



## The Brazilian beef cattle supply chain in the next decades

Guilherme Cunha Malafaia<sup>a</sup>, Giana de Vargas Mores<sup>b,\*</sup>, Yasmin Gomes Casagrande<sup>c</sup>,  
Júlio Otávio Jardim Barcellos<sup>d</sup>, Fernando Paim Costa<sup>e</sup>

<sup>a</sup> Brazilian Agricultural Research Corporation (Embrapa), 830 Rádio Maia Avenue, Vila Popular, Campo Grande, State of Mato Grosso do Sul 79106-550, Brazil

<sup>b</sup> Federal University of Mato Grosso do Sul (Ufms)/Imed Business School, 304 Senador Pinheiro Street, Vila Rodrigues, Passo Fundo, State of Rio Grande do Sul 99070-220, Brazil

<sup>c</sup> Federal University of Mato Grosso do Sul (Ufms), Costa e Silva Avenue, University City, Pioneiros, Campo Grande, State of Mato Grosso do Sul 79070-900, Brazil

<sup>d</sup> Federal University of Rio Grande do Sul (Ufrgs), 7712 Bento Gonçalves Avenue, Agronomia, Porto Alegre, State of Rio Grande do Sul 91540-000, Brazil

<sup>e</sup> Brazilian Agricultural Research Corporation (Embrapa), 830 Rádio Maia Avenue, Vila Popular, Campo Grande, State of Mato Grosso do Sul 79106-550, Brazil

### HIGHLIGHTS

- The prognosis was obtained by Delphi method with 153 Brazilian specialists.
- Global advances will impact on Brazilian beef cattle supply chain.
- Scenarios and ten megatrends were defined for the beef supply chain in 2040.
- The results were based on quality and technology with sustainable implications.
- Advances will come from technical, professional and competitive livestock production.

### ARTICLE INFO

#### Keywords:

Cattle livestock  
Meat  
Expert opinion  
Delphi method  
Agribusiness

### ABSTRACT

The Brazilian beef cattle supply chain has undergone technological modernisation in its production systems, resulting in better productivity, meat quality and competitiveness. The research aims to identify the megatrends in the Brazilian beef cattle supply chain expected by 2040. The Delphi method was used to identify the challenges. Scenarios were created and ten megatrends were defined: i) biological advances in waste management; ii) biotechnological transformation of beef farming; iii) less grass and more meat; iv) profits based on animal welfare; v) consolidated livestock with major players; vi) more natural and quality-demanding slaughterhouses; vii) meat with a designation of origin; viii) digital technology that transforms the entire supply chain; ix) availability of qualified labour; x) Brazil as a major exporter of meat and genetics. The development of this research has economic, social and environmental implications for both the public and private spheres. In the international scenario, Brazil could be a major exporter of meat and probably animal genetics, specialised and with added value. Global advances in the supply chain will come from highly technical, professional and competitive livestock production, mainly based on technology and quality.

### 1. Introduction

Brazil stands out in global beef and dairy cattle production. In 2020, the gross domestic product (GDP) of beef cattle accounted for 8.5% of the Brazilian GDP (Cepea, 2021). This scenario is confirmed by the increase in importing countries and the consolidation of markets, such as China, Hong Kong, the European Union, Egypt and Chile (Secretariat of Foreign Trade Secex, 2021) and is corroborated by the decrease in

pasture area and an increase in livestock productivity.

Meat is an important source of protein in human diets and its consumption depends on socioeconomic factors, ethics or religious beliefs, traditions (Food and Agriculture Organization of the United Nations FAO, 1992). Since the 1990s, the Brazilian beef cattle supply chain has undergone a technological modernisation in its production and organisation systems, resulting in higher productivity, better meat quality and greater competitiveness. This scenario was due to the country's

\* Corresponding author.

E-mail addresses: [guilherme.malafaia@embrapa.br](mailto:guilherme.malafaia@embrapa.br) (G.C. Malafaia), [gimores@gmail.com](mailto:gimores@gmail.com), [giana.mores@imed.edu.br](mailto:giana.mores@imed.edu.br) (G.V. Mores), [yasmin.casagrande@ufms.br](mailto:yasmin.casagrande@ufms.br) (Y.G. Casagrande), [julio.barcellos@ufrgs.br](mailto:julio.barcellos@ufrgs.br) (J.O.J. Barcellos), [gferpaim@gmail.com](mailto:gferpaim@gmail.com) (F.P. Costa).

<https://doi.org/10.1016/j.livsci.2021.104704>

Received 27 June 2021; Received in revised form 23 August 2021; Accepted 15 September 2021

Available online 17 September 2021

1871-1413/© 2021 Elsevier B.V. All rights reserved.

favourable climatic conditions, availability of land at low prices, adequate labour supply and production technology adapted to a tropical country.

Despite this favourable scenario, a shortage of beef required imports until the 1980s. The supply chain was encouraged to increase production, resulting in what is considered the first wave of beef cattle development in Brazil (McManus et al., 2016). Over the years, the production system has been based on productivity, since the horizontal growth of production was unsustainable (Brazilian Agricultural Research Corporation, 2020). The livestock production model in Brazil has prioritised more capital-intensive technologies (i.e. “land-saving” technologies) with better technical and economic performances (Marta Júnior et al., 2011).

Key solutions have been the integrated production systems, new forages, genetic improvement of the herd, management and recovery of pastures, feed supplementation, good production practices and calf early production (Pelicano and Capdeville, 2021). However, since the 2010s, cost pressures have arisen, derived from production costs, land valorisation and social and environmental restrictions (Cortner et al., 2019; Nunes et al., 2019; Wetlesen et al., 2020).

