



Swine production in Brazil and worldwide: A general overview

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Abstract

The production of pigs plays a crucial role in global agriculture, providing a vital source of animal protein for human consumption. However, the expansion of pig farming poses significant environmental concerns. Thus, promoting sustainable practices in pig production is imperative to ensure economic efficiency, environmental protection, and animal welfare. In this context, we delve into various aspects of sustainable pig farming, ranging from waste management to water resource conservation. Our aim is to offer guidance and recommendations for more responsible and environmentally conscious pig production.

Furthermore, we explore diverse facets related to sustainable pig production, including the significance of environmental education, responsible agricultural practices, and their environmental impacts. Topics such as waste management, water resource conservation, animal welfare, and community engagement are addressed. Through this review, we seek to raise awareness about the importance of sustainable pig farming, identify challenges and opportunities, and provide actionable guidance for the adoption of responsible agricultural practices in pig production.

Keywords: Sustainability, pig farming, livestock

Introduction

According to Otoni *et al*, 2013 ^[1], the domestication of pigs has its roots since the Neolithic period, which began around 10,000 BC. During this period, the first evidence of coexistence between pigs and humans began to emerge. Ancient peoples quickly recognized the advantages of raising pigs to obtain meat, skin, and other resources. Pig domestication began over 10,000 years ago, according to archaeological evidence. Pigs have been raised by many ancient civilizations, including the Egyptians, Greeks, and Romans (Ensminger, 1990) ^[10].

The selection and breeding of specific breeds of pigs likely began to become more prominent during ancient times, as human populations expanded, and the needs of animal production became more complex. Civilizations such as the Greeks and Romans showed interest and skill in the selective breeding of pigs to meet various needs. Over the centuries, different regions of the world developed their own breeds of pigs, adapted to local conditions and specific production requirements (Larson *et al.*, 2014) ^[22]. This has led to the diversity of pig breeds that we see today, each with its own distinct characteristics, resulting from centuries of interaction between humans and pigs.

According to the list of the Food and Agriculture Organization of the United Nations there are various pig breeds existing in the world, each with its own distinct characteristics. Some examples of pig breeds include the Large White, Duroc, Hampshire, Landrace, Pietran and Yorkshire. Each breed may differ in terms of size, color, temperament, breeding abilities, and adaptation to different environments. Selective breeding over the years has led to the development of specialized breeds, some focused on meat production, others on bacon production, and some on adaptability to different climatic conditions. This diversity of pig breeds reflects a long history of interaction between humans and these highly adaptable animals.

The world population of pigs varies over time due to various factors, including market demand, animal health issues, and government policies. However, to provide you with a recent estimate, the global pig population in 2022 was approximately 1 billion animals, according to data from the Food and Agriculture Organization of the United Nations (FAO). It is important to note that this number may vary across different sources and over time. According to the FAO (2021), the 10 countries with the largest pig populations (Table 1):

Table 1: The countries with the largest pig populations on the worlds

Total Beginning Stocks	2020	2021	2022	2023 (Jan)	2024(Jan)
Brazil	37850.0	37350.0	35688.0	34250.0	32900.0
Canada	14065.0	14120.0	14170.0	13920.0	13037.0
China	310410.0	406500.0	449220.0	452560.0	423600.0
European Union	143146.0	145911.0	141681.0	134410.0	133875.0
Japan	9090.0	9290.0	8949.0	8956.0	9040.0
Korea South	11280.0	11078.0	11217.0	11124.0	11028.0
Mexico	11050.0	11500.0	11775.0	12250.0	12560.0
United Kingdom	4741.0	4828.0	5100.0	4650.0	4050.0
United States	77323.0	77022.0	74606.0	74956.0	74971.0
Others	30890.0	31730.0	31918.0	31140.0	31900.0
Total	649845.0	749329.0	784324.0	778216.0	746961.0

Source: USDA. Modified by Souza, C.F.

