020). In SEEG (Ed.), *Análise das Emissões Brasileiras de Gases de Efeito Estufa e suas Implicações para as Metas de Clima do Brasil - 1970-2019*. SEEG/Observatório do Clima.

de Andrade, J. C., Sobral, L. D., Ares, G., & Deliza, R. (2016). Understanding consumers' perception of lamb meat using free word association. *Meat Science, 117*, 68–74. https://doi.org/10.1016/j.meatsci.2016.02.039

de Barcellos, M. D., Krystallis, A., de Melo Saab, M. S., Kuegler, J. O., & Grunert, K. G. (2011). Investigating the gap between citizens' sustainability attitudes and food purchasing behaviour: Empirical evidence from Brazilian pork consumers. *International Journal of Consumer Studies, 35*(4), 391–402. https://doi.org/10.1111/j.1470-6431.2010.00978.x

Barone, B., Nogueira, R. M., de Queiroz Guimarães, K. R. L. S. L, & Behrens, J. H. (2018). Sustainable diet from the urban Brazilian consumer perspective. *Food Research International*. https://doi.org/10.1016/j.foodres.2018.05.027. in press.

Battagin, H. V., Panea, B., & Trindade, M. A. (2021). Study on the lamb meat consumer behavior in Brazil. *Foods, 10*(8). https://doi.org/10.3390/foods10081713

Bayvel, A. C. D., Diesch, T. J., & Cross, N. (2012). Animal welfare: A complex international public policy issue: Economic, policy, societal, cultural and other drivers and constraints. A 20-year international perspective. *Animal Welfare, 21*(S1), 11–18. https://doi.org/10.7120/096272812x13345905673485

Behrens, J. H., Barcellos, M. N., Frewer, L. J., Nunes, T. P., Franco, B. D. G. M., Destro, M. T., & Landgraf, M. (2010). Consumer purchase habits and views on food safety: A Brazilian study. *Food Control, 21*(7), 963–969. https://doi.org/10.1016/j.foodcont.2009.07.018

Bonamigo, A., Bonamigo, C. B. S. S., & Molento, C. F. M. (2012). Broiler meat characteristics relevant to the consumer: Focus on animal welfare. *Brazilian Journal of Animal Science, 41*(4), 1044–1050.

Brasil. (1997). Mapa do Analfabetismo no Brasil. from https://download.inep.gov.br/publicacoes/institucionais/estatisticas_e_indicadores/mapa_do_analfabetismo_do_brasil.pdf.

Brasil. (2019). *Plano de ação nacional de prevenção e controle da resistência aos antimicrobianos no âmbito da saúde única 2018–2022 (PAN-BR)* (p. 24). Brasília: Ministério da Saúde, Secretaria de Vigilância em Saúde, Departamento de Vigilância das Doenças Transmissíveis.

Brasil. (2020). *Instrução Normativa N° 113, de 16 de dezembro de 2020*.

Brasil. (2021). *PORTARIA N° 365, DE 16 DE JULHO DE 2021. 365*. from https://www.in.gov.br/en/web/dou/-/portaria-n-365-de-16-de-julho-de-2021-334038845.

Brasil. (2021a). *PORTARIA N° 52, DE 15 DE MARÇO DE 2021*.

Brasil. (2022). Consumption and types of fish in Brazil. Retrieved 9 May 2022, 2022, from https://www.gov.br/agricultura/pt-br/assuntos/aquicultura-e-pesca/rede-do-pescado/consumo-e-tipos-de-peixes-no-brasil.

