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Indian Zebu breeds outperforming abroad: a story on the “pizza effect”

Abstract – Indian cattle breeds, such as Gir and Nellore, have been used extensively in breeding programs across various countries due to their exceptional adaptability, disease resistance, and resilience under harsh environmental conditions. Notably, the introduction of Indian Zebu cattle significantly enhanced milk and meat productivity in several South American countries. A prominent example is Brazil, where, over the past 35 years, Indian Zebu breeds underwent a substantial genetic improvement for dairy and beef production. In recent years, there has been a growing interest in India to re-import these genetically enhanced Zebu breeds from Brazil. This phenomenon exemplifies what is commonly referred to as the “pizza effect” – a cultural or biological element originating in one country, being significantly transformed abroad and, subsequently, reintroduced to its place of origin in an enhanced form. This article also explores the metaphorical “flavor and aroma” of an alternative to the pizza effect – India’s growing interest in incorporating exotic *Bos taurus* genetics as a strategy to enhance the dairy performance of its indigenous breeds, rather than relying solely on the reimportation of improved native germplasm.

Index terms: *Bos indicus*, animal breeding, introduced breeds, milk production.

Melhor desempenho de raças de zebu indianas no exterior: uma história sobre o “efeito pizza”

Resumo – Raças bovinas indianas, como Gir e Nelore, têm sido amplamente utilizadas em programas de melhoramento genético em vários países devido à sua excepcional adaptabilidade, resistência a doenças e resiliência em condições ambientais adversas. Notavelmente, a introdução do gado zebu indiano aumentou significativamente a produtividade de leite e carne em diversos países da América do Sul. Um exemplo proeminente é o Brasil, onde, nos últimos 35 anos, as raças zebus indianas passaram por melhoramento genético substancial para a produção de leite e carne. Nos últimos anos, tem havido um interesse crescente na Índia em reimportar essas raças zebus geneticamente melhoradas do Brasil. Esse fenômeno exemplifica o que é comumente chamado de “efeito pizza” – um elemento cultural ou biológico originado em um país, sendo significativamente transformado no exterior, e, posteriormente, reintroduzido em seu local de origem de forma aprimorada. Este artigo também explora o “sabor e aroma” metafóricos de uma alternativa ao efeito pizza – o crescente interesse da Índia em incorporar a genética exótica do *Bos taurus* como estratégia para melhorar o desempenho leiteiro de suas raças indígenas, em vez de depender somente da reimportação de germoplasma nativo aprimorado.

Termos para indexação: *Bos indicus*, criação animal, raças introduzidas, produção de leite.

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Introduction

In 1970, the Austrian professor of anthropology Agehananda Bharati coined the term "pizza effect" to refer to anthropological aspects of one nation that are routed to another, where they undergo changes, being later reintroduced to their place of origin in an evolved state or a new form (White, 1991).

An example of this anthropological phenomenon are the *Bos indicus* animals exported from India, which are selected and upgraded abroad and are currently re-imported by the country as high-milk yielding germplasm (Rodrigues et al., 2017). This seems to be an interesting alternative to importing exotic germplasm of *Bos taurus* from developed countries in order to increase the milk productivity of *Bos indicus* in India.

This illustrates how the livestock industry plays a critical role in agrarian economies as those of India, Brazil, Argentina, and some African nations (Landes et al., 2017). The Compound Annual Growth Rate of the Indian livestock sector increased in 13.36% between the 2014/2015 and 2021/2022 crop seasons, contributing in 5.73% to the gross added value of 2021/2022 (India, 2023b). In this scenario, India is considered the largest milk-producing country, covering ~24.64% of global production, followed by the United States, Pakistan, China, Brazil, Germany, Russia, France, Turkey, and New Zealand (Vonderschmidt et al., 2024). In India, the increase in total milk production was 58% in the 9 years from the 2014/2015 to the 2022/2023 crop season (India, 2023a), compared with the worldwide increase of 77% over 30 years, from 1992 to 2022 (Larson et al., 2022). In the 2022/2023 crop season, the average availability of milk per capita in India was 459 g per day (India, 2023a), in comparison with the world average of 322 g per day in 2022 (FAO, 2023).