Rostagno, (2020) ^[35] affirms that the swine industry is an essential economic activity in Brazil, playing a vital role in food production, job creation, and economic development in various regions of the country. With a long tradition in pig farming and extensive favorable territorial conditions for this practice, Brazil has emerged as one of the world's leading producers and exporters of pork. According to the Brazilian Swine Breeders Association (ABCS) and the Brazilian Institute of Geography and Statistics (IBGE), the main Brazilian states producing pork in Brazil are: Santa Catarina, Rio Grande do Sul, Paraná, Minas Gerais, and São Paulo.

According to Embrapa Swine and Poultry, (2024) ^[9] Brazil has 2,067,749 matrices housed 4,983 million tons produced [4th place in the world]; 5.99% increase in national production [compared to 2021]. Production destination: domestic market 78%, export 22% 1,120 million tons exported [4th place worldwide] 1.49% drop in exports [compared to 2021] consumption of 18 kg of meat per capita.

Practices of animal welfare in pig farming

Dias *et al.* (2014) ^[14] and Mejdell & Rutherford (2019) ^[27] reported the importance of Animal Welfare in Animal Agriculture, Husbandry, Stewardship, and Sustainability in Animal Production. For the authors, the animal welfare plays a important role in pig farming, as it affects not only the health and happiness of pigs but also productivity efficiency and meat quality (Figure 1).



Fig 1: Piglets play with an old tire and plastic bag on the barn.

Animal welfare is an essential aspect of pig farming, impacting various facets of the industry. Ensuring good welfare practices not only promotes ethical treatment of animals but also has significant implications for productivity, product quality, and public perception. In summary, prioritizing animal welfare in pig farming is essential for enhancing productivity, ensuring product quality, meeting consumer expectations, complying with regulations, and upholding ethical principles. By adopting welfare-focused practices, pig farmers can create a more sustainable and socially responsible industry while also reaping economic benefits.

- 1. Productive Performance:** Pigs subjected to stress or discomfort conditions may show inferior productive performance, including reduced weight gain, compromised feed conversion rate, and increased susceptibility to diseases. This can result in lower productivity and profitability for producers. By the way, High levels of animal welfare can lead to better productivity in pig farming. Content and comfortable pigs are likely to exhibit healthier growth rates, lower stress levels, and reduced susceptibility to diseases. This ultimately translates to improved efficiency and profitability for farmers. For the producer of futures have expectations the use high technology and good welfare to the animals. This way, they will achieve high productivity, quality products, minimizing animal production stress - an excellent animal welfare activity (Roe *et al.*, 2011) ^[33].
- 2. Meat Quality:** Animal welfare can directly influence the quality of pork products. Stressed or unhealthy pigs may produce meat of inferior quality, with potential implications for taste, texture, and nutritional value. By prioritizing animal welfare, farmers can enhance the overall quality and reputation of their products in the market. Stress and suffering of pigs can affect meat quality, including characteristics such as color, texture, juiciness, and flavor. Pigs experiencing good welfare tend to produce better-quality meat, which is more valued by consumers.
- 3. Animal Health:** Pig welfare is directly related to their health and resistance to diseases. Pigs kept under stress conditions have compromised immune systems and are more susceptible to infections and illnesses, which can increase veterinary treatment costs and reduce overall herd health.
- 4. Industry Image:** Concerns about animal welfare are

growing among consumers, which means that inadequate handling and welfare practices can have a negative impact on the image and reputation of the pig industry. This can lead to a loss of consumer trust and potentially affect sales and profitability.

5. **Public Perception and Consumer Demand:** Consumer awareness and concern for animal welfare are on the rise, leading to increased scrutiny of farming practices. Adhering to high welfare standards not only meets regulatory requirements but also aligns with consumer expectations. Pig farms that prioritize animal welfare are more likely to gain consumer trust and loyalty, ultimately driving demand for their products.
6. **Regulatory Compliance:** Many countries have established regulations and standards governing animal welfare in farming operations. Compliance with these regulations is not only a legal requirement but also essential for maintaining the social license to operate. Failure to meet welfare standards can result in reputational damage, legal consequences, and market exclusion.
7. **Ethical Considerations:** Beyond economic and practical considerations, ensuring good animal welfare is a moral obligation for pig farmers. Treating pigs with respect and compassion reflects ethical values and contributes to a more humane society.

