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Contemporary trends in broiler meat production in North America: A literature review

Viktoriia Melnyk*
Doctor of Historical Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0003-2491-757X

Nataliia Prokopenko
Doctor of Agricultural Sciences, Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0001-7967-884X

Svitlana Bazyvoliak
PhD in Agricultural Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0003-1656-5754

Abstract. Global broiler meat production is increasing at a faster rate than any other type of meat. The United States is the largest producer of broiler meat worldwide. In 2022, the USA, together with Canada and Mexico, accounted for 20% of the total global broiler meat production. This study aimed to analyse and summarise the literature on contemporary trends in broiler chicken production technologies in the USA, Canada, and Mexico. The study employed methods of analysis, synthesis, and content analysis. It was found that among the North American countries, the USA ranks first in both the number of chickens and broiler meat production. Globally, in 2022, the total chicken population was 26,561,634.0 thousand birds. China held the first position (5,185,477.0 thousand birds), with the USA in fifth place (1,528,000.0 thousand birds), Mexico in eighth (611,202.0 thousand birds), and Canada in 29th (173,942.0 thousand birds). In the global

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*Corresponding author

rankings of broiler meat producers in 2022, the USA was first, Mexico seventh, and Canada 22nd. A consistent increase in broiler meat production was observed in North American countries over the period 2018-2022. In 2022, the USA produced 20,652,970.91 tonnes of broiler meat, Canada 1,332,967.57 tonnes, and Mexico 3,668,552.28 tonnes. The leading producers of meat products in the USA and across North America are Tyson Foods, Cargill, and Bell & Evans. The most common broiler breeds used in North American poultry farming are Cobb and Ross. A comparative analysis of the performance of the Cobb-500 and Cobb-700 breeds indicated that Cobb-500 broilers outperform in terms of live weight. Overall, Cobb-700 broilers exhibit slower growth rates, with a production cycle extending up to 63 days. The predominant production method involves raising broilers on litter-based floor systems. Researchers from South American universities are conducting various studies that address contemporary challenges in meat poultry production. These studies focus on issues such as housing, feeding, welfare, health, and carcass quality of broilers

Keywords: USA; Canada; Mexico; chickens meat; cross; live weight; feeding

Introduction

Over the past 50 years, the poultry industry worldwide has undergone rapid development, and the progress achieved has been substantial. Significant scientific advancements have focused on enhancing the understanding of poultry science, facilitating the rapid transition from backyard production to industrial-scale farming, reducing the cost of broiler meat, and addressing cultural and religious restrictions on chicken consumption (Siegel, 2023). T. Mcdougal (2022) highlights that poultry meat consumption has increased in nearly all countries and regions, driven by its relatively low price, desirable texture, and higher protein content compared to lower fat content. Global poultry meat consumption is projected to increase to 154 tonnes by 2031. This long-term shift towards poultry meat is expected to continue. In countries with middle and low-income populations, poultry meat has become a more affordable alternative to other meats. As a result, the availability of protein from poultry is projected to increase by 16% by 2031, accounting for 47% of protein consumed from meat sources, followed by pork, lamb, and beef. However, in high-income countries where per capita consumption is already high, demand is expected to level off or even decline, given ageing populations and a greater emphasis on diversified diets. The short-term shift in meat consumption from food service to home cooking, observed during the COVID-19 pandemic, is anticipated to be temporary, with consumers returning to their previous spending habits. Global meat supply will increase to meet growing demand, reaching 377 million tonnes by 2031. The global expansion of poultry farming means that, according to forecasts, the majority of the growth in meat production will come from China, followed by the USA, Brazil, and India.

Broiler production plays a pivotal role in meeting the global demand for poultry meat, which is essential to feed a continually growing population. In 2022, North American countries accounted for 20% of total broiler meat production. Scientific support for the broiler industry in North America is provided by researchers from the USA, Canada, and Mexico. They conduct research in various areas. For instance, J. Purswell *et al.* (2021) demonstrated that feeder size can influence broiler growth, especially during the early stages of rearing. J. Jespersen *et al.* (2024) determined the optimal levels of starch, oil, and amino acids in diets for broilers infected with coccidiosis. A. Myers & S. Rochell (2024) evaluated the impact of energy

content in starter diets on nutrient digestibility and growth performance of broilers, using different coccidiosis control programs. L. Aloui *et al.* (2024) investigated the effects of heat stress on the hypothalamic gene expression profile related to water homeostasis in broilers. Scientists S. Sgavioli *et al.* (2023) assessed the behaviour of broiler chickens subjected to heat stress at different times of the day and found that birds spent more time feeding in the morning, regardless of age and rearing temperature. G. Baldi *et al.* (2020) studied factors influencing the high pH of the pectoralis major muscle in broilers affected by wooden breast condition.