To achieve a broad understanding, a study of scenarios can be conducted. A scenario project has an argument defined to address the common experiences of organisations (Gordon, 2020). Actual arguments to describe agribusiness scenarios include risk management (Behzadi et al., 2018), economic consequences (Riley et al., 2019), production expansion (Vale et al., 2019), climate change impacts (Payen et al., 2020), carbon footprint (Vreys et al., 2019), non-renewable energy/resources and land use (González-Quintero et al., 2021) and the effects of diverse periods (Coluccia et al., 2021).

The originality and the theoretical and managerial relevance of this research, since it could increase the possibility of generating more assessments of the international markets for conducting the scenarios presented. It should reveal the connections along the beef cattle supply chain and the possible megatrends, guide future solutions for supply chain management and improve production to achieve new strategic methods for organisations. In this context, this research aims to identify the megatrends in the Brazilian beef cattle supply chain expected by 2040.

## 2. Materials and methods

Bibliographic research and the Delphi method were used to validate and establish the steps of the research. This method is justified when the research problem does not use precise analysis techniques but instead uses the reliable consensus of experts in the area who work directly on the topic (Linstone and Turoff, 2002; Grisham, 2009), helping to define future-orientated research (Rowe and Wright, 1999). The Delphi method is an important research technique, as it allows the collection of expert opinions and leads to robust results in the complex topics researched (Landeta, 2006; Rikkonen et al., 2006).

The authors obtained a prognosis regarding the challenges faced by the Brazilian beef cattle supply chain by defining the guiding question for performing the Delphi method: What are the challenges facing the beef cattle supply chain in Brazil in 2040? (Step 1). The Delphi method was conducted in 2020, using the 20-year timeframe for long-term future studies (in this case, 2040). The relevant steps are listed in Fig. 1.

A group of experts on future events was consulted by means of a questionnaire, which was repeated twice until the convergence of



Fig. 1. Steps of the Delphi method.

responses was obtained. This method has often been used in research on challenges in supply chains and global trends (Hu et al., 2019; Raut et al., 2021).

Regarding future drivers (basis for defining possible events) (Step 2), the facts that are occurring and those that may have an impact on the future were raised, comprising a matrix of themes that link the main stages of the beef cattle supply chain (inputs, agricultural production, industry, commercialisation and consumption) with the dimensions of the Steeple methodology. This methodology contemplates the following dimensions: social, technological, economic, environmental, political, legal and ethical (Lomas and McLeod, 2020). Thus, 754 future drivers were identified that might affect the beef cattle supply chain in the future.

In sequence, the results led to 96 possible events in eight blocks (Step 3): inputs (health/genetics), inputs (nutrition/forage), production (management), production (structure), slaughterhouse, consumption, commercialisation and regulation. These events were analysed by specialists who rated the probability of occurrence of each of them (Step 4). The investigations started by contacting 803 Brazilian specialists from all regions of the country. Each specialist received a specific topic according to their speciality and was able to answer other topics of free choice. The authors received 187 responses in the first round and 109 in the second round, with a total participation of 153 experts in both.

After completing the four steps, the data on probabilities and pertinence were consolidated to calculate motricity and dependence of the

events (Step 5). The cross-impact matrix was used to quantify how much each possible event can impact the others in the actual scenario (Step 6). The statistical analysis was based on the Bayes theorem, which calculates the probability of an event occurring given the occurrence of a previous event (Joyce, 2019).

In sequence, the most likely future scenarios were selected through the analysis of the control group (multidisciplinary group of specialists from the Ministry of Agriculture, Livestock and Food Supply [MAPA] and the (Brazilian Agricultural Research Corporation, 2020)), which was composed of its own specialists to analyse the results and create possible scenarios (Step 7). The scenario with the highest probability of occurrence was called the most likely scenario.

Finally, future scenarios were presented based on analysis of the control group and on the megatrends for the Brazilian beef cattle supply chain in 2040, with the main challenges (Step 8). The megatrends were created by clustering trends mapped by stage and grouping the tendencies by similarity.

### 3. Results and discussion

#### 3.1. Megatrends

Ten megatrends were defined for the Brazilian beef cattle supply chain in 2040:

- 1) biological advances in waste management; 2) biotechnological

**Table 1**  
Megatrends and stages of the Brazilian beef supply chain in 2040.

Stages Megatrends	Inputs	Production	Industry	Commercialization	Consumption
1 Bioinputs	low residue medicines	veterinary medicine, reverse logistics	animal welfare industry with types of medicines that do not leave residues	changes in the ideologies that take meat off the market choices	elimination of questions about food security in Brazilian beef
2 Biotechnology	biological disease control	genetically modified animals	legalisation of reverse logistics	genetic export	demand supplied by animal protein substitute proteins
3 Intensification	pasture reforms	adaptation to international requirements of good practices	legalisation of good practices in slaughterhouse	availability of own-brand stores from slaughterhouses and farms	product that meets organoleptic needs, convenience, cultural habits, and market income
4 Animal welfare	elimination of compulsory vaccination	welfare strategies	animal welfare certificates	animal welfare certificates	market acceptability consumers for acceptability consumers of the products
5 Concentration	lower economic losses	technology transformation	more specialisation	connectivity in advertising and marketing, automatic consumer provisioning	the product will no longer be a niche one, with more than 25% of the market
6 Quality	increasing requirements demands for raw material	advances in meat quality; sustainable management systems	changes in productive system and in supply of raw materials	meet the needs of the foreign and domestic markets	market-oriented supply chain, changes in consumer profile
7 Meat origin	different cuts of meat and productive systems	adding value	integration of the productive system via digital	system transparency; designation of origin	consumers looking for new gastronomic experiences
8 Digital	some intermediaries will leave the supply chain	bottlenecks will be reduced from digital management	greater process automation will reduce costs especially, increasing productivity and quality	digital interaction in marketing	quality, sustainability and digitalisation will bring better results for more demanding consumers
9 Labour shortage	rural exodus will bring challenges in the labour factor	greater automation of processes will compensate for less availability of labour	advances in technology and management will need more specialised professionals in this field	e-commerce sales growth	consumers preferring more varied types of meat
10 Brazilian exportation	exponent in bovine genetics	animal welfare, meat quality	biotechnology and the entire supply chain oriented towards sustainable production	export of genetics, live animals, cut meat and by-products, to emerging and developed countries	internal growth and may represent more than 20% of world meat exports