Improving animal welfare in pig farming is essential for ethical, social, legal, economic, and environmental reasons. By prioritizing the well-being of pigs, farmers can build a more sustainable and responsible industry that benefits animals, consumers, and society as a whole.

By implementing these strategies and prioritizing the welfare of pigs, you can contribute to creating a more humane and sustainable pig farming industry.

Some procedures is important, for example

- **Adequate Environment:** Providing a comfortable and enriched environment for pigs, with sufficient space to move around, comfortable resting areas, access to clean and fresh water, and proper temperature and ventilation control.
- **Proper Handling:** Adopting careful and respectful handling practices, including gentle animal handling, safe transportation, and group management strategies that minimize stress and aggression among pigs.
- **Balanced Nutrition:** Offering a nutritionally balanced diet tailored to the needs of pigs, ensuring they receive all essential nutrients for healthy growth and proper development.

These practices not only benefit the welfare of pigs but also contribute to sustainable and ethical pig farming practices, enhancing the overall quality of the industry.

Certifications and Animal Welfare Programs: Participate in animal welfare certifications and adhere to good production practice programs that establish standards and guidelines to ensure the welfare of pigs throughout the entire production chain.

Education and Training: Ensure that farm staff are

properly trained in animal handling and welfare. Provide ongoing education on best practices, including how to recognize signs of distress and illness in pigs.

Environmental Enrichment: Enhance the pigs' living environment by providing enrichment items such as straw, toys, and structures for exploration and stimulation. Enrichment encourages natural behaviors and reduces boredom and stress.

Housing Improvements: Evaluate and upgrade housing facilities to provide adequate space, ventilation, and comfort for pigs. Consider options such as group housing, bedding materials, and temperature control systems to optimize welfare conditions.

Health Management: Implement rigorous health management protocols to prevent and control diseases. This includes vaccination programs, regular veterinary checks, and prompt treatment of sick or injured animals.

Handling and Transport: Minimize stress during handling and transport by using low stress handling techniques and providing appropriate facilities and equipment. Plan transportation routes to minimize travel time and ensure comfortable conditions for pigs during transit.

Monitoring and Evaluation: Regularly monitor and assess the welfare of pigs on the farm. Use indicators such as body condition, behavior, and health status to identify areas for improvement and track progress over time.

Continuous Improvement: Foster a culture of continuous improvement by soliciting feedback from farm staff, veterinarians, and other stakeholders. Stay informed about advancements in animal welfare science and technology, and be open to adopting new practices and technologies that enhance pig welfare.