Although a high milk production characterizes the India dairy sector, there is still room for improvement (Sarkar et al., 2024). The country's milk productivity is below that of 30 kg per day of the United States and of 22 kg per day of the United Kingdom (Mani & Beillard, 2021). In addition, the milk productivity in India using Zebu breeds is far behind that with crossbred cattle (Ghosh, 2019). In this scenario, the government of India has recently taken important steps to ameliorate livestock farming practices (Gowda et al., 2023), aiming to ensure that the farmers' income is doubled (Chand, 2023).

This article covers the scientific strategies and policies related to the improvement of cattle germplasm, considering the alternatives of importing germplasm of *Bos indicus* animals upgraded abroad or of exotic *Bos Taurus*, focusing on the breeds imported by Brazil and upgraded in the country, leading to the pizza effect.

Indian breeds imported by Brazil and other countries

For over more than 100 years, germplasm from undivided India has been exported to other countries (Pérez-Pardal et al., 2018). In Brazil, the first Indian cattle breeds were imported in the mid-19th century, when the main objective was to improve the rusticity of the cattle to produce milk and beef in harsh tropical areas (Medrado, 2018).

Brazilian cattle farming is based on the pastoral system, in which the following seven cattle breeds are currently carrying Indian Zebu blood: Gir (Gyr), Nellore (Ongole), Guzerá (Kankrej or Gujarat), Sindi (Red Sindhi), Tabapuã, Indubrasil, and Brahman. Taurine breeds, such as Curraleiro Pé-Duro and Pantaneiro, may also have genetic material from Indian Zebu (Felix et al., 2013; Kim et al., 2017). According to the literature, about 70% of the breeds producing milk in Brazil contain some level of Zebu genetics in their compositions (Miranda & Freitas, 2009).

The stories of the Nellore, Brahman, Gir, Guzerá, Sindhi, Tabapuã, and Indubrasil Zebu breeds are further discussed, including their potential after genetic improvement.

Nellore (Ongole) – The place of origin of this breed is the Prakasam District of Andhra Pradesh, India, specifically Ongole, which used to be a city of the Nellore District in the same state, explaining why the cattle are known as Ongole or Nellore (Reddy, 1925; Murari, 1956). In 1858, the British colonizers identified the potential of Nellore cattle during a show hosted by a collector to promote the breed among local breeders in Ongole (Pundir et al., 2006). In 1868, a couple of Nellore animals were taken to Salvador, the capital of the state of Bahia, in Northeastern Brazil, leading to the introduction of the Nellore herd book in the country in 1875 (Reddy, 1925; ACNB, 2025). In 1878, Dr. Manoel Lemgruber, a Brazilian of German heritage, brought another couple of Nellore animals to Brazil after seeing

the breed at a zoo in Hamburg, Germany (Lôbo, 2025). The Nellore adapted positively to a native African grass called "bread grass" [*Urochloa brizantha* (A.Rich.) R.D.Webster], which became a common feed for the breed as it was flourishing in several parts of Brazil, mainly in the states of Rio de Janeiro, São Paulo, and Minas Gerais (Lôbo, 2025). Currently, Nellore is the primary source of beef production in Brazil (Lôbo, 2025), where 9.72 million tonnes of beef were produced in 2014, only 13.89% less than in the United States, with 11.07 million tonnes (O'Donoghue et al., 2019; Zia et al., 2019); for comparison, in 1960, the difference was of 429% (Thornton, 2010). The Nellore breed has gained international importance due to its meat production potential (Nunes et al., 2024).

Brahman cattle – The Brahman breed in Brazil was developed from the Guzerá, Nellore, Gir, and Krishna Valley Indian cattle breeds, with some intermixture of British cattle (Porter et al., 2016; ABBA, 2025). Presently, Brahman cattle are also used in Australia, Malaysia, Argentina, and Paraguay for beef production (Frisch et al., 1987).