transformation of beef farming; 3) less grass and more meat; 4) profits based on animal welfare; 5) consolidated livestock with major players; 6) more natural and quality-demanding slaughterhouses; 7) meat with a designation of origin; 8) digital technology that transforms the entire supply chain; 9) availability of qualified labour; 10) Brazil as a major exporter of meat and genetics.

The results are interpreted amongst the 10 megatrends to the Brazilian beef cattle supply chain in 2040, interconnecting their stages (inputs, agricultural production, industry, commercialisation and consumption) (Table 1). It is useful to understand which changes could occur in all of them.

Data analysis allows an understanding of how feeding in the grazing system can assist the production and which type of management should be used to improve the production results. This is a concern to be highlighted regarding resource availability issues (Cardoso et al., 2020). The use of inputs related to environmental concerns will have a movement towards the thrifty use of environmental resources (Ruviaro et al., 2015). These processes are linked to the reverse logistics of veterinary medicines and lead to more effective disease control.

The tendency to use biological inputs is a result of farmer efforts. Examples of expanding applications in production could be alternative and biological therapies and integrated epidemiological control in the treatment of diseases. This field highlights that room exists for studies on new strategies to reduce the frequency of illnesses, such as respiratory diseases currently treated with antimicrobial programmes (Devant and Marti, 2020).

The transformation related to health and genetics will concern the biological control of parasites and the quality of meat by transgenic manipulation. The implementation of reproductive biotechnology is known to improve outcomes (Fernandez-Novo et al., 2020). The diffusion of breeding biotechniques could occur with an increase in the number of genetically improved animals. Brazil could be prominent in genetic exports. The genetic and production improvements can result in less pasture area and higher yields (Fernandes et al., 2020; Dohlman et al., 2021).

The integrated crop-livestock-forest system (ILPF) changes the level of technological adoption in beef cattle systems. The change to a reduction in pastures should lead to an increase in the number of animals per property, with greater productivity. Investments in the transformation of pastures led to the recovery of degraded areas. However, cattle stocking rate per hectare can result in animal behaviour disorders (Tarantola et al., 2020) and negative externalities can occur depending on soil and crop management and local climate (Tavanti et al., 2020).

This path, supported by public policies, should improve the image of the beef cattle industry in Brazil. This improvement can be seen within the country and worldwide. A productive diversity with the environment should increase the number of cattle produced. Animal welfare is a crucial issue to beef cattle, as the animals are subject to problems, such as respiratory diseases, mixing of animals and digestive and behaviour disorders. In this context, the farmer must identify and select suitable welfare measures for the production system (Tarantola et al., 2020).

Achieving animal welfare will be mandatory (Canozzi et al., 2020). Certificates that prove better production practices will be required throughout the supply chain (Boito et al., 2021). Management is a determining aspect for conducting production with the aim of adopting guidance that is more technical and specialised. The managerial and entrepreneurial technology transformation should select players in the market and eliminate those that are not updated. A new reality is expected that will force farms to improve their production patterns (Dill et al., 2015).

As a result, requirements for quantity and quality could appear. Turning production into a player with more needs for investments and control should be indispensable. The number of farmers is predicted to decrease, while the committed professionals should remain in the sector. Several characteristics will be added to this discussion, such as which farmers will be prepared to reach differentiated markets (Sobrosa Neto

et al., 2018), more accurate evaluations about the industry (Liang et al., 2020) and new policies focused on the producers (Vilpoux et al., 2021).

Agribusiness is going through a time when market orientation suggests a shift to product quality coupled with quantity. The beef cattle supply chain is one of the main examples of products that suffer from adverse effects (Robles, 2010). The sixth megatrend supports this situation by prioritising aspects of demand for more natural and quality products. The increasingly demanding consumer could require more natural products with less additives.

New requirements will be needed in the acquisition of raw materials (inputs), such as meat quality and more sustainable management systems (Magnier et al., 2016) derived from biological products and animal welfare in rural properties (Queiroz et al., 2018; Winckler, 2019). This is observed in the foreign market but will be, in the coming years, intensified by the Brazilian consumer, especially in terms of product quality (Panea and Ripoll, 2020; Grasso et al., 2021).

The debate in the literature regarding the designation of origin is recurrent, as in the case of products with more sophisticated consumers, such as cheese and wine. The seventh megatrend brings up the discussion of the designation of origin for meats in the coming decades (Gianezini et al., 2014), as in Europe. In the search for added value, the first stages of the beef cattle supply chain will seek different cuts for meat (Savell et al., 1989) and production processes that meet new national and international requirements (Panea and Ripoll, 2020).

In this sense, this megatrend indicates that consumers will be looking for new gastronomic experiences (EIT, 2021), linked to the improvements that could occur in the meat supply chain. The integration of production via digital technology will help in maintaining the transparency of the process to stakeholders (Hou et al., 2019; Bogataj et al., 2020).

Distribution (inputs, meat) should be the key to the eighth megatrend, as the activity of intermediaries could be extinguished in the supply chain in the coming years. Recurrently, words like quality, sustainability and digital interaction with the consumer should be the great differentials for those who intend to remain in the sector and have positive results.