The findings of S. Zhou *et al.* (2024) indicate that Cobb-700 broilers with a medium growth rate (weight gain <50 g/day) reach a market live weight of 3 kg at 52 days of age, while slowergrowing birds (weight gain 50-60 g/day) reach this weight at 62 days. Given that broiler carcass colour is a significant factor for poultry consumers in various countries, including Mexico, L. Pantoja & O. Gonzalez (2020) characterised the factors influencing skin pigmentation, highlighting genetics, nutrition, and diseases as key contributors. R. Urtecho-Novelo *et al.* (2021) studied the ethology, health, and productivity of Hubbard cross broilers under tropical Mexican conditions. L. Bean-Hodgins & E. Kiarie (2021) highlighted the mandatory restrictions on the use of medically important antibiotics in broiler chicken production in Canada. S. Che *et al.* (2022) provided data on the prevalence of breast muscle myopathies and associated risk factors in broiler chickens raised on farms in Ontario, Canada. The research of H. Sammari *et al.* (2023) confirmed the presence of numerous broiler carcass quality issues by examining 206 breast fillets purchased from grocery stores in Quebec and assessing them for various defects. Myopathy of the breast muscles was detected in 48.5% of these fillets. J. Lee & M. Mienaltowski (2023) highlight that the increased growth rates and sizes of broilers disrupt certain biochemical processes in the bird's body, leading to inflammation and hypoxia, and subsequently to the formation of foamy cells from macrophages and the deposition of fat along muscle tissues in the form of white stripes.

Considerable attention has been given to broiler welfare issues in North American poultry farms. For example, M. Anderson *et al.* (2021) demonstrated the need to enrich the environment for broiler chickens to improve their welfare. The results of the study by T. Shynkaruk *et al.* (2023) indicate that broiler welfare is compromised at higher stocking densities, as birds experience reduced productivity, poorer litter quality, and increased foot pad lesions. P. Regmi (2024) reports that in Canada, the recommended stocking density for broilers should not exceed 31 kg/m^2, while in the USA, this figure is considered optimal within the range of 32-44 kg/m^2. I. Chan *et al.* (2022) argue that reducing chicken consumption can help avoid potential trade-offs between animal welfare and environmental protection.

This study aimed to analyse FAOSTAT data and synthesise the findings of scientific research conducted by North American scientists between 2019 and 2024 regarding broiler chicken meat production technology in the USA, Canada, and Mexico. The study employed content analysis, analysis and synthesis, and comparative analysis. The authors analysed and adapted data from sources such as FAOSTAT (2024); Cobb 500 Broiler Performance & Nutrition Supplement (2022); and Cobb 700 Broiler Performance & Nutrition Supplement (2020).

Contemporary state of broiler meat production in the USA, Canada and Mexico

M. Jordan (2020), Executive Director of LEAP Market Analytics, analysed broiler meat exports from the USA to Canada and Mexico over the recent period, starting in 2012. The two largest US trading partners in North America (Canada and Mexico) are reliable and important partners

for broiler meat exports. The author cites data from the US Department of Agriculture Economic Research Service (USDA ERS), according to which, in 2019, just over a quarter of the approximately 7.1 billion pounds of broiler meat exported from the USA to all countries was sent to Canada and Mexico. Over the past five years, exports to Mexico totalled nearly 7.2 billion pounds, while shipments to Canada amounted to nearly 1.7 billion. The US broiler industry has expanded its presence in both Canada and Mexico in recent years. Trade peaked in 2014 when total exports reached 1.9 billion pounds, representing 4.9% of total domestic broiler meat production that year. Challenges arose when industry workers had to contend with trade restrictions imposed in response to the outbreak of highly pathogenic avian influenza. Exports of poultry meat to Canada and Mexico declined further in 2017 as the US administration implemented antagonistic policies towards these countries. In that year, combined shipments of broiler meat from the USA to Canada and Mexico fell short of 1.7 billion pounds, or slightly less than 4.0% of total domestic production. While shipping broiler meat to China and other countries may seem advantageous, as it could improve trade dynamics and generate significant export revenue in a relatively short time, the expert believes that the USA would be safer to focus on positive relations with historically reliable and geographically proximate trading partners. US poultry companies, struggling to offload surpluses of boneless, skinless chicken breasts, which have been consistently selling for less than 1 USD per pound since September 2019 and are sitting in cold storage in large quantities, undoubtedly welcome the US-Mexico-Canada Agreement (USMCA), which will provide expanded access, primarily to the Canadian market, for poultry products.

H. Unveren & J. Luckstead (2020) constructed a comprehensive supply chain model for the US broiler industry. This model was developed to analyse the impact of tariffs on corn and soybean meal imposed by China and changes to Canada's tariff-rate quota proposed under the USMexicoCanada Agreement. The first scenario assumes that a decrease in feed prices will increase supply, which will contribute to lower production costs for breeding companies and broiler farms. The second scenario suggests that broiler meat exports to Canada will increase at the expense of exports to Mexico.