Gir (Gyr) – India has four dairy breeds: Sahiwal, Red-Sindhi, Gir, and Deoni. The Gir breed originated in the Gir forest region of the state of Gujarat, India (Breda et al., 2023). The breed is moderately large sized (350 to 550 kg), with a pure-red/yellowish-red to spotted-white color (Gaur et al., 2003). Average milk yield per lactation ranges from 1,590 to 2,400 kg, with 4.5% fat (Felius, 1995; Gaur et al., 2003). In the 18th century, the Maharaja of Bhavnagar gifted some Gir cows to Brazil, where they were preserved genetically (Shah, 2024). In recent years, the reported average milk yield per lactation of purebred Gir cows in Brazil was around 4,500 kg in 305 days (Costa et al., 2021; Hortolani et al., 2022); however, most milk production herds are composed of Gir and Holstein crossbred animals, which are called Girolando (Angelo et al., 2022). In 1938, Associação Brasileira dos Criadores de Zebu (ABCZ), the Brazilian Zebu breeders association, located in the municipality of Uberaba, in the state of Minas Gerais, recorded the Zebu breed for the first time, contributing to the regularization and dissemination of the Gir breed in Brazil; since then, more than 600,000 purebred Gir animals have been registered in ABCZ's herdbook (Santana Junior et al., 2014).

Guzerá (Kankrej or Gujarat) – The major use of this breed is for the production of beef and dairy products (Barbara & Pilling, 2007). The Guzerá cow has an excellent udder with strong ligaments, while the Guzerá bull is used as a Zebu alternative for crossbreeding (Carrara et al., 2023). From the early history of Zebu in Brazil, there has been an interbreeding between Guzerá and Holstein, known as the Guzolando breed (Porter et al., 2016).

Sindi (Sindhi) – This breed is popularly known as Malir or Red Karachi in India and Pakistan (Pundir et al., 2007). Sindi cattle have adapted well to the Northeastern region of Brazil, which is characterized by harsh environmental conditions, with high average temperatures and a very low precipitation (Mello et al., 2020). Selection in the herds was performed mostly for dairy traits in the Northeast, but for beef traits in the Southeast of the country (Panetto et al., 2017).

Tabapuã – The Tabapuã breed is a pooled Zebu breed used in Brazil for the production of beef (Caires et al., 2012; Bernandes et al., 2016). These crossbred animals were crossed with Nellore and, at a smaller extent, with Gir and Guzerá animals.

Indubrasil – Also called Induberaba in the 1930s, the Indubrasil breed was developed in Brazil by crossing Gir, Guzerá, and Nellore animals (Mason, 1996). Indubrasil is a tall crossbred with pendulous ears, its striking feature (Morales, 2009).

What made the Brazilian dairy industry flourish?

The Brazilian dairy sector has changed significantly over time. Until the early 1990s, the Brazilian Federal Government established a price-controlling policy, which caused investor reluctance (Farina et al., 2005), working against the development of the dairy sector. In the post-regulation period, a series of mergers and acquisitions took place, leading several farms and firms to go out of business (Farina, 2002; Farina et al., 2005; Carvalho, 2010). However, in spite of these occurrences, the dairy sector still accounted for the second-largest turnover of USD 22 billion in 2017 (Fonseca, 2018).

In the late 1990s and early 2000s, the expansion of the grain and livestock sectors and of the sugarcane industry, plus the growth of agribusiness exports, increased the competition for land use in Brazil

(Harvey & Pilgrim, 2011; Novo et al., 2012). This led to a sudden decrease in the number of operating dairy farms: in 1996, there were around 1.8 million dairy farms (IBGE, 1998), a number that dropped to 1.2 million in 2017 (IBGE, 2018). However, milk production reached 30.2 billion liters in 2017 (IBGE, 2018), a higher value than the 17.9 billion liters in 1996 (IBGE, 1998). Similarly, over the past 26 years, the number of dairy cows continued the same across the globe, while yield per cow experienced a sharp increase of 118% (McDonald et al., 2020). In Brazil, this was a result of the technological advancements in dairy production due to improvements in key areas such as genetics, reproduction, and forage, in addition to the inclusion of precision dairy farming (Silvi et al., 2021). With this amelioration, Brazilian milk production grew 125% from 1990 to 2016, which was much higher than the increase of 37.2% observed worldwide (FAO, 2023; Oliveira et al., 2024).