In slaughterhouses, technological processes will enable more assertiveness, with lower costs and higher productivity and product quality (Fernandes et al., 2019). For this, the management of rural properties will undergo a new paradigm for intensification (Jaurena et al., 2021) and a transformation resulting from digital and technological tools, identifying opportunities for improvements and superior results. An example of this is the smart farming, which has been applied in several countries (Pivoto et al., 2018, 2019).

The increase in the Brazilian urban population, something that is already occurring in several countries, brings up a way to rethink the organisation of the supply chains that depend on rural labour. This has technological innovation as its main driver of change (Pivoto et al., 2019). For instance, internet of things, more technological production systems, integrated crop-livestock-forest system and efficient management of rural properties should demand highly trained professionals for the new paths of Brazilian agribusiness.

The tenth megatrend refers to a more widespread subject in academia and in public and private organisations: Brazil as a major exporter of meat and probably animal genetics. It is worth highlighting the importance of observing this from the stages that make up the beef cattle supply chain, which has been emerging in national and international markets and contributing to the Brazilian trade balance surplus (Ministry of Economy, 2021).

Brazil's position as one of the largest food producers and exporters in the world will be maintained and even surpassed (Food and Agriculture Organization of the United Nations FAO, 2021). However, biotechnology and the greater alignment of the entire supply chain to ensure better genetic standards, sustainable production systems, animal welfare and meat quality will be the basis for the growth and development of the beef cattle supply chain (Kanashiro and Fraisse, 2015).

### 3.2. Social, managerial and policy implications

The Covid-19 pandemic changed consumption habits, as well as the labour force and the perspectives of food supply chains (Manojkrishnan and Aravind, 2020; Coluccia et al., 2021). Adjustments are predicted regarding consumer priorities for human health and environmental sustainability. Until 2040, consumers should change their consumption patterns, due to increasing awareness of food safety and ethical issues that should have a greater impact on preferences. These factors will lead consumers to increasingly incorporate self-stable foods into their diets, a change that is relevant in the protein sector (Knoll et al., 2017; Global Panel, 2021).

Emerging markets are seeking to adopt new technologies driven by resources and food scarcity, health awareness and environmental impact (Navarrete-Molina et al., 2019; Cardoso et al., 2020). Cultured meat is one of the results of new technologies aimed at providing alternative affordable foods by creating pathogen-free products and plant-based meat (Bryant and Sanctorum, 2021; Jairath et al., 2021). If the cell protein costs used in this process are reduced and the developed products provide accessible nutrition, this technology can help the poorest populations and reduce the risk of food shortages in developing countries (Fitch Solutions, 2020; Hong et al., 2021).

The protein market could achieve new product alternatives in the coming years. This sector has been dynamic in terms of product innovation, distribution and marketing strategies. However, the impact on this sector should be minimal based on the actual levels of beef consumption *per capita* (especially on a global scale) in the short term. It may begin to have a greater impact in the medium and long terms (Fitch Solutions, 2021a).

International inquiries regarding Brazil's environmental protection, particularly in relation to deforestation in the Amazon, pose a risk to the reputation of Brazilian agribusiness and to foreign investment in the sector. Brazil's beef and soy sectors are at the greatest risk, as these sectors are associated with illegal deforestation.

Large global companies operating in Brazil demand better monitoring of environmental measures against these problems. Major beef exporters are expected to continue to improve supply chain traceability and to implement changes in governance, which is important for Brazilian slaughterhouses (Fernandes et al., 2020; Lovarelli et al., 2020). In addition, several Brazilian regions have acquired a new sanitary status for foot and mouth disease, which will result in a new wave of livestock with international repercussions (Menezes et al., 2020).

However, the challenge is not an easy to overcome. Livestock properties with fewer than 50 animals account for 76.3% of the total and 16.5% of the Brazilian herd. These properties are estimated to be responsible for 13% of the total production of animals, with 50% of the total production in calves (IBGE, 2017). These numbers are accompanied by social challenges for managers and for the future of food and agribusiness (Food and Agriculture Organization of the United Nations FAO, 2017; Freitas et al., 2019).

The unfeasibility of establishing efficient control can pressure the market, reducing the number of players (producers) that could be able to meet all requirements. It can contribute to informality where there is no inspection, traceability or generation of taxes. If combatting this is successful, it could be achieved at a high cost of excluding small farmers and increasing meat prices to consumers. Despite the importance of controlling each stage of the supply chain, it is essential that these actions be planned in a coordinated and inclusive manner, taking into account the knowledge available about the reality of the field (Jaurena et al., 2021).

International investors (mainly in the United States and Western Europe) are likely to attribute a greater environmental, social and corporate governance risk to Brazilian agribusiness companies if the sector remains connected to environmental degradation. The Central Bank of Brazil is increasingly engaged in this concern, recognising its role in mitigating the financial effects of social and environmental risks

and guaranteeing that Brazilian companies have continuous access to the capital market (Fitch Solutions, 2021b). To change this, it is expected that Brazilian producers increasingly learn and improve their practices.

### 4. Final remarks

The development of this research presents economic, social and environmental issues for the public and private spheres. For instance, producing more meat in a smaller area could increase the amount of land available for agriculture and forestry. In the international scenario, Brazil is expected to be a major exporter of meat and probably animal genetics, specialised and with added value, thereby contributing more to the Brazilian GDP.

The authors provide the construction of an original way to understand what could happen in the Brazilian beef cattle supply chain until 2040. The data provide a basis for policy insights and can be used to improve company and government practices. The global reference in the supply chain should come from highly technical, professional and competitive livestock production, mainly based on innovation, technology and quality.