Economic Importance

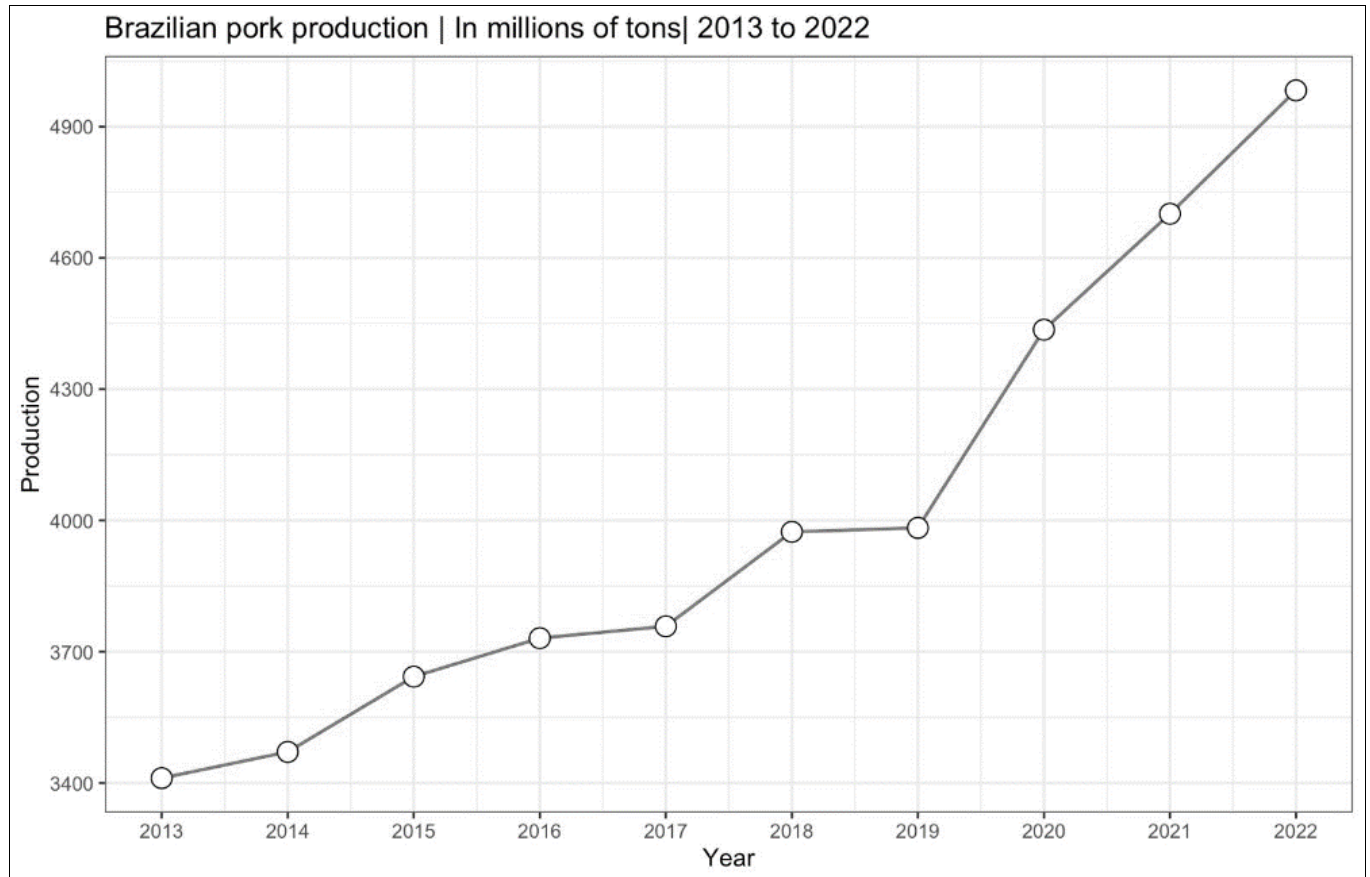
Brazilian pig farming significantly contributes to the national economy, generating thousands of direct and indirect jobs in all stages of the production chain, from feed production to meat processing and distribution. Additionally, pork and its derivatives' exportation are an essential source of foreign exchange for the country, contributing to Brazil's positive balance of trade (IBGE, 2023) ^[20].

According to Rodrigues, (2020), Brazil has emerged as one of the main producers and exporters of pork in the world. The quality of the meat, competitiveness in production costs, and logistical efficiency have contributed to the success of Brazilian pork exports to international markets.

Brazil is a significant player in the global pork production landscape, boasting a thriving industry that contributes substantially to the country's economy and food security (Figure 2). With its vast landmass, favorable climate, and abundant natural resources, Brazil has emerged as one of the world's leading pork producers. In recent years, Brazil's pork production has experienced steady growth, fueled by increasing domestic demand and expanding export markets. According to data from the Brazilian Association of Animal

Protein (ABPA, 2024), Brazil produced approximately X million tons of pork in [latest year available], cementing its position as one of the top pork-producing countries globally IBGE, (2024) ^[20]. Driven by technological advancements, efficient production practices, and a competitive advantage in feed grain production, Brazil's pork industry continues to thrive. The country's pork exports have also seen significant growth, with Brazil exporting approximately 10 million tons of pork products to various international markets FAO,

(2024a). Despite facing challenges such as fluctuating feed prices, disease outbreaks, and environmental concerns, Brazil's pork industry remains resilient and poised for further expansion. With a strong commitment to sustainability, animal welfare, and quality assurance, Brazilian pork producers are well-positioned to meet the growing global demand for high-quality pork products (FAO, 2022).