Other key points that have favored the expansion of the dairy agribusiness in Brazil include (Carvalho et al., 2015):

- a great potential demand for products and services, considering the country is the fifth largest in the world, with 210 million people;
- the growing consumption of dairy products in Brazil, with room for increase since the average consumption is much lower than that of developed countries;
- competitiveness in corn and soybean, which results in a favorable ratio between the milk price paid to the farmer and feed price;
- location of the country in the Southern Hemisphere, where the climate conditions allow to have pasture and forage throughout the year, which is not the case in the Northern Hemisphere countries; and
- availability of land and water resources.

For a continued growth of the dairy sector, an important step of the development process are breeding programs (Cole et al., 2023; National Dairy Development, 2025a). In 1985, the Brazilian Agricultural Research Corporation (Embrapa) and Associação Brasileira dos Criadores de Gir Leiteiro (ABCGIL), the Brazilian dairy Gir breeders association, launched Programa Nacional de Melhoramento do Gir Leiteiro (PNMGL), the national dairy Gir breeding program (Pereira et al., 2012) and the first Zebu breeding program in the world for milk-production improvement (Panetto et al., 2019). Breeding programs for the Guzerá and Girolando breeds followed in 1994 and 1997, respectively, allowing of better decisions in semen selection and herd improvement (Panetto et al., 2023).

Up to 2019, PNMGL, based on the progeny testing of bulls, proved 444 sires, which contributed to a major improvement of the Gir breed in Brazil (Panetto et al., 2019). In 2016, a genomic selection program was implemented for the selection of sires and dams within the program, in which the average milk yield of purebred Gir cows was around 4,500 kg, with 4.24% fat and 3.41% protein (Nayee et al., 2021). Because of these improvements, the Gir breed has attracted cattle breeders from South American (Canaza-Cayo et al., 2015; Pereira et al., 2019) and African countries, especially due to some unique features such as heat resistance and tolerance to several tropical diseases (Canaza-Cayo et al., 2015; Pereira et al., 2019). The breed was also crossed with Friesian cattle to improve milk production, resulting in the Girolando breed (Canaza-Cayo et al., 2015).

In 1997, the Girolando breed progeny test was carried out due to a partnership between Embrapa Dairy Cattle and Associação Brasileira dos Criadores de Girolando, the Brazilian Girolando breeders association; the latter was responsible for genealogical register and dairy control services, which led to this cooperation (Silva et al., 2021).

In 1997, Programa de Melhoramento Genético da Raça Girolando (PMGG), the genetic improvement program of the Girolando breed, was launched. The main objectives were the identification of genetically superior individuals, a technically oriented multiplication of genetics, the evaluation of economic traits, and the promotion of sustainable dairy activities (Daltro et al., 2021b). In order to accomplish these goals, the program presented a linear evaluation system to assess animal traits in order to improve selection (Biassus et al., 2011; Canaza-Cayo et al., 2016). The PMGG allowed increasing rates of Girolando semen production in Brazil, with more than 536,176 semen doses collected from Girolando sires in 2016, representing an increase of more than 43% when compared to 2013 (Silva et al., 2017).

The gain in milk yield during the first three lactations of Girolando cows is another important achievement of

PMGG. In 2000, the average milk yield of Girolando cows in a lactation period of 305 days was 3,703 kg, whereas, in 2015, it reached 5,663 kg, representing an increase of 53% (Silva et al., 2018). Girolando is currently considered the preferable dairy breed in tropical regions. In Brazil, for example, around 80% of the milk produced is from Girolando cows (Daltro et al., 2021a).