Brunoro, J. R. P., Lopes, M. A., Demeu, F. A., Bruhn, F. R. P., Rigueira, L. L., Faria, P. B., … Junqueira, L. V. (2020). Factors associated with consumer perception and conduct toward certified beef from Brazil. *Journal of Food Science, 85*(5), 1542–1547. https://doi.org/10.1111/1750-3841.15012

Bryant, C. J., Anderson, J. E., Asher, K. E., Green, C., & Gasteratos, K. (2019). Strategies for overcoming aversion to unnaturalness: The case of clean meat. *Meat Science, 154*, 37–45. https://doi.org/10.1016/j.meatsci.2019.04.004

Burnier, P. C., Spers, E. E., & de Barcellos, M. D. (2021). Role of sustainability attributes and occasion matters in determining consumers' beef choice. *Food Quality and Preference, 88*, Article 104075. https://doi.org/10.1016/j.foodqual.2020.104075

Caporal, F. (1991). *A extensão rural e os limites à prática dos extensionistas do serviço público*. Masters. Federal University of Universidade, Postgraduate course in Rural Extension.

Cardoso, C., von Keyserlingk, M., & Hötzel, M. J. (2017). Brazilian citizens: Expectations regarding dairy cattle welfare and awareness of contentious practices. *Animals, 7*(12), 89. https://doi.org/10.3390/ani7120089

Cardoso, C. S., von Keyserlingk, M. G., & Hötzel, M. J. (2019). Views of dairy farmers, agricultural advisors, and lay citizens on the ideal dairy farm. *Journal of Dairy Science, 102*(2), 1811–1821. https://doi.org/10.3168/jds.2018-14688

Castelfranchi, Y., Vilela, E. M., Lima, L. B.d., Moreira, I.d. C., & Massarani, L. (2013). Brazilian opinions about science and technology: The 'paradox' of the relation between information and attitudes. *História, Ciências, Saúde-Manguinhos, 20*, 1163–1183. https://doi.org/10.1590/S0104-59702013000400005

Ceballos, M. C., Sant'Anna, A. C., Boivin, X., Costa, F.d. O., Carvalhal, M. V.d. L., & Paranhos da Costa, M. J. R. (2018). Impact of good practices of handling training on beef cattle welfare and stockpeople attitudes and behaviors. *Livestock Science, 216*, 24–31. https://doi.org/10.1016/j.livsci.2018.06.019

CFMV. (2012). O papel do CFMV na visão dos médicos veterinários e dos zootecnistas (The role of CFMV in the views of veterinarians and animal scientists). *Revista CFMV (Conselho Federal de Medicina Veterinária), 57*, 8–14.

Chriki, S., Payet, V., Pflanzer, S. B., Ellies-Oury, M.-P., Liu, J., Hocquette, É., … Hocquette, J.-F. (2021). Brazilian consumers' attitudes towards so-called "cell-based meat". *Foods, 10*(11). https://doi.org/10.3390/foods10112588

CIDASC. (2021). Cidasc inicia a verificação oficial de granjas que exportam para China e Rússia. from http://www.cidasc.sc.gov.br/blog/2021/10/14/cidasc-inicia-a-verificacao-oficial-de-granjas-que-exportam-para-china-e-russia/.

Clark, B., Stewart, G. B., Panzone, L. A., Kyriazakis, I., & Frewer, L. J. (2016). A systematic review of public attitudes, perceptions and behaviours towards production diseases associated with farm animal welfare. *Journal of Agricultural and Environmental Ethics, 29*(3), 455–478. https://doi.org/10.1007/s10806-016-9615-x

Clark, B., Stewart, G. B., Panzone, L. A., Kyriazakis, I., & Frewer, L. J. (2017). Citizens, consumers and farm animal welfare: A meta-analysis of willingness-to-pay studies. [article]. *Food Policy, 68*, 112–127. https://doi.org/10.1016/j.foodpol.2017.01.006

CNA. (2021). Panorama do Agro. Retrieved 07/02/2022, 2022, from https://www.cnabrasil.org.br/cna/panorama-do-agro.

Comin, V. C., Karsburg, H. F., Souza, B. M. S.d., Almeida, H. M.d. S., Neira, L. M., & Rossi, G. A. M. (2022). Perception of animal welfare and its certification system by Brazilian consumers and dairy farmers. *Journal of Dairy Research, 1-4*. https://doi.org/10.1017/S0022029922000024

CompreRural. (2021). *Per capita consumption of the main meats in Brazil*. Retrieved 9 May 2022, 2022, from https://www.comprerural.com/veja-o-consumo-per-capita-das-principais-carnes-no-brasil/.