Characterising the current state of poultry farming, it should be noted that, according to FAOSTAT (2024), the global stocks chickens in 2023 was 27,223,471.0 thousand heads. China ranks first in terms of stocks chickens (5,217,362.0 thousand birds), the USA is fifth (1,526,000.0 thousand birds), Mexico is eighth (621,072.0 thousand birds), and Canada is 30th (171,487.0 thousand birds). For comparison, Ukraine ranks 32nd with a stocks chickens of 165,468.0 thousand birds. The authors investigated the trend in the stocks chickens in North America (Table 1). It should be noted that FAOSTAT, when indicating the stocks chickens in North America, only considers data for the USA and Canada (FAOSTAT, 2024).

Table 1. *Stocks chickens in North America, thousand birds*

Year	Northern America	USA	Canada	Mexico
2019	1,699,609.0	1,530,000.0	169,609.0	580,829.0
2020	1,707,555.0	1,537,000.0	170,555.0	591,596.0
2021	1,692,711.0	1,522,000.0	170,711.0	604,682.0
2022	1,703,099.0	1,532,000.0	171,099.0	609,506.0
2023	1,697,487.0	1,526,000.0	171,487.0	621,072.0

Source: developed by the authors for FAOSTAT (2024)

An analysis of the presented data reveals that the USA has the largest poultry population. Mexico ranks second. Overall, the poultry population in Canada and Mexico has shown an increasing trend from 2019 to 2023. Compared to 2019, the US stocks chickens decreased by 0.1% in 2023 (Fig. 1).

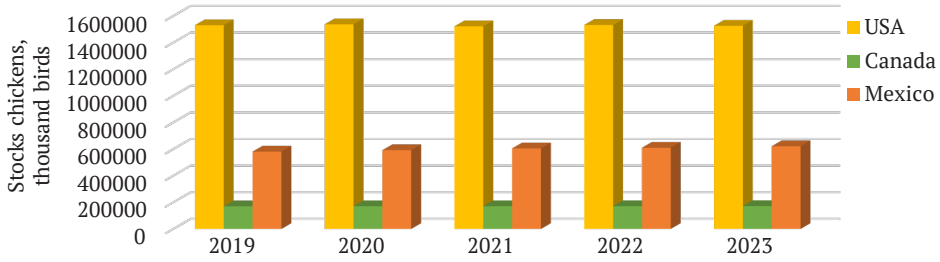

Figure 1. Changes in the stocks chickens in North America, thousand birds
Source: developed by the authors for FAOSTAT (2024)

Regarding poultry meat production, the world produced 123,631,334.7 tonnes in 2023 (FAOSTAT, 2024). The USA ranked first (19,901,890.0 tonnes), followed by Brazil (14,833,000.0 tonnes), China (14,800,000.0 tonnes), Mexico (3,888,207.9 tonnes), and Canada (1,415,926.0 tonnes) in the seventh and 24th positions respectively. The authors also analysed broiler meat production in North American countries (Table 2) (FAOSTAT, 2024).

Table 2. *Broiler meat production in North American countries, tonnes*

Year	USA	Canada	Mexico
2019	20,197,090.5	1,331,571.0	3,476,622.2
2020	18,814,264.0	1,305,207.0	3,578,694.1
2021	19,230,123.0	1,334,020.0	3,668,551.3
2022	19,841,239.0	1,370,800.0	3,781,735.3
2023	19,901,890.0	1,415,926.0	3,888,207.9

Source: developed by the authors for FAOSTAT (2024)

An analysis of broiler meat production shows that, as with the stocks chickens, the USA is the leading producer, followed by Mexico. Overall, there has been an increase in meat production over the five-year period examined in Canada and Mexico, while in the USA, production increased only from 2021 to 2023 (Fig. 2).

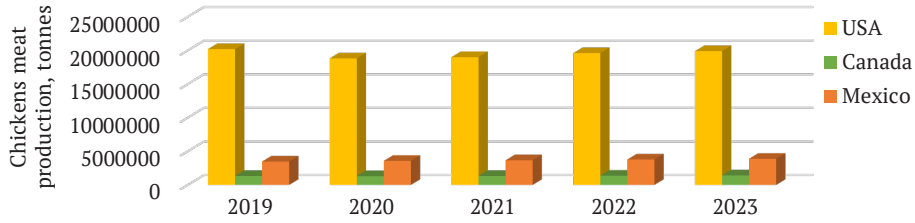

Figure 2. Dynamics of chickens meat (fresh or chilled) production in North America, tonnes
Source: developed by the authors for FAOSTAT (2024)

According to the US Department of Agriculture (USDA), broiler meat production is projected to grow steadily until 2033, after a significant decline in the poultry population in 2022 and 2023 due to outbreaks of highly pathogenic avian influenza (Hein, 2024).