The reality expected in the coming years should be a technified, intensive and short cycle beef supply chain. However, this could demand crucial adjustments to the production flow to achieve new market requirements, with different consciousness about the product and its process. Finally, the challenge is to use this research to continuously improve discussions about the megatrends as a way to achieve new agendas and originate scenarios that impact supply chain transitions.

### CRedit authorship contribution statement

**Guilherme Cunha Malafaia:** Conceptualization, Methodology, Software, Formal analysis, Investigation, Resources, Data curation, Writing – review & editing, Supervision, Funding acquisition. **Giana de Vargas Mores:** Conceptualization, Methodology, Validation, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Yasmin Gomes Casagrande:** Conceptualization, Methodology, Validation, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Júlio Otávio Jardim Barcellos:** Writing – review & editing. **Fernando Paim Costa:** Writing – review & editing.

### Declaration of Competing Interest

None.

### Acknowledgement

This work was supported by the National Council for Scientific and Technological Development (CNPq - Brazil) [grant number 420981/2018-7] and the Ministry of Agriculture, Livestock and Food Supply (MAPA - Brazil).

### Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.livsci.2021.104704](https://doi.org/10.1016/j.livsci.2021.104704).

### References

- Behzadi, G., O'Sullivan, M.J., Olsen, T.L., Zhang, A., 2018. Agribusiness supply chain risk management: a review of quantitative decision models. *Omega* 79, 21–42. <https://doi.org/10.1016/j.omega.2017.07.005>.
- Bogatay, D., Hudoklin, D., Bogatay, M., Dimovski, V., Colnar, S., 2020. Risk mitigation in a meat supply chain with options of redirection. *Sustainability* 12 (20), 8690. <https://doi.org/10.3390/su12208690>.