Cornish, A., Raubenheimer, D., & McGreevy, P. (2016). What we know about the public's level of concern for farm animal welfare in food production in developed countries. *Animals, 6*(11), 74.

Cunha, C. F.d., Spers, E. E., & Zylbersztajn, D. (2011). Percepção sobre atributos de sustentabilidade em um varejo supermercadista. *Revista de Administração de Empresas, 51*, 542–552.

Dill, M. D., de Andrade, A. R. S., Boito, B., Araujo, M. C. D., de Morais, M. D., da Silva, T. A., & Barcellos, J. O. J. (2021). Concerns, attitudes, and opinions of meat buyers in Garanhuns, Pernambuco, Brazil. *Brazilian Journal of Animal Science, 50*. https://doi.org/10.37496/rbz5020200003

Domingues, O. (1960). *Introdução à Zootecnia* (2 ed.). Rio de Janeiro: MA/SIA.

Estadão. (2021). 'Flexitarianos' ditam tendências para negócios de carne vegetal. Retrieved 04/04/2021, 04/04/2021, from https://headtopics.com/br/flexitarianos-ditam-tend-ncias-para-neg-cios-de-carne-vegetal-geral-estad-o-19566569.

FAO. (2022). Food and Agriculture Organization of the United Nations. *FAOSTAT, (Vol. 2014)*..

FAO, & WHO. (2019). Joint FAO/WHO Expert Meeting in collaboration with OIE on Foodborne Antimicrobial Resistance: Role of the Environment, Crops and Biocides – Meeting report. Microbiological Risk Assessment Series no. 34. Rome. In *Microbiological Risk Assessment Series No. 34*. Rome: FAO and WHO.

FAWC. (2012). *Five freedoms Retrieved Fevereiro. 6* p. 2018). from http://webarchive.nationalarchives.gov.uk/20121010012427/http://www.fawc.org.uk/freedoms.htm.

Fernandes, A. M., Costa, L. T., Teixeira, O. D., dos Santos, F. V., Revillion, J. P. P., & de Souza, A. R. L. (2021). Consumption behavior and purchase intention of cultured meat in the capital of the "state of barbecue," Brazil. *British Food Journal, 123*(9), 3032–3055. https://doi.org/10.1108/bfj-08-2020-0698

Ferrante, L., & Fearnside, P. M. (2022). Countries should boycott Brazil over export-driven deforestation. *Nature, 601*(7893), 318.

da Fonseca, M.d. C. P., & Salay, E. (2008). Beef, chicken and pork consumption and consumer safety and nutritional concerns in the city of Campinas, Brazil. *Food Control, 19*(11), 1051–1058. https://doi.org/10.1016/j.foodcont.2007.11.003

Franco, B. M. R., Souza, A. P. O., & Molento, C. F. M. (2018). Welfare-friendly products: Availability, labeling and opinion of retailers in Curitiba, Southern Brazil. *Revista de Economia e Sociologia Rural, 56*, 9–18.

G1. (2021). Datafolha: 67% of Brazilians reduced meat consumption and 47% of bread. from https://g1.globo.com/economia/noticia/2021/09/20/datafolha-67percent-dos-brasileiros-reduziram-consumo-de-carne-e-47percent-de-pao-frances.ghtml.

GFI. (2020). O consumidor brasileiro e o mercado plant-based. from https://gfi.org.br/2020/12/07/50-dos-brasileiros-afirmam-reduzir-o-consumo-de-carne/.

GIF. (2021). O consumidor brasileiro e o mercado plant-based. from https://gfi.org.br/wp-content/uploads/2021/02/O-consumidor-brasileiro-e-o-mercado-plant-based.pdf.