S. Beets (2019) highlights that chicken meat, or broiler, production in the United States is a vertically integrated industry where integrator corporations control all aspects of the business. Primarily due to a series of mergers and acquisitions, a duopoly has formed. The two dominant integrator corporations, Pilgrim's Pride and Tyson Foods, are highly profitable, and their executives and shareholders benefit from the corporations' financial success. However, many local farmers who raise chickens for meat and sell to integrators (wholesale buyers) receive minimal benefits from the integrators' financial success, as farmers face a multitude of financial, environmental, social, and health problems. Many producers find it difficult to abandon an occupation that requires a significant initial investment or debt of hundreds of thousands of dollars. Another issue with large-scale broiler production is air pollution and the creation of unfavourable conditions for people living nearby. Several demographic, economic, educational, health, and quality-of-life indicators in 50 states of the USA were analysed to gain insight into the ethics of the broiler industry and why some states produce significantly more broilers than others.

A. Pescatore *et al.* (2019) report that the USA is the world leader in chicken consumption, reaching a level of 90 pounds per capita. To meet this demand, the country produces approximately 9 billion chickens annually, providing over 50 billion pounds of broiler meat. The broiler market is segmented as follows: 55% of sales are attributed to retail and 45% to the food service sector. Any changes in the production system can impact the sustainability and economic efficiency of the poultry industry. Over the past 50 years, broiler chickens have significantly changed due to genetic improvements and enhanced diets. However, rapid growth and increased productivity have also led to problems such as muscular myopathies and skeletal disorders. In response to these challenges, some producers have begun transitioning to slower-growing chicken genotypes, which yield less than 50 grams of average daily weight gain. The popularity of such approaches is growing among restaurants and stores, including Whole Foods, Panera Bread, Chipotle, Noodles and Co., and Quiznos. They prefer poultry raised according to Global Animal Production (GAP) standards. For example, the company Bell and Evans implements slower-growing chickens through their proprietary breed (cross) Das Klassenbester. The shift towards slower-growing chickens and GAP standards could significantly impact the entire poultry meat production industry.

The Canadian poultry sector plays a significant role in the Canadian economy. Canada's broiler industry benefits both urban and rural economies. As a driving force in the Canadian economy, 2,877 poultry farmers and 185 poultry processors create jobs, increase prosperity, and help sustain agricultural communities in every province of the country. Specifically, the sector: supports 101,900 jobs and contributes 8 billion USD to Canada's gross domestic product. It pays 1.9 billion USD in taxes, and purchases 3 million tonnes of feed, thereby supporting other farmers. Canadian poultry farmers are a stabilising factor for rural regions of Canada and create a variety of jobs not only in agriculture and processing but also in transportation, retail, restaurants, and more (Good for Canada, 2021).

In 2021, Canada had 2,823 chicken producers who produced 1.3 billion kilograms of chicken meat (in eviscerated carcasses), 60% of which was produced in Ontario and Quebec. Overall, in 2021, chicken production in Canada generated 3.3 billion USD, accounting for 4.0% of cash receipts in farming operations. In 2021, Canada also had over 78 primary processing

establishments, 40 of which are federally inspected, along with many other processors whose business depends on chicken supplies. In 2020, chicken was the most consumed animal protein in Canada with consumption of 34.4 kg per capita, slightly below the 2019 level. This was the first annual decline in a decade, attributed to the impact of the COVID-19 pandemic on the poultry industry, as well as closures and reduced offerings from food service establishments, which account for a significant portion of chicken consumption in Canada. Canada also imports chicken, and imports are regulated by tariff-rate quotas (TRQ). In 2021, imports amounted to 164.7 million kilograms in carcass weight, primarily from the USA, followed by Brazil, Thailand, and Hungary. In the same year, 111.8 million kg of meat and meat products (fresh, chilled, frozen) valued at 554.8 million USD were exported to over 50 countries worldwide, with the USA, Philippines, and Taiwan being the largest importers (Canada's chicken industry, 2024).

In April 2023, Canadian Poultry Magazine (Ontario investing in new poultry research centre, 2023) reported that the Ontario government is investing 13.5 million USD in a new poultry research centre in Elora. The Ontario government, the Agricultural Research Institute of Ontario (ARIO), and the province's four poultry councils have signed a Memorandum of Understanding to invest in the new Ontario Poultry Research Centre to advance research and innovation in the poultry sector. "As part of the Grow Ontario Strategy, our government is focused on enhancing our research and innovation capabilities across the agri-food sector," says Lisa Thompson, Minister of Agriculture, Food and Rural Affairs.