- Boito, B., Lisbinski, E., Campo, M.M., Guerrero, A., Resconi, V., Oliveira, T.E., Barcellos, J.O.J., 2021. Perception of beef quality for Spanish and Brazilian consumers. *Meat Sci.* 172, 108312 <https://doi.org/10.1016/j.meatsci.2020.108312>.
- Brazilian Agricultural Research Corporation, 2020. A terceira onda da pecuária de corte no Brasil. Campo Grande, Embrapa.
- Brazilian Institute of Geography and Statistics, 2017. Censo agropecuário 2017. <https://censos.ibge.gov.br/agro/2017/> (accessed 05 April 2021).
- Bryant, C., Sanctorem, H., 2021. Alternative proteins, evolving attitudes: comparing consumer attitudes to plant-based and cultured meat in Belgium in two consecutive years. *Appetite* 161 (1), 105161. <https://doi.org/10.1016/j.appet.2021.105161>.
- Ministry of Economy-Brazil, 2021. Comex Stat: general exports and imports. <http://comexstat.mdic.gov.br/en/geral>. Accessed 10 June 2021.
- Canozzi, M.E., Borges, J.A.R., Barcellos, J.O.J., 2020. Attitudes of cattle veterinarians and animal scientists to pain and painful procedures in Brazil. *Prev. Vet. Med.* 177, 104909 <https://doi.org/10.1016/j.prevetmed.2020.104909>.
- Cardoso, A., Barbero, R.P., Romanzini, E.P., Teobaldo, R.W., Ongaratto, F., Fernandes, M.H.M.R., Ruggieri, A.C., Reis, R.A., 2020. Intensification: a key strategy to achieve great animal and environmental beef cattle production sustainability in Brachiaria grasslands. *Sustainability* 12 (16), 1–17. <https://doi.org/10.3390/su12166656>.
- Cepea, 2021. PIB de cadeias agropecuárias. Esalq/USP. <https://www.cepea.esalq.usp.br/br/pib-de-cadeias-agropecuarias.aspx>. (Accessed 12 March 2021). accessed 12 March 2021.
- Coluccia, B., Agnusdei, G.P., Miglietta, P.P., Leo, F., 2021. Effects of Covid-19 on the Italian agri-food supply and value chains. *Food Control* 123, 107839. <https://doi.org/10.1016/j.foodcont.2020.107839>.
- Cortner, O., Garrett, R.D., Valentim, J.F., Ferreira, J., Niles, M.T., Reis, J., Gil, J., 2019. Perceptions of integrated crop-livestock systems for sustainable intensification in the Brazilian Amazon. *Land Use Policy* 82, 841–853. <https://doi.org/10.1016/j.landusepol.2019.01.006>.
- Devant, M., Marti, S., 2020. Strategies for feeding unweaned dairy beef cattle to improve their health. *Animals* 10 (10), 1–20. <https://doi.org/10.3390/ani10101908>.
- Dill, M.D., Pereira, G.D., Costa, J.B.G., Canellas, L.C., Peripolli, V., Braccini Neto, J., Sant'anna, D.M., McManus, C., Barcellos, J.O.J., 2015. Technologies that affect the weaning rate in beef cattle production systems. *Trop. Anim. Health Prod.* 47, 1255–1260. <https://doi.org/10.1007/s11250-015-0856-x>.
- Dohlman, E., Hansen, J., Boussios, D., 2021. USDA agricultural projections to 2030. Global agriculture: projections to 2020 and U.S. trade trends, 1–124.
- Fernandes, A.M., Teixeira, O.S., Rios, H.V., Canozzi, M.E.A., Schultz, G., Barcellos, J.O.J., 2019. Insights of innovation and competitiveness in meat supply chains. *Int. Food Agribus. Manage. Rev.* 22 (3), 413–427. <https://doi.org/10.22434/IFAMR2018.0031>.
- Fernandes, E.A., Sarriés, G.A., Bacchi, M.A., Mazola, Y.T., Gonzaga, C.L., Sarriés, S.R.V., 2020. Trace elements and machine learning for Brazilian beef traceability. *Food Chem.* 333 (15), 127462 <https://doi.org/10.1016/j.foodchem.2020.127462>.
- Fernandez-Novo, A., Pérez-Garnelo, S.S., Villagrà, A., Pérez-Villalobos, N., Astiz, S., 2020. The effect of stress on reproduction and reproductive technologies in beef cattle: a review. *Animals* 10 (11), 1–23. <https://doi.org/10.3390/ani10112096>.
- European Institute of Innovation and Technology (EIT Food), 2021. The top 5 trends for the agrifood industry in 2021. <https://www.eitfood.eu/blog/post/the-top-5-trends-for-the-agrifood-industry-in-2021> (accessed 25 May 2021).
- Fitch Solutions, 2020. Towards 2050: megatrends in industry politics and the global economy. <https://www.fitchsolutions.com/white-papers/towards-2050-megatrends-industry-politics-and-global-economy-2020-edition> (accessed 23 May 2021).
- Fitch Solutions, 2021a. Americas agribusiness. <https://www.fitchsolutions.com/sites/default/files/white-papers/Americas%20Agribusiness%20Insight%20March%202021.pdf> (accessed 23 May 2021).
- Fitch Solutions, 2021b. Brazil agribusiness report includes 5 years forecast to 2050. [https://app.fitchconnect.com/search/research/article/BMI\\_D78E1C1D-F197-46D8-B A2B-E47390BC11CB](https://app.fitchconnect.com/search/research/article/BMI_D78E1C1D-F197-46D8-B A2B-E47390BC11CB) (accessed 23 May 2021).
- Secretariat of Foreign Trade (Secex), 2021. Secex. <http://www.siscomex.gov.br/legislacao/secex/> (accessed 22 March 2021).
- Food and Agriculture Organization of the United Nations (FAO), 1992. Meat and meat products in human nutrition in developing countries. <http://www.fao.org/3/t0562e/t0562e00.htm#Contents> (accessed 20 March 2021).
- Freitas, D.S., Oliveira, T.E., Oliveira, J.M., 2019. Sustainability in the Brazilian pampa biome: a composite index to integrate beef production, social equity, and ecosystem conservation. *Ecol. Indic.* 98, 317–326. <https://doi.org/10.1016/j.ecolind.2018.10.012>.
- Food and Agriculture Organization of the United Nations (FAO), 2021. Brazil. <http://www.fao.org/countryprofiles/index/en/?iso3=BRA> (accessed 12 June 2021).
- Global Panel, 2021. Covid-19: safeguarding food systems and promoting healthy diets. <https://www.glopan.org/resources-documents/covid-19/> (accessed 24 May 2021).
- Gianezini, M., Barcellos, J.O.J., Ruviano, C.F., Oliveira, T.E., Dewes, H., 2014. Sustainability and market orientation in the Brazilian beef chain. *Journal of Agricultural Science and Technology* 4, 249–260. <https://doi.org/10.17265/2161-6264/2014.04B.001>.
- González-Quintero, R., Bolívar-Vergara, D.M., Chirinda, N., Arango, J., Pantevez, H., Barahona-Rosales, R., Sánchez-Pinzón, M.S., 2021. Environmental impact of primary beef production chain in Colombia: carbon footprint, non-renewable energy and land use using life cycle assessment. *Sci. Total Environ.* 773, 145573 <https://doi.org/10.1016/j.scitotenv.2021.145573>.
- Gordon, A.V., 2020. Matrix purpose in scenario planning: implications of congruence with scenario project purpose. *Futures* 115, 102479. <https://doi.org/10.1016/j.futures.2019.102479>.