Globo Rural. (2017). Learn all about Halal and Kosher slaughters - Brazilian meat supplies about 20% of the international market. from https://revistagloborural.globo.com/Noticias/Criacao/Boi/noticia/2017/09/saiba-tudo-sobre-os-abates-halal-e-kosher.html.

Gomez-Luciano, C. A., de Aguiar, L. K., Vriesekoop, F., & Urbano, B. (2019). Consumers' willingness to purchase three alternatives to meat proteins in the United Kingdom, Spain, Brazil and the Dominican Republic. *Food Quality and Preference, 78*. https://doi.org/10.1016/j.foodqual.2019.103732

Grunert, K. G., Sonntag, W. I., 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*, 123–129. https://doi.org/10.1016/j.meatsci.2017.11.022

Hampton, J. O., Jones, B., & McGreevy, P. D. (2020). Social license and animal welfare: Developments from the past decade in Australia. *Animals, 10*(12). https://doi.org/10.3390/ani10122237

Happer, C., & Wellesley, L. (2019). Meat consumption, behaviour and the media environment: A focus group analysis across four countries. *Food Security, 11*(1), 123–139. https://doi.org/10.1007/s12571-018-0877-1

Hobbs, J. E. (2021). The Covid-19 pandemic and meat supply chains. *Meat Science, 181*, Article 108459. https://doi.org/10.1016/j.meatsci.2021.108459

Hötzel, M. J. (2014). Improving farm animal welfare: Is evolution or revolution needed in production systems? In M. C. Appleby, D. M. Weary, & P. Sandoe (Eds.), *Dilemmas in animal welfare* (pp. 67–84). Oxfordshire, UK: CABI.

Hötzel, M. J., Mota, S. M., Ludtke, C. B., & Poletto, R. (2018). Knowledge and attitudes of official inspectors at slaughterhouses in southern Brazil regarding animal welfare. *Revista Brasileira de Zootecnia, 47*.

Hötzel, M. J., Yunes, M. C., Vandresen, B., Albernaz-Gonçalves, R., & Woodroffe, R. E. (2020). On the road to end pig pain: Knowledge and attitudes of Brazilian citizens regarding castration. *Animals, 10*(10). https://doi.org/10.3390/ani10101826

IBGE. (2017). Censo Agropecuário 2017 - Resultados Definitivos. Retrieved February 07, 2022, from https://sidra.ibge.gov.br/pesquisa/censo-agropecuario/censo-agropecuario-2017.

IBGE. (2019). POF 2017–2018: Famílias com até R$ 1,9 mil destinam 61,2% de seus gastos à alimentação e habitação. from https://censos.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/25598-pof-2017-2018-familias-com-ate-r-1-9-mil-destinam-61-2-de-seus-gastos-a-alimentacao-e-habitacao.

IBGE. (2020). *Pesquisa Nacional por Amostra de Domicílios Contínua Anual*.

von Keyserlingk, M. A. G., & Hötzel, M. J. (2015). The ticking clock: Addressing farm animal welfare in emerging countries. *Journal of Agricultural and Environmental Ethics, 28*(1), 179–195. https://doi.org/10.1007/s10806-014-9518-7

Krystallis, A., Grunert, K. G., de Barcellos, M. D., Perrea, T., & Verbeke, W. (2012). Consumer attitudes towards sustainability aspects of food production: Insights from three continents. *Journal of Marketing Management, 28*(3–4), 334–372. https://doi.org/10.1080/0267257X.2012.658836

Maciel, C. T., Mol, A. P. J., & Bock, B. B. (2015). Paving the way for farm animal welfare in international relations: An EU–Brazil case study. *Contemporary Politics, 21*(4), 435–450. https://doi.org/10.1080/13569775.2015.1013291

Malafaia, G. C., Mores, G. D., Casagranda, Y. G., Barcellos, J. O. J., & Costa, F. P. (2021). The Brazilian beef cattle supply chain in the next decades. *Livestock Science, 253*. https://doi.org/10.1016/j.livsci.2021.104704

MAPA. (2008). *Instrução Normativa No 56, 6 de novembro de 2008, Ministério da Agricultura, Pecuária e Abastecimento*. Ministério da Agricultura, Pecuária e Abastecimento, Diário Oficial da União.