N. Berkhout (2021) noted that imports account for about 18% of total domestic chicken meat consumption in Mexico, with chilled leg quarters and mechanically deboned chicken meat from the USA making up almost half of all imports. Frozen breasts, wings, and drumsticks are also imported from Brazil. Companies that further process poultry for use in products such as sausages, ham, and meat assortments are the main source of demand for imports.

The COVID-19 pandemic and economic recession led to a decrease in chicken meat consumption in 2020 and resulted in a decline in imports. A persistent risk to the highly concentrated poultry industry is avian influenza. Despite vaccination of breeding and laying flocks, the virus is endemic in some states. The prolonged COVID-19 pandemic impacted the poultry industry, especially chicken meat production, in 2021 (Mexico's role in the global poultry industry, 2022).

L. Estévez-Moreno & G. Miranda-de la Lama (2022) indicate that meat is a significant component of contemporary Mexican culture. Its consumption is linked to ancestral traditions as well as agri-food globalisation. Mexicans consume three types of meat the most: chicken (35 kg/person/year), pork (20 kg/person/year), and beef (15 kg/person/year). The authors also note that Mexico has a significant population of people adhering to plant-based diets: 19% are vegetarians, 15% are flexitarians, and 9% are vegans. Overall, throughout the 21st century, Mexican society has become increasingly concerned about the negative health impacts of meat, animal welfare, and the environmental effects of livestock farming. Given that Cobb and Ross crosses are the most common in North America, the authors analysed the performance indicators of Cobb broiler crosses – a leading American breeding company (Table 3).

An analysis of the presented data indicates that the Cobb-500 and Cobb-700 crosses exhibit differences in both live weight and feed conversion. Cobb-500 broilers have an advantage in terms of live weight. At 42 days of age, they reach a live weight of 3278 g, surpassing the Cobb-700 cross (2,847 g) by 431 g. At 56 days, this difference increases to 528 g, and the feed conversion ratio is also lower in Cobb-500 broilers. However, over a 42-day growing period,

they require 5,100 g of feed per bird, compared to 4547 g for the Cobb-700 cross. Overall, Cobb-700 broilers grow more slowly and can be raised to 63 days of age. Cobb-700 broilers achieve a live weight similar to Cobb-500 broilers one week later. Therefore, the producer chooses a cross depending on the final goal of production in a particular farm.

Table 3. *Live weight and feed conversion in Cobb broilers*

Age, days	Cobb-500			Cobb-700		
	Live weight, g	Feed intake, kg/kg gain	Cumulative Feed Consumption, g	Live weight, g	Feed intake, kg/kg gain	Cumulative Feed Consumption, g
0	42	-	-	42	-	-
7	202	0.891	180	183	0.883	162
14	570	1.029	588	468	1.028	481
21	1,116	1.018	1,320	916	1.174	1,076
28	1,783	1.322	2,359	1,500	1.319	1,978
35	2,521	1.441	3,635	2,163	1.460	3,158
42	3,278	1.555	5,100	2,847	1.597	4,547
49	4,001	1.686	6,749	3,509	1.727	6,058
56	4,641	1.842	8,549	4,113	1.849	7,605
63	-	-	-	4,643	1.964	9,117

Source: adapted by the authors from Cobb 500 Broiler Performance & Nutrition Supplement (2022); Cobb 700 Broiler Performance & Nutrition Supplement (2020)

In the poultry processing industry, North American broiler plants are increasingly shifting from water chilling to air chilling carcasses. Several large processors in the USA are already extremely satisfied users of air chilling tunnels (Air chilling growth in North America, 2021). Canadian broiler processors have also been effectively using air chilling systems for some time. Marel is a leading company in carcass processing and offers a product portfolio ideally suited for this market. Immersing products in a chill chiller, which has been the most popular cooling method in the USA, leads to additional water absorption. A representative of the American processor Bell & Evans comments on this: "With conventional chilling systems, chickens absorb up to 12% of their body weight in added chlorinated water. This water "weeps" out of the meat and is trapped in the "diaper" you will find in most fresh chicken packaging". In North America, sanitising chemicals are added to the water tank. Air chilling does not require chemicals, while still maintaining a super-hygienic process. Air chilling fully supports the process with less labour. This also enables better tracking of the entire process. End-to-end traceability combined with food safety is a top priority for customers and consumers in North America (Air chilling growth in North America, 2021).