Source: Embrapa Aves e suínos, (2024) ^[9] modified by Souza, C.F.

Fig 2: Brazilian pork production from 2013 to 2022 [Million tons]

The outlook for the swine sector in 2024 appears promising, driven by potential increases in domestic consumption and exports coupled with anticipated reductions in production costs compared to previous years. The Center for Advanced Studies on Applied Economics (CEPEA) forecasts suggest that domestic demand for pork meat may remain robust, with an expected 2.8% increase in consumption compared to 2023. Furthermore, the swine industry anticipates that the export performance achieved in 2023 will continue into the current year. With Brazilian exports totaling 1.1 million tons from January to November of the previous year, there is a possibility of surpassing the record set in 2021, which stood at 1.12 million tons. Renewed agreements between the Brazilian Association of Animal Protein (ABPA) and ApexBrasil, extending until 2025, aim to bolster meat exports, including pork. Despite an 11% decrease in exports to China from 2022 to 2023, due to increased cases of African Swine Fever (ASF) in Europe redirecting demand to Brazil, shipments to China are expected to remain steady in 2024. This trend is reinforced by projections indicating a

1.6% decline in pork meat production within the European Union for the same year. To meet both domestic and international demands for fresh and processed products, Cepea estimates a potential 3.3% increase in the number of animals slaughtered from 2023 to 2024, reaching 59.1 million animals (CEPEA, 2024) ^[6].

Environmental impacts of pig farming

The growth of pig farming raises environmental concerns, especially regarding waste management and greenhouse gas emissions. However, producers are adopting more sustainable practices, such as waste recycling, effluent treatment, and biogas production from waste.

Sustainability has become a priority for modern pig farming, with a growing focus on reducing environmental impact, conserving natural resources, animal welfare, and social responsibility. Consumers are increasingly aware of food origins and seek products produced sustainably.

Sustainable livestock production systems encompass a multifaceted approach aimed at ensuring the long-term

viability and resilience of the livestock sector. Key strategies include the development of livestock master plans to guide investments and policies, fostering improved feeding systems by expanding feed resources and promoting feed safety, and encouraging the adoption of animal welfare practices. Additionally, efforts are directed towards reducing antimicrobial usage, implementing animal identification and traceability systems, and supporting value-chain development and livestock breeding programs through farmer field schools (FAO, 2024b).

Livestock, climate change, and natural resource use are central considerations in sustainable development initiatives. Measures include integrating livestock into agroecosystems to enhance ecosystem services and evaluating the effectiveness of agroecological systems. Addressing climate change impacts on livestock, reducing the environmental footprint of livestock supply chains, and assessing the greenhouse gas emissions associated with projects and investments are essential components of sustainable livestock management. Through these concerted efforts, the livestock sector can contribute to environmental sustainability while promoting economic viability and social well-being (FAO, 2024b).

The growth of pig farming presents a series of opportunities and challenges, ranging from improving meat quality to mitigating environmental impacts. It is essential for producers and the industry to work together to ensure sustainable and responsible growth, meeting consumer demands for high-quality pork produced ethically and environmentally consciously. The future of pig farming will be characterized by innovation, efficiency, and a commitment to sustainability.

Pig production systems and environmental conservation are interconnected in various ways, and it is essential to find a balance between efficient pork production and environmental protection. Here are some important considerations on how pig production systems can be adapted to promote environmental conservation:

Waste Management: One of the main environmental challenges associated with pig farming is proper waste management, including manure and effluents. Strategies such as composting, anaerobic digestion for biogas production, and waste treatment systems can help minimize environmental impacts by reducing soil and water pollution.