The "pizza effect"

Inspired by the Brazilian saga of breed improvement, Nellore farmers in India are now eager to use cutting-edge technologies (such as multiple ovulation and embryo transfer, as well as molecular marker-based animal selection) to breed and multiply the Nellore population in their country (Das & Mattoo, 2024). In addition, the extraordinary performances of Indian breeds in Brazil, where their milk yield and production were doubled (Hortolani et al., 2022; Carrara et al., 2023), have increased the interest of dairy farmers in Andhra Pradesh and Telangana in importing these upgraded germplasms and embryos (Shah, 2024), which is known as the "pizza effect".

Though the "pizza effect" may sound ironic, it is a way to ensure that milk production in India is increased using indigenous cattle germplasms, which requires drafting policies on the subject. The government of India and some Indian states have shouldered the responsibility. Delegates from Telangana and Andhra Pradesh, accompanied by the Indian Non-Governmental Organization Ankush, for example, attended the 82nd exposition of Zebu animals, held from April 30 to May 7, 2016, in the state of Minas Gerais, Brazil, gathering around 1,800 animals from nine different Zebu breeds (Pimenta, 2016). Mona Khandhar, the secretary of the Animal Husbandry Department of Gujarat, pointed out that the government of this state has sanctioned a project to import "scientifically selected" semen from the Gir and Kankrej breeds to increase their dwindling number through artificial insemination (Lalchandani, 2023). These are only a couple of examples of steps towards the formulation of policies to increase milk productivity in India.

Recent initiatives in India to improve milk production

On March 15, 1950, a Planning Commission was implemented in India (India, 2025e), aiming agricultural development through a five year-long plan (Zachariah, 2016). Some of the expected results included a gradual growth in the gross domestic product of India, crossbreeding of dairy animals to increase milk productivity and availability (Ojango et al., 2017; Osei-Amponsah et al., 2020), and improvement of the indigenous breeds through selective breeding (Landes et al., 2017). However, a mismatch was observed between plans and their execution (Patil, 2006). The government of India noticed an underdevelopment of various sectors in agriculture and in human resources, which led to the dismantlement of the Planning Commission in 2014 and to the establishment of National Institution for Transforming India (NITI Aayog) on January 1, 2015 (Mehrotra & Guichard, 2020). The primary goal of NITI Aayog was to attain sustainable development through a bottom-up approach, enhancing cooperative federalism by involving state governments in the formulation of economic policies. Reforms are sought through the implementation and monitoring of related plans, including the following initiatives:

- Adoption of a land-leasing model law that gives underprivileged tenant farmers access to benefits (such as farm credit, crop insurance, and compensation for crop damage) and protects the fundamental rights of landowners (Chandran, 2016).
- Reformation of the Agricultural Produce Marketing Committee Act, which was implemented in 2003, incorporating contract farming, flexibility of market norms, and the right to sell products in the market, but suffered malpractice and monopolization of intermediary and licensed traders (Bisen & Kumar, 2018; Nuthalapati et al., 2020; Kumar et al., 2023). In 2014, the National Agriculture Market, a virtual market model, adopted from the Rashtriya e-Market Services of the Karnataka State Agricultural Marketing Board, was launched with the idea to establish a pan-Indian marketing platform and to promote uniformity.