S. Barbut (2019) indicates that in recent years, there has been an increasing incidence of myopathies in young broilers worldwide, such as white striping (WS), woody breast (WB), and spaghetti meat (SP) in breast muscle tissue. According to some industry reports, the prevalence of WB in fast-growing heavy broilers (~4.0 kg) can reach 20%, which is estimated to cost the US poultry industry over 500 million USD annually, although actual losses may be significantly higher. The severity and frequency of these anomalies depend on the specific flock and are associated with factors such as genetics, nutrition (particularly protein levels in the bird's diet during rapid growth), growth rate,

chick activity at an early age, sudden physical exertion, the number of embryonic stem cells, and litter management in the poultry house. These three myopathies can occur separately or together, but there is some interrelationship between them. During meat processing, they create quality issues (denser meat structure and/or reduced water-holding capacity, poor appearance), but do not affect food safety. The poultry industry is now focused on finding ways to reduce or eliminate these anomalies. Recent progress has been made due to a better understanding of the interaction between environmental conditions and management practices, such as nutrition, and some producers have already begun to apply new approaches.

Thus, broiler production in countries such as the USA, Canada, and Mexico exhibits certain differences, as evidenced primarily by the analysis of statistical data on poultry populations and meat production. The Cobb and Ross crosses are the most common in North America, characterised by high meat production performance. Broilers are predominantly kept in industrial conditions on litter floors. A distinctive feature of poultry processing in North American countries is the widespread use of air chilling for carcasses.

Characterisation of leading North American meat poultry producers and processed product suppliers

Tyson Foods is a leading meat production company in the USA, founded in the 1930s in Arkansas (Our history, n.d.). Before characterising the activities of Tyson Foods, it is worth quoting its chairman, John Tyson: "From the beginning, our company has been built on faith, family, and hard work. That tradition, our Core Values, and "doing what's right" are deeply embedded in our culture" (Our core values, n.d.).

K. Christensen (2020), a PhD and Senior Director of Animal Welfare at Tyson Foods, discussed the creation of a new broiler research farm at Tyson Foods. This farm represents a new initiative focused on protecting and promoting the welfare of poultry. Tyson Foods' approach to animal welfare is rooted in a commitment to becoming an industry leader, relying on sound scientific evidence. The company openly shares key animal welfare metrics and results of independent audits in its annual sustainability report. The new Tyson Foods research farm with a focus on broiler welfare is unique in the industry. It is a four-house farm that allows for the study of the impact of social enrichment methods on bird behaviour in production settings. Observation rooms on the farm enable researchers and customers to observe the birds without disturbing them. This allows for the discovery of entirely new behavioural patterns when birds do not perceive a human presence. The facility is also used to test new technologies aimed at improving welfare assessment methods and continuously enhancing welfare standards. The company representative further elaborated on the research projects conducted at the farm, highlighting the scientists' focus on lighting and environmental enrichment to stimulate the birds. The farm's staff concentrated on enrichment that was both appealing to the birds and safe for the producer. They explored enrichment made from recycled materials that could be easily cleaned and installed. To carry out this research, the company's scientists received a US poultry industry grant to study the effects of various lighting and environmental enrichment schemes on the welfare and leg health of broilers. The lighting research involved refining the existing system, providing bright light over feeders and optimal lighting in other areas of the house. The company employed various methods to analyse bird preferences and assess welfare indicators to confirm that behaviour, performance, and physiological parameters indicated the best outcomes. It was emphasised that chickens have a very different perception of their environment, and this must be considered when making technological decisions. For instance, their response

to light differs significantly from humans, so it is crucial to consider these characteristics when developing lighting programs. What may seem comfortable for humans can cause stress or discomfort in poultry.

Cargill is the largest privately held corporation in the United States, headquartered in Minneapolis, Minnesota. Founded by the Cargill and McMillan families, Cargill is a family-owned company. In 1865, William Wallace Cargill purchased a small grain elevator in Conover, Iowa, marking the beginning of the company's history. In the late 1890s, the family merged with another family involved in banking and the grain business, D.D. McMillan & Sons, forming W.W. Cargill. In 1898, a son of the elder McMillan married a daughter of the elder Cargill, further strengthening the business alliance through family ties. By 1935, Cargill had acquired its own fleet. During the war, the company lost most of its branches in occupied European countries but compensated for this through shipping and shipbuilding. Concurrently, Cargill developed the industrial processing of soybeans and later ventured into livestock, poultry, and other agricultural sectors. Today, Cargill is a large international corporation with a presence in 70 countries and over 150,000 employees, supplying a quarter of US grain exports and one-fifth of the domestic meat market. Cargill employees also work in the energy, steel, textile, oil, and chemical industries, as well as providing financial services. Eighty-three per cent of the company's shares are owned by descendants of the founders, representing the fourth and fifth generations of the Cargill-McMillan family clan. Eighty per cent of profits are reinvested in business growth (Cargill, 2024).

It has been reported (Cargill timeline, 2022) that the company's annual revenue in 2021 was 134.4 billion USD. Notably, in 2019, Cargill and Heifer International joined forces to launch the global Hatching Hope initiative, aimed at improving nutrition and boosting the economic wellbeing of 100 million people by 2030 through the development of poultry production, promotion, and consumption.