Efficient Resource Use: Pig producers can adopt practices that promote efficient use of natural resources such as water and energy. This may include implementing efficient irrigation systems, utilizing renewable energy sources such as solar or wind power, and optimizing the use of inputs such as feed and fertilizers.

Biodiversity Conservation: Pig production systems can be designed to minimize impact on local ecosystems and promote biodiversity conservation. This can be achieved through preserving natural areas, implementing sustainable land management practices, and protecting natural habitats.

Environmental Certifications: Environmental certification programs, such as Global GAP (Good Agricultural Practice), can help producers implement sustainable

practices in their operations. These certifications encourage the adoption of environmental and animal welfare standards, providing consumers with assurance that pork has been produced responsibly (FAO/WHO, 2014, Leong, 2020) ^[14]. In summary, it is possible to integrate environmental conservation into pig production systems through the adoption of sustainable practices that minimize environmental impact and promote responsible use of natural resources. By adopting a holistic approach that considers both the economic and environmental aspects of pork production, producers can contribute to building a more sustainable and resilient sector.

Minimizing impacts with maximum productivity

Feed efficiency plays a pivotal role in the success of pig production, influencing both profitability and sustainability. The interplay between genetics, pig nutrition, and feeding management significantly impacts how efficiently pigs convert feed into body weight. Understanding these factors is essential for achieving sustainable and profitable production practices. To maximize productivity while minimizing environmental impact, it's crucial to identify and implement practical strategies to improve feed efficiency. By enhancing feed efficiency, pig producers can realize several key benefits. Firstly, there are significant cost savings associated with reduced feed consumption. Since feed represents a substantial portion of total production costs in pig farming, improving feed efficiency means pigs require fewer resources to reach market weight, resulting in lower feed costs and increased profit margins. Moreover, enhanced feed efficiency translates into increased productivity. Pigs that efficiently convert feed into body weight grow faster and reach market weight sooner, thereby shortening the production cycle. This acceleration allows farmers to raise and sell more pigs within a given timeframe, optimizing production capacity and overall productivity. Additionally, improving feed efficiency contributes to sustainability by reducing feed wastage and minimizing the environmental footprint of pig production. With fewer nutrients excreted in manure, there's a decreased risk of environmental pollution, promoting responsible agricultural practices and long-term sustainability (Rooney, 2023) ^[34].

Large pig farms can exert a considerable influence on water resources, particularly if not adequately managed. To mitigate potential impacts on springs, streams, and rivers while maximizing productivity, several measures must be considered. Firstly, effective waste management systems, such as composting, biodigesters, or treatment lagoon systems, are crucial for minimizing soil and water contamination from the substantial amount of waste produced by these farms. Additionally, implementing soil conservation practices like no-till farming, vegetation cover, and terrace construction can help control erosion and protect nearby water bodies. Proper animal nutrition management plays a vital role in reducing nutrient excretion, thus minimizing water pollution; balanced feed formulation and optimizing feed conversion efficiency are essential in this regard. Furthermore, liquid effluents from large pig farms should undergo proper treatment using systems like stabilization ponds, biological filters, or constructed wetlands to remove pollutants before discharge into the

environment. Regular monitoring of water quality in nearby water sources is essential to promptly identify and address any environmental concerns arising from pig farming activities.

Factors influencing feed efficiency in pigs are multifaceted, encompassing genetics, nutrition, and feeding management practices. Understanding and optimizing these factors are essential for enhancing production practices and improving overall efficiency within the pig industry.

Genetics plays a pivotal role in determining feed efficiency, influencing key metrics such as feed conversion ratio (FCR) and lean-to-fat ratio. Selective breeding programs can identify and propagate genetic lines with superior FCRs and leaner compositions, thereby promoting more efficient feed utilization. Meanwhile, nutrition significantly impacts feed efficiency by ensuring a well-balanced diet that meets pigs' specific nutrient requirements at different growth stages. Access to clean water is also crucial for maintaining optimal feed intake and nutrient utilization. Feeding management practices, such as providing adequate feed space and ensuring the appropriate physical form of the diet, further contribute to optimizing feed efficiency. Sufficient feed space and accessibility help prevent competition during feeding, ensuring all pigs have equal access to feed. Additionally, pelleted or extruded diets are preferred over mash diets due to their enhanced digestibility and reduced feed wastage. By addressing these factors comprehensively, pig producers can enhance feed efficiency, promote uniform growth, and ultimately improve productivity within their operations (Rooney, 2023)^[34].