- Implementation of the Agricultural Marketing and Farmer Friendly Reforms Index rank, in which each state is assigned a score from 0 to 100 based on marketing and farmer-friendly reforms, taking into account a conducive environment for undertaking agri-business (Sekhar & Bhatt 2018; Yadav, 2018).
- Establishment of a task force to eliminate poverty through the modernization of agricultural practices, as well as to create a link between the center and state governments (NITI Aayog, 2017).
- Implementation of the National Dairy Plan Phase-I (NDP-I), with an allocation of 22.42 billion rupees (National Dairy Development, 2025b). On February 2012, NDP-I aimed to meet the national demand of 150 million tonnes of milk by 2016/2017. The plan initiatives included an increase in productivity, direct market access, improvement in village-level infrastructure for milk acquisition, herd genetic improvement, selection of bulls for semen collection, and adoption of biosecurity measures. The National Dairy Development Board executes the plan through agencies as state dairy cooperative federations, unions, and dairy agro-industries.
- Implementation of the National Livestock Mission, which was launched in 2014/2015 (Mitra et al., 2024). The objectives were the improvement of livestock production systems and the capacitation of stakeholders to support the expected improvements. Examples of implemented activities include: introduction of new feeding sources, exploration of exporting-market potential, productivity enhancement, entrepreneurship development, opening of new job posts, modernization of the infrastructure of state farms, introduction of automation and biosecurity protocols, preservation of threatened breeds, development of minor livestock, establishment of rural slaughterhouses, insurance of fallen animals and livestock, technology transfer from lab to land, and promotion of new technologies to be adopted by farmers.
- Implementation of the Pashudhan Sanjivani Nakul Swasthya Patra Scheme by the Minister of Agriculture (85 lakh milk production…, 2025; Pashudhan Sanjivani Nakul Swasthya Patra Scheme, 2025). This is a health care initiative to maintain livestock health, followed up by an identification system, called Unique Identity.
- Implementation of the Rashtriya Gokul Mission, launched in December 2014, through funding with 5.0 billion rupees (India, 2025d). The objective was the conservation and promotion of domestic species under the National Bovine Genetic and Dairy Development Program. For this, 14 villages in the city of Gokul were established, and 41 livestock zones were settled for the conservation of bull species (Adcock, 2019). This initiative is also responsible for giving away awards as the Best Field Vet Award, the Best AI-Technician Award, and the Gopal Ratna Award in order to promote advanced dairy farming practices.
- Establishment of the National Bovine Genetic Centre, devoted to the improvement of domestic species (Milanese et al., 2022).
- Implementation of the National Program for Dairy Development, which has already approved 14 projects in seven Indian states, using funds of more than 2.0 billion rupees (India, 2025c).
- Implementation of the Krishi Kalyan Abhiyan Scheme, an initiative carried out by the Ministry of Agriculture and Farmers' Welfare, launched in June 1, 2018 (India, 2018). The objective was to double farmers' income by 2022. Part of this initiative encompasses policies towards a complete vaccination coverage and the eradication of the foot and mouth disease and *peste des petits ruminants*.
- Launch of the E-Pashu Haat or the "e-livestock portal". This is a web portal hosted by the Ministry of Agriculture and Farmers' Welfare, which aims to organize the livestock market on a single and accessible platform. The portal shares information on bovine germplasms, buying and selling of bovines, and feed-fodder information, for example.

In addition to these initiatives, the government of India aims to establish an Infrastructure Development Fund, with a budget layout of 296.1 billion rupees (India, 2024a). These funds will be used to encourage the processing and diversification of dairy and meat products; the establishment of plants for the production of vaccines, drugs, and animal feed; the creation of programs for waste management; and the establishment of breed multiplication farms.

Entrepreneurs and start-ups venturing into these areas are eligible. The government of India will offer eight year-long loans with a 3% interest and a two-year loan-moratorium from specified banks (India, 2024b). The overall focus is dairy-sector modernization and capacity building to meet the targeted milk processing and clean milk production.

Other centralized initiatives coordinated by the government of India towards dairy production include the National Program for Bovine Breeding and Dairy Development (NPBBDD), the previously cited NDP-I, and the Dairy Entrepreneurship Development Scheme (India, 2025b). The NPBBDD is the result of the merge of the four following existing schemes: the Intensive Dairy Development Program, the Strengthening Infrastructure for Quality & Clean Milk Production, Assistant to Cooperatives, and the National Project for Cattle & Buffalo Breeding. The available budget reaches 18 billion rupees.