Michelle Grogg, Vice President of Corporate Responsibility at Cargill, noted that the conflict between Ukraine and Russia has been a significant challenge for the world and the company (Cargill annual report, 2022). While ensuring the safety of Cargill employees was the primary priority, the company also worked to support its colleagues and others in the region in need of humanitarian aid. One of the key humanitarian aid centres in Ukraine is the Kyiv Food Bank, established with the help of Cargill in 2012. Cargill employees in Ukraine provided essential logistical support and warehouse space, serving over 3,000 people daily. The company allocated an initial 40 million USD for humanitarian aid in Ukraine, neighbouring countries, and across Europe. This includes support for global humanitarian organisations such as Save the Children, CARE, the Red Cross, and the European Food Banks Federation. Additionally, the company is collaborating with local humanitarian organisations, assisting Ukrainian employees who are members of Cargill Cares Councils. Their activities encompass donating food and supplies to support families and pets, as well as organising and delivering welcome packages to Ukrainian refugees upon arrival at their destinations.

Cargill noted in its 2022 annual report that with 157 years of experience, it is no stranger to challenging times. However, the extreme events of the 2022 financial year, including the ongoing COVID-19 pandemic, severe weather conditions, trade disruptions, and the Russian invasion of Ukraine, forced the company to focus on what matters most: providing the world with essential food. The company believes that food is a basic human right and is committed to doing everything possible to help farmers bring their products to market. Cargill supplies its customers with the ingredients needed to produce food. Wherever the company operates, it acts as a global partner, focused on creating a more sustainable and efficient food system.

Founded in 1894, Bell & Evans is the oldest branded poultry company in the USA (Bell & Evans timeline, n.d.). In 1894, Howard G. Bell of Bellmore, New Jersey, started a poultry business on the family farm. In 1910, Bell partnered with another local farmer, Carlton Evans, to form the Bell & Evans company. In 1926, Bell & Evans opened its first poultry processing plant in Camden, New Jersey, and in 1927 the company was officially incorporated. In 1958, the company, headed by CF Manbeck, Inc./Farmers Pride, began branding products under the strict Bell & Evans standards. In 1984, Clarence Manbeck retired and sold the business to Scott Sechler. The following year, Sechler initiated the use of cement floors in poultry houses and mandatory disinfection between flocks. In 1986, Sechler acquired the Bell & Evans brand from the Bell family and merged it with Farmers Pride. In 1998, the company introduced all-natural feeds and began raising poultry without antibiotics. In 2000, a 10 million USD production expansion was completed, doubling the plant's capacity, increasing the number of employees to over 700, and the number of farming families to over 90. In 2001, Bell & Evans launched chicken nuggets, in 2005 gluten-free nuggets, and 2009 introduced a line of organic products.

In 2010, Bell & Evans introduced innovative, eco-friendly packaging suitable for freezing and made from recycled materials. In 2011, the company implemented the Slow Induction Anaesthesia (SSA) method and introduced the Bell & Evans Humane Animal Welfare standard, which received high praise from the Humane Society of the United States (HSUS) and People for the Ethical Treatment of Animals (PETA). In 2015, Bell & Evans opened a state-of-the-art further processing, packaging, and frying facility, with a total cost of 110 million USD and an area of 160,000 square feet. In 2016, the company launched a premium line of organic, gluten-free, ready-to-cook products. In 2017, Bell & Evans opened the world's first certified organic chicken hatchery, focused on animal welfare. In the same year, the company introduced a new chicken breed (cross) called Das Klassenbester™, designed for high animal welfare standards. In December 2021, Bell & Evans opened a new Organic-Certified Chicken Harvesting Facility (Bell & Evans timeline, n.d.).

The company closely manages every stage of chicken production to ensure the health of the birds and the quality of the product. The breeder farm is where male and female chickens produce hatching eggs, which are transported to an organic, certified incubator focused on animal welfare and then transferred for rearing. The company uses its own developed breed (cross) called Das Klassenbester, which is adapted to housing conditions that meet poultry welfare requirements (Our farms, n.d.). Thus, American companies such as Tyson Foods, Bell & Evans, and Cargill are leaders not only in North American production but also have a global reputation.

Scientific research by scientists from the USA, Canada, and Mexico on broiler meat production technology

There is a substantial body of literature characterising changes in broiler chicken productivity and highlighting the challenges faced by these birds due to increased growth rates as a result of long-term selective breeding. For example, scientists from the University of Guelph in Canada (Widowski & Rentsch, 2022), in characterising the broiler industry, indicate that broiler chickens are primarily selected for rapid growth rates, improved feed conversion efficiency, high productivity, and a high breast meat yield. Broilers currently reach a market live weight of 2.1 kg at just 35 days of age. A comparison of two commercial broiler crosses from 1950 and 2005 shows a 400% increase in growth rate, a 50% improvement in feed conversion, and an 80% increase in breast meat yield.