Large pig farms have the opportunity to forge partnerships with governmental agencies, non-governmental organizations, and local communities to safeguard water resources. Through community engagement, environmental concerns can be identified and collaborative solutions devised to mitigate negative impacts. By integrating environmentally sustainable management practices with efforts to maximize productivity, these farms can reduce their footprint on springs, streams, and rivers, thereby safeguarding these crucial resources for both the environment and local communities.

Conclusion

In conclusion, the historical evolution and contemporary status of pig farming underscore its pivotal role in global agriculture and economy. From its ancient roots in human civilization to its modern-day prominence, pig farming has evolved into a sophisticated industry characterized by diverse breeds, advanced production techniques, and significant economic contributions. As evidenced by the data presented, countries like Brazil have emerged as key players in pork production, leveraging their natural resources, technological innovations, and strategic partnerships to meet domestic demand and capture international markets. Furthermore, the importance of prioritizing animal welfare in pig farming cannot be overstated. By ensuring the well-being of pigs, farmers not only uphold ethical standards but also enhance productivity, product quality, and industry reputation. Practices that promote animal welfare, such as providing a comfortable environment, proper nutrition, and humane handling, are integral to sustainable and responsible pig farming.

Moreover, certifications and programs that establish welfare standards and guidelines contribute to industry transparency and consumer trust. Looking ahead, the future of pig farming lies in continued innovation, sustainability, and adaptation to evolving market dynamics and consumer preferences. By embracing technological advancements, best practices in animal welfare, and environmental stewardship, pig producers can navigate challenges, seize opportunities, and contribute to a more resilient and socially responsible industry. Ultimately, the success of pig farming hinges on a balanced approach that prioritizes both economic prosperity and ethical stewardship, ensuring a sustainable and prosperous future for generations to come.

The outlook for the swine sector in 2024 is optimistic, driven by anticipated increases in domestic consumption and exports, along with expected reductions in production costs. Forecasts indicate robust domestic demand for pork meat, with a projected 2.8% consumption increase compared to 2023. Additionally, the industry anticipates continued export performance, potentially surpassing the record set in 2021. Renewed agreements between industry associations aim to bolster meat exports, including pork. Despite export declines to China in recent years, ongoing cases of African Swine Fever in Europe may redirect demand to Brazil, sustaining export levels. To meet demand, slaughter rates are estimated to increase by 3.3% from 2023 to 2024. Concurrently, environmental concerns associated with pig farming prompt sustainable practices adoption, including waste management, resource efficiency, and biodiversity conservation. The growth of pig farming presents both opportunities and challenges, necessitating a balance between productivity and environmental stewardship. Large pig farms can mitigate environmental impacts by collaborating with stakeholders and implementing sustainable practices. Effective waste management, erosion control measures, and proper effluent treatment are vital to minimize pollution risks.

Additionally, optimizing animal nutrition, utilizing efficient resource management, and adopting environmentally friendly certifications contribute to sustainability efforts. By integrating these practices, pig producers can foster a more sustainable and resilient sector, meeting consumer demands for responsibly produced pork while safeguarding natural resources. Ultimately, the future of pig farming lies in innovation, efficiency, and a steadfast commitment to environmental sustainability, ensuring the industry's long-term viability and social responsibility.

Conflict of interests

The authors declare no conflicts of interest.

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Competing Interests

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Author Contributions

Carolina Fregonesi de Souza: write and discussion; Robson

Carlos Antunes: write and discussion, adviser of the first author; Julio Cesar de Souza: write and discussion
All authors contributed to the study conception and design.

Data Availability

The datasets can be accessed by following the references.

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