- Grasso, A.C., Hung, Y., Olthof, M.R., Brouwer, I.A., Verbeke, W., 2021. Understanding meat consumption in later life: a segmentation of older consumers in the EU. *Food Qual. Prefer.* 93, 104242 <https://doi.org/10.1016/j.foodqual.2021.104242>.
- Grisham, T., 2009. The Delphi technique: a method for testing complex and multifaceted topics. *Int. J. Manag. Projects Bus.* 2 (1), 112–130. <https://doi.org/10.1108/17538370910930545>.
- Hong, T.K., Shin, D.-M., Choi, J., Do, J.T., Sung, G.H., 2021. Current issues and technical advances in cultured meat production: a review. *Food Sci. Anim. Resour.* 41 (3), 355–372. <https://doi.org/10.5851/kosfa.2021.e14>.
- Hou, B., Wu, L., Chen, X., Zhu, D., Ying, Tsai, F.-S., 2019. Consumers' willingness to pay for foods with traceability information: ex-ante quality assurance or ex-post traceability? *Sustainability* 11 (5), 1464. <https://doi.org/10.3390/su11051464>.
- Hu, K., Liu, J., Li, B., Liu, L., Gharibzadeh, S.M.T., Su, Y., Jiang, Y., Tan, J., Wang, Y., Guo, Y., 2019. Global research trends in food safety in agriculture and industry from 1991 to 2018: a data-driven analysis. *Trends Food Sci. Technol.* 85, 262–276. <https://doi.org/10.1016/j.tifs.2019.01.011>.
- Jairath, G., Mal, G., Gopinath, D., Singh, B., 2021. A holistic approach to access the viability of cultured meat: a review. *Trends Food Sci. Technol.* 110, 700–710. <https://doi.org/10.1016/j.tifs.2021.02.024>.
- Jaurena, M., Durante, M., Devincenzi, T., Savian, J.V., Bendersky, D., Moojen, F.G., Pereira, M., Soca, P., Quadros, F.L.F., Nabinger, C., Carvalho, P.C.F., Lattanzi, F.A., 2021. Native grasslands at the core: a new paradigm of intensification for the Campos of southern South America to increase economic and environmental sustainability. *Front. Sustain. Food Syst.* 5, 1–15. <https://doi.org/10.3389/fsufs.2021.547834>.
- Joyce, J., 2019. Bayes' theorem. In: Zalta, E.N. (Ed.), *The Stanford Encyclopedia of Philosophy*. <https://plato.stanford.edu/archives/spr2019/entries/bayes-theorem/>. accessed 28 January 2021.
- Kanashiro, M.I., Fraisse, C.W., 2015. Sustainability initiatives driving supply chain: climate governance on beef production system. *J. Technol. Manage. Innov.* 10 (1), 215–224. <https://doi.org/10.4067/S0718-27242015000100016>.
- Knoll, S., Marques, C.S.S., Liu, J., Zhong, F., Padula, A.D., Barcellos, J.O.B., 2017. The Sino-Brazilian beef supply chain: mapping and risk detection. *Br. Food J.* 119 (1), 164–180. <https://doi.org/10.1108/BFJ-07-2016-0346>.
- Landeta, J., 2006. Current validity of the Delphi method in social sciences. *Technol. Forecast. Soc. Change* 73 (5), 467–482. <https://doi.org/10.1016/j.techfore.2005.09.002>.
- Liang, C., MacDonald, J.D., Desjardins, R., McConkey, B.G., Beauchemin, K., Flemming, C., Cerkowniak, D., Blondel, A., 2020. Beef cattle production impacts soil organic carbon storage. *Science of the Total Environment* 718, 137273. <https://doi.org/10.1016/j.scitotenv.2020.137273>.
- Linstone, H.A., Turoff, M., 2002. *The Delphi method: techniques and applications*. Addison Wesley Newark, New Jersey Institute of Technology.
- Lomas, E., McLeod, J., 2020. Engaging with change: information and communication technology professionals' perspectives on change at the mid-point in the UK/EU Brexit process. *PLoS ONE* 15 (1), e0227089. <https://doi.org/10.1371/journal.pone.0227089>.
- Lovarelli, D., Bacenetti, J., Guarino, M., 2020. A review on dairy cattle farming: is precision livestock farming the compromise for an environmental, economic and social sustainable production? *J. Clean. Prod.* 262, 121409 <https://doi.org/10.1016/j.jclepro.2020.121409>.
- Magnier, L., Schoormans, J., Mugge, R., 2016. Judging a product by its cover: packaging sustainability and perceptions of quality in food products. *Food Qual. Prefer.* 53, 132–142. <https://doi.org/10.1016/j.foodqual.2016.06.006>.
- Manojkrishnan, C.G., Aravind, M., 2020. Covid-19 pandemic and its impact on labor force: a new model based on social stress theory and prospect theory. *Sci. Papers Univ. Pardubice* 28 (3), 1070. <https://doi.org/10.46585/sp28031070>.
- Marta Júnior, G.B., Alves, E.R., Contini, E., 2011. Pecuária brasileira e a economia dos recursos naturais. Embrapa, Brasília. <https://ainfo.cnptia.embrapa.br/digital/bitstream/item/1151530/1/PecuariaBrasileira.pdf>. accessed 28 February 2021.
- McManus, C., Barcellos, J.O.J., Formenton, B.K., Hermuche, P.M., Carvalho, O.A., Guimarães, R., Gianezini, M., Dias, E.A., Lampert, V.N., Zago, D., Braccini Neto, J., 2016. Dynamics of cattle production in Brazil. *PLoS ONE* 11 (1), e0147138. <https://doi.org/10.1371/journal.pone.0147138>.
- Menezes, T., Luna, L., Miranda, S.H.G., 2020. Network analysis of cattle movement in Mato Grosso do Sul (Brazil) and implications of foot-and-mouth disease. *Front. Vet. Sci.* 7 (219), 1–17. <https://doi.org/10.3389/fvets.2020.00219>.
- Navarrete-Molina, C., Meza-Herrera, C.A., Herrera-Machuca, M.A., Lopez-Villalobos, N., Lopez-Santos, A., Veliz-Deras, F.G., 2019. To beef or not to beef: unveiling the economic environmental impact generated by the intensive beef cattle industry in an arid region. *J. Clean. Prod.* 231, 1027–1035. <https://doi.org/10.1016/j.jclepro.2019.05.267>.
- Nunes, A.V., Peres, C.A., Constantino, P.A.L., Santos, B.A., Fischer, E., 2019. Irreplaceable socioeconomic value of wild meat extraction to local food security in rural Amazonia. *Biol. Conserv.* 236, 171–179. <https://doi.org/10.1016/j.biocon.2019.05.010>.
- Panea, B., Ripoll, G., 2020. Quality and safety of meat products. *Foods* 9 (6), 803. <https://doi.org/10.3390/foods9060803>.
- Payen, S., Falconer, S., Carlson, B., Yang, W., Ledgard, S., 2020. Eutrophication and climate change impacts of a case study of New Zealand beef to the European market. *Sci. Total Environ.* 710, 136120 <https://doi.org/10.1016/j.scitotenv.2019.136120>.
- Pelicano, S.F., Capdeville, T.G., 2021. *Tecnologias poupa-terra*. Embrapa, Brasília.
- Pivoto, D., Barham, B., Waquil, P.D., Foguesatto, C.R., Dalla Corte, V.F., Zhang, D., Talamini, E., 2019. Factors influencing the adoption of smart farming by Brazilian grain farmers. *Int. Food Agribus. Manage. Rev.* 22 (4), 571–588. <https://doi.org/10.22434/IFAMR2018.0086>.