Menchaca, A. (2021). Sustainable food production: The contribution of genome editing in livestock. *Sustainability, 13*(12). https://doi.org/10.3390/su13126788

Monteiro, C. A., Cannon, G., Moubarac, J.-C., Martins, A. P. B., Martins, C. A., Garzillo, J., … Jaime, P. C. (2015). Dietary guidelines to nourish humanity and the planet in the twenty-first century. A blueprint from Brazil. *Public Health Nutrition, 18*(13), 2311–2322. https://doi.org/10.1017/S1368980015002165

Nogueira, S. S. C., & Nogueira-Filho, S. L. G. (2011). Wildlife farming: An alternative to unsustainable hunting and deforestation in Neotropical forests? *Biodiversity and Conservation, 20*(7), 1385–1397. https://doi.org/10.1007/s10531-011-0047-7

OECD-FAO. (2021). *OECD-FAO agricultural outlook (edition 2021)* (Publication no. doi: 10.1787/4bde2d83-en). https://doi.org/10.1787/4bde2d83-en) https://www.oecd-ilibrary.org/content/data/4bde2d83-en.

de Oliveira, G. A., Domingues, C. H.d. F., & Borges, J. A. R. (2021). Analyzing the importance of attributes for Brazilian consumers to replace conventional beef with cultured meat. *PLoS One, 16*(5), Article e0251432.

Ortez, M., Widmar, N. O., Thompson, N. M., & Brad Kim, Y. H. (2022). What do U.S. consumers care about regarding beef and its supply chain? *Meat Science, 108748*. https://doi.org/10.1016/j.meatsci.2022.108748

Paranhos da Costa, M. J. R., Huertas, S. M., Gallo, C., & Dalla Costa, O. A. (2012). Strategies to promote farm animal welfare in Latin America and their effects on carcass and meat quality traits. *Meat Science, 92*(3), 221–226. https://doi.org/10.1016/j.meatsci.2012.03.005

Phillips, C. J. C., & Molento, C. F. M. (2020). Animal welfare Centres: Are they useful for the improvement of animal welfare? *Animals, 10*(5). https://doi.org/10.3390/ani10050877

Queiroz, M. L.d. V., Delfino Barbosa Filho, J. A., Albiero, D., Brasil, D.d. F., & Melo, R. P. (2014). Consumer perception about welfare of livestock in Fortaleza, Ceará, Brazil. *Revista Ciência Agronômica, 45*(2), 379–386.

Queiroz, R. G.d., Domingues, C. H.d. F., Canozzi, M. E. A., Garcia, R. G., Ruviaro, C. F., Barcellos, J. O. J., & Borges, J. A. R. (2018). How do Brazilian citizens perceive animal welfare conditions in poultry, beef, and dairy supply chains? *PLoS One, 13*(12), Article e0202062. https://doi.org/10.1371/journal.pone.0202062

Ribeiro, C. S. C., & Corção, M. (2013). The consumption of meat in Brazil: Between socio-cultural and nutritional values. *Demetra: Food, Nutrition & Health, 8*(3), 425–437.

Ribeiro, T. G., Barone, B., & Behrens, J. H. (2016). Genetically modified foods and their social representation. *Food Research International, 84*, 120–127. https://doi.org/10.1016/j.foodres.2016.03.029

Rodrigues, R. M., Souza, A.d. M., Bezerra, I. N., Pereira, R. A., Yokoo, E. M., & Sichieri, R. (2021). Most consumed foods in Brazil: evolution between 2008–2009 and 2017–2018. *Revista de Saúde Pública*, 55.