Importing dairy genetics to India: hope and hype

Keeping abreast with the Indian government, some state governments have taken appreciable initiatives. The Punjab government has proposed establishing an advanced dairy farming institute in Mohali, Punjab, in a joint venture with Israeli company Dairy Farming Solutions (Sudha, 2014). The goal was to support dairy farmers in Punjab and give them access to the latest technologies. Currently, there is a plan to use doses of frozen semen from top-ranking Brazilian Gir bulls in the states of Andhra Pradesh, Madhya Pradesh, West Bengal, and Maharashtra (India, 2025a). The Department of Animal Husbandry and Dairying of the government of India is in the process of importing Gir sex-sorted and un-sorted semen. The National Dairy Development Board of India, for example, has already imported 40,000 doses of frozen semen from genetically improved Indian breeds, intending to reach the annual milk production target of 330 million tonnes in a decade (Das & Mattoo, 2024). Over time, advanced artificial reproductive technologies will also be included to boost genetic gain among the Indian breeds in a short period.

Both India and Brazil collaborate in several platforms such as G-4, G-20, BRICS, and IBSA, which directly affect the import and export of livestock genetics (India, 2022). The Ministry of Agriculture, Livestock and Food Supply of Brazil and the Department of Animal Husbandry and Dairying of India are planning and executing trade agreements between the two nations. Brazil is now surpassing India in terms of genetic potential given the higher number of Gir cows (4.0 million vs. 2.3 million, respectively), a result of the genetic improvement program initiated in 1976 in the country (Milanese et al., 2022). In this context, the cattle breeding policies in India need to be (re)considered taking into account common issues such as lower female replacement rates and limited record keeping (Shah, 2024). In this line, a group of farmers from Saurashtra has questioned the use of imported genetics and its consequences to India.

To meet the high demand for milk in India, an alternative to the "pizza effect" is the importation of dairy genetics from Europe and especially the United States, considering how much this country's dairy sector has evolved. According to data of the National Agricultural Statistics Service (NASS) of United States Department of Agriculture (USDA, 2025), productivity increased nearly five times per animal, with milk yield in 2022 being 107% higher than in 1940, even though 60% fewer cows were used. In this era of carbon footprint and carbon credit system, it is paramount to decrease the headcount of cows and increase milk productivity (Salcedo Díaz et al., 2024).

In this scenario, some progressive farmers are proposing to import and maintain exotic purebreds such as Holstein and Jersey. In the dairy belt of the United States, Holstein cows are used to produce fresh milk, while the milk of Jersey cows is used to make cheese. Other popular dairy breeds in the country are Ayrshire, Brown Swiss, and Dairy Shorthorn. Although dairy farming is mostly a family business, it is characterized by mechanized animal control and by tracking of herd healthfulness and performance, with connections to other farmers in an information-sharing network (Nogueira & Hötzel, 2024). The Quick Stats site of NASS (USDA, 2025) shows that, in 2022, 9.4 million cows were maintained in 27,932 herds, each with an average of 337 animals. Milk yield in the United States was 10.9 thousand kilograms per cow, showing how much the dairy sector in India still has room to improve.

Final Considerations

In order to increase milk production in India, it is necessary to improve the production environment and the genetics of dairy herds. On the one hand, there is an urgent need to introduce milking automation, regular health monitoring, recurrent farm assessments, and proper recording in the country. On the other hand, the genetics of local animals needs to be addressed. One alternative is to bring back the improved germplasm from Brazil and other countries, which is known as the "pizza effect". Another alternative is to import *Bos taurus* genetics from North America and Europe. Either way, the replacement of cattle on farms is still necessary to ensure a higher increase in productivity over the years.

The emergence of new technologies and practices, as well as the importation of genetic material, requires linkages between stakeholders, farmers, and agents in the dairy chain. The private-public partnership may be a way to enable solutions in these areas.

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Research data not available because the current review article has not generated any data to make available.

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No generative artificial intelligence (AI) was used in this study.

Conflict of interest statement

The authors declare that there is no conflict of interest(s) between the authors.

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