- Pivoto, D., Waquil, P.D., Talamini, E., Finocchio, C.P.S., Dalla Corte, V.F., Mores, G.V., 2018. Scientific development of smart farming technologies and their application in Brazil. *Inf. Process. Agric.* 5 (1), 21–32. <https://doi.org/10.1016/j.inpa.2017.12.002>.
- Queiroz, R.G., Domingues, C.H.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), e0202062. <https://doi.org/10.1371/journal.pone.0202062>.
- Raut, R.D., Yadav, V.S., Cheikhrouhou, N., Narwane, V.S., Narkhede, B.E., 2021. Big data analytics: implementation challenges in Indian manufacturing supply chains. *Comput. Ind.* 125, 103368. <https://doi.org/10.1016/j.compind.2020.103368>.
- Rikkonen, P., Aakkula, J., Kaivo-Oja, J., 2006. How can future long-term changes in finish agriculture and agricultural policy be faced? Defining strategic agendas on the basis of a Delphi study. *Eur. Plan. Stud.* 14 (2), 147–167. <https://doi.org/10.1080/09654310500417962>.
- Riley, J.M., Peel, D.S., Raper, K.C., Hurt, C., 2019. Economic consequences of beef cow-calf disease mismanagement: bovine viral diarrhoea virus. *Appl. Anim. Sci.* 35 (6), 606–614. <https://doi.org/10.15232/aas.2019-01861>.
- Robles, R., 2010. Integrating extensive beef production into the agro-food chain. *Acta Agric. Scand.* 7 (2–4), 69–81. <https://doi.org/10.1080/16507541.2010.531936>.
- Rowe, G., Wright, G., 1999. The Delphi technique as a forecasting tool: issues and analysis. *Int. J. Forecast.* 15 (4), 353–375. [https://doi.org/10.1016/S0169-2070\(99\)00018-7](https://doi.org/10.1016/S0169-2070(99)00018-7).
- Ruviaro, C.F., Léis, C.M., Lampert, V.N., Barcellos, J.O.J., Dewes, H., 2015. Carbon footprint in different beef production systems on a southern Brazilian farm: a case study. *J. Clean. Prod.* 96, 435–443. <https://doi.org/10.1016/j.jclepro.2014.01.037>.
- Savell, J.W., Cross, H.R., Francis, J.J., Wise, J.W., Hale, D.S., Wilkes, D.L., Smith, G.C., 1989. National consumer retail beef study: interaction of trim level, price and grade on consumer acceptance of beef steaks and roasts. *J. Food Qual.* 12 (4), 251–274. <https://doi.org/10.1111/j.1745-4557.1989.tb00328.x>.
- Sobrosa Neto, R.C., Berchin, I.L., Magtoto, M., Berchin, S., Xavier, W.G., Guerra, J.B.S.O.A., 2018. An integrative approach for the water-energy-food nexus in beef cattle production: a simulation of the proposed model to Brazil. *Journal of Cleaner Production* 204, 1108–1123. <https://doi.org/10.1016/j.jclepro.2018.08.200>.
- Tarantola, M., Biasato, I., Biasibetti, E., Biagini, D., Capra, P., Guarda, F., Leporati, M., Malfatto, V., Cavallarin, L., Miniscalco, B., Mioletti, S., Vincenti, M., Gastaldo, A., Capucchio, M.T., 2020. Beef cattle welfare assessment: use of resource and animal-based indicators, blood parameters and hair 20 $\beta$ -dihydrocortisol. *Ital. J. Anim. Sci.* 19 (1), 341–350. <https://doi.org/10.1080/1828051X.2020.1743783>.
- Tavanti, R.F.R., Montanari, R., Panosso, A.R., Scala, N., Chiquitelli Neto, M., Freddi, O.S., González, A.P., Carvalho, M.A.C., Soares, M.B., Tavanti, T.R., Galindo, F.S., 2020. What is the impact of pasture reform on organic carbon compartments and CO<sub>2</sub> emissions in the Brazilian Cerrado? *Catena* 194, 104702. <https://doi.org/10.1016/j.catena.2020.104702>.
- Vale, P., Gibbs, H., Vale, R., Christie, M., Florence, E., Munger, J., Sabaini, D., 2019. The expansion of intensive beef farming to the Brazilian Amazon. *Glob. Environ. Change* 57, 101922. <https://doi.org/10.1016/j.gloenvcha.2019.05.006>.
- Vilpoux, O.F., Gonzaga, J.F., Pereira, M.W.G., 2021. Agrarian reform in the Brazilian Midwest: difficulties of modernization via conventional or organic production systems. *Land Use Policy* 103, 105327. <https://doi.org/10.1016/j.landusepol.2021.105327>.
- Vreys, K., Lizin, S., van Dael, M., Tharakan, J., Malina, R., 2019. Exploring the future of carbon capture and utilisation by combining an international Delphi study with local scenario development. *Resour. Conserv. Recycl.* 146, 484–501. <https://doi.org/10.1016/j.resconrec.2019.01.027>.
- Wetlesen, M.S., Åby, B.A., Vangen, O., Aass, L., 2020. Simulations of feed intake, production output, and economic result within extensive and intensive suckler cow beef production systems. *Livest. Sci.* 241, 104229. <https://doi.org/10.1016/j.livsci.2020.104229>.
- Winckler, C., 2019. Assessing animal welfare at the farm level: do we care sufficiently about the individual? *Anim. Welf.* 28 (1), 77–82. <https://doi.org/10.7120/09627286.28.1.077>.
- Food and Agriculture Organization of the United Nations (FAO), 2017. The future of food and agriculture: trends and challenges. <http://www.fao.org/3/i6583e/i6583e.pdf> (accessed 25 March 2021).