da Rosa, P. P., Avila, B. P., Angelo, I. D. V., Chesini, R. G., Fernandes, T. A., Camacho, J. D., … Gularte, M. A. (2021). Impact of different chicken meat production systems on consumers' purchase perception. *British Poultry Science, 62*(3), 387–395. https://doi.org/10.1080/00071668.2020.1857335

Ruby, M. B., Alvarenga, M. S., Rozin, P., Kirby, T. A., Richer, E., & Rutsztein, G. (2016). Attitudes toward beef and vegetarians in Argentina, Brazil, France, and the USA. *Appetite, 96*, 546–554. https://doi.org/10.1016/j.appet.2015.10.018

Rucinque, D. S., Souza, A. P. O., & Molento, C. F. M. (2017). Perception of fish sentience, welfare and humane slaughter by highly educated citizens of Bogotá, Colombia and Curitiba, Brazil. *PLoS One, 12*(1), Article e0168197. https://doi.org/10.1371/journal.pone.0168197

Sato, P., Ludtke, C. B., Ciocca, J. R. P., Dandin, T., Lima, V., Vilela, J. A., … Miranda, Z. B. (2015). Avaliação dos resultados dos cursos de capacitação em bem-estar animal na pendura e na qualidade de carcaça de frangos. *Revista Brasileira de Medicina Veterinária, 37*(1), 88–92.

Schaly, L. M., de Oliveira, M. C., Salviano, P. A. P., & de Abreu, J. M. (2010). Percepção do consumidor sobre bem-estar de animais de produção em Rio Verde, GO. *Pubvet, 4*. Art. 962-967.

Schillings, J., Bennett, R., & Rose, D. C. (2021). Exploring the potential of precision livestock farming technologies to help address farm animal welfare (Review) *Frontiers in Animal Science, 2*. https://doi.org/10.3389/fanim.2021.639678.

Schlindwein, M. M., & Kassouf, A. L. (2006). Análise da influência de alguns fatores socioeconômicos e demográficos no consumo domiciliar de carnes no Brasil. *Revista de Economia e Sociologia Rural, 44*(3), 549–572.

Silva, C. A. D. S., Joset, W. C. L., Lourenço Júnior, J. D. B., Barbosa, A. V. C., Silva, W. C. D., & Silva, J. A. R. D. (2021). Animal protein consumer's perception on the welfare of production animals in Belém, Pará State, Brazil. *Acta Scientiarum. Animal Sciences, 43*, Article e53784. https://doi.org/10.4025/actascianimsci.v43i1.53784

Stampa, E., Schipmann-Schwarze, C., & Hamm, U. (2020). Consumer perceptions, preferences, and behavior regarding pasture-raised livestock products: A review. *Food Quality and Preference, 82*, Article 103872. https://doi.org/10.1016/j.foodqual.2020.103872

Stevenson, P. (2017). Precision livestock farming: Could it drive the livestock sector in the wrong direction. In *Paper presented at the proceedings of the 8th European conference of precision livestock farming*. EC-PLF.

SVB. (2018). IBOPE survey shows historical growth in the number of vegetarians in Brazil. https://www.svb.org.br/2469-pesquisa-do-ibope-aponta-crescimento-historico-no-numero-de-vegetarianos-no-brasil. from https://www.svb.org.br/2469-pesquisa-do-ibope-aponta-crescimento-historico-no-numero-de-vegetarianos-no-brasil.

Szendro, K., Szabo-Szentgroti, E., & Szigeti, O. (2020). Consumers' attitude to consumption of rabbit meat in eight countries depending on the production method and its purchase form. *Foods, 9*(5). https://doi.org/10.3390/foods9050654

Teixeira, D. L., Larraín, R., & Hötzel, M. J. (2018). Are views towards egg farming associated with Brazilian and Chilean egg consumers' purchasing habits? *PLoS One, 13*(9), Article e0203867. https://doi.org/10.1371/journal.pone.0203867

Tiseo, K., Huber, L., Gilbert, M., Robinson, T. P., & Van Boeckel, T. P. (2020). Global trends in antimicrobial use in food animals from 2017 to 2030. *Antibiotics, 9*(12). https://doi.org/10.3390/antibiotics9120918

Tomasevic, I., Bahelka, I., Čítek, J., Čandek-Potokar, M., Djekić, I., Getya, A., … Font-i-Furnols, M. (2020). Attitudes and beliefs of eastern European consumers towards animal welfare. *Animals, 10*(7), 1220.

Tonsor, G. T., Wolf, C., & Olynk, N. (2009). Consumer voting and demand behavior regarding swine gestation crates. *Food Policy, 34*(6), 492–498.

Tuyttens, F. A. M., Molento, C. F. M., & Benaissa, S. (2022). Twelve Threats of Precision Livestock Farming (PLF) for Animal Welfare [Review]. *Frontiers in Veterinary Science, 9*, 889623. https://doi.org/10.3389/fvets.2022.889623

USDA. (2022). *Livestock and poultry: World markets and trade (F. A. S. United States Department of Agriculture, Trans.)* (p. 29). Washington, DC: United States Department of Agriculture.

Valente, J.d. P. S., Fiedler, R. A., Sucha Heidemann, M., & Molento, C. F. M. (2019). First glimpse on attitudes of highly educated consumers towards cell-based meat and related issues in Brazil. *PLoS One, 14*(8), Article e0221129. https://doi.org/10.1371/journal.pone.0221129

Vandresen, B., & Hötzel, M. J. (2021). “Mothers should have freedom of movement”: Attitudes regarding farrowing housing systems for sows and their piglets. *Animals, 11*(12). https://doi.org/10.3390/ani11123439

Velho, J. P., Barcellos, J. O. J., Lengler, L., Elias, S. A.-A., & Oliveira, T. E. (2009). Disposição dos consumidores porto-alegrenses à compra de carne bovina com certificação. *Revista Brasileira de Zootecnia, 38*(2), 399–404.

Viana, M. M., Silva, V. L. D., & Trindade, M. A. (2014). Consumers’ perception of beef burgers with different healthy attributes. *LWT- Food Science and Technology, 59*(2), 1227–1232. https://doi.org/10.1016/j.lwt.2014.05.009

Vigitel. (2022). More than half of Brazilians were overweight in 2021. Retrieved 9 May 2022, 2022, from https://agenciabrasil.ebc.com.br/saude/noticia/2022-04/mais-da-metade-dos-brasileiros-estava-com-sobrepeso-em-2021.

WAP. (2016). *Consumo às cegas - Percepção do consumidor sobre o bem-estar animal* (p. 56). World Animal Protection. https://www.worldanimalprotection.org.br/sites/default/files/media/br_files/consumo_as_cegas_latam.pdf.

Whitton, C., Bogueva, D., Marinova, D., & Phillips, C. J. C. (2021). Are we approaching peak meat consumption? Analysis of meat consumption from 2000 to 2019 in 35 countries and its relationship to gross domestic product. *Animals, 11*(12). https://doi.org/10.3390/ani11123466

Yunes, M. C. (2021). *Building bridges to promote sustainable livestock systems: Opinions of stakeholders in Brazil towards gene editing of farm animals* (p. 30).

Yunes, M. C., Osório-Santos, Z., von Keyserlingk, M. A. G., & Hötzel, M. J. (2021). Gene editing for improved animal welfare and production traits in cattle: Will this technology be embraced or rejected by the public? *Sustainability, 13*(9), 4966. https://doi.org/10.3390/su13094966

Yunes, M. C., Teixeira, D. L., von Keyserlingk, M. A. G., & Hötzel, M. J. (2019). Is gene editing an acceptable alternative to castration in pigs? *PLoS One, 14*(6), Article e0218176. https://doi.org/10.1371/journal.pone.0218176

Yunes, M. C., von Keyserlingk, M. A. G., & Hötzel, M. J. (2017). Brazilian citizens’ opinions and attitudes about farm animal production systems. *Animals, 7*(10), 75. https://doi.org/10.3390/ani7100075