Scientists from Auburn University, a public research university located in Auburn,

Alabama, USA, L. Orellana *et al.* (2023) investigated the impact of eggshell transparency and intensity of colouration on the hatchability of eggs, weight loss, and hatchling weight of Ross 708 broiler chicks. The researchers' results indicated that translucency affected initial egg weight and egg weight on the 18th day of incubation, where low-translucent eggs had a higher weight (68.12 g and 62.21 g) than high-translucent eggs (67.50 and 61.08 g). Regarding chick weight, those from lowtranslucent eggs were 1.44 g heavier than those from high-translucent eggs. The percentage of weight loss at hatch ($P < 0.0001$), in contrast to the above, was higher in high-translucent eggs (9.5%) than in low-translucent eggs (8.9%). Eggshell thickness ($P < 0.0001$) was found to be greater in high-translucent eggs (468.6 μm) compared to low-translucent eggs (432.2 μm). It was found that eggshell colour affected egg weight. Darker eggs had a higher weight (68.10 g, 62.07 g) than lighter eggs (67.45 g, 61.07 g). Chicks hatched from dark-coloured eggs were 0.55 g heavier than those from light-coloured eggs. Weight loss ($P < 0.0001$) was higher in light-coloured eggs (9.9%) than in dark-coloured eggs (8.8%). Thus, low-translucent and dark-coloured eggs had better egg quality based on the studied parameters. The greatest decrease was observed for weight loss and eggshell thickness in eggs that were highly translucent or light-coloured.

Canadian scientists A. Tsementzis *et al.* (2023) conducted an analysis of the impact of adding specialised protein feed and antibiotic growth promoters to the starter diet of broiler chickens on growth performance up to 49 days of age. Specialised highly digestible protein feeds and antibiotic growth promoters are often used to partially replace traditional soybean meal in the early stages of broiler rearing. However, the number of comparative studies evaluating the effects of different feed components on the productivity and development of poultry throughout their entire life cycle remains limited. Bacitracin methylene disalicylate and narasin were used as antibiotic additives in the period from 0 to 10 days of age. At 49 days of age, broiler chickens of the Ross 708 cross in this group had a live weight of 3,479 kg.

Results of research by scientists from Purdue University (Indiana, USA) A. Aderibigbe *et al.* (2020) indicate improved growth rate and nutrient utilisation in broiler chickens fed diets supplemented with α-amylase. Although starch and energy digestibility varied depending on the intestinal segment, the effectiveness of the α-amylase supplement was greater in the small intestine compared to other intestinal sections.

At the Department of Poultry Science, Auburn University, D. Ventura *et al.* (2023) investigated the interactive effects of dietary isoleucine-to-valine ratios and leucine-to-lysine ratios on broiler growth and intestinal gene expression. The researchers found that different amino acid ratios may alter gene expression in the small intestine, which could help explain the mechanisms affecting broiler growth. S. Fathima *et al.* (2023) note that poultry producers are interested in using alternatives to feed antibiotics that can enhance bird performance and reduce disease incidence. For instance, yeasts and their fermentation products are commonly used in animal feed. Yeast cell walls are composed of polysaccharides, including chitin, mannans, 1,6-glucans, and β-1,3-glucans. These biologically active substances enhance the bird's immune response, reducing the burden of pathogens, and influencing digestive enzymes. W. Al Hakeem *et al.* (2022) highlight that *C. jejuni* is a primary cause of gastrointestinal illnesses in humans consuming poultry, beef, and pork. This pathogen is prevalent in poultry farms. Broilers are typically infected at 2-4 weeks of age. In the USA, where chickens are raised without the use of antibiotics, additional measures are necessary to reduce the prevalence of *C. jejuni* on broiler farms. Vaccination and the addition of prebiotics, synbiotics, probiotics, organic

acids, bacteriophages, and bacteriocins to broiler feed can improve gut health during the rearing period. B. Dixon *et al.* (2022) emphasise that the meat productivity of broilers and feed efficiency are influenced by the bird's gut health, which is determined by the intestinal microbial balance. Furthermore, the authors note that probiotic preparations improve the microbial balance of the gastrointestinal tract and have a positive impact on the bird's organism.

T. Thornton *et al.* (2023) from the University of Tennessee and the University of TennesseeKnoxville (USA) highlight that Precision Livestock Farming (PLF) technologies offer the opportunity to increase production efficiency and labour productivity while addressing consumer concerns about poultry production conditions. In the US poultry science community, there is a significant knowledge gap regarding current perceptions and needs for PLF. American researchers conducted a study aimed at developing a survey to examine attitudes and needs for PLF among scientists. The survey was conducted online using the Qualtrics platform and included 25 questions. The survey was sent to 276 poultry scientists in the USA, identified through university websites, and lasted for a month. A total of 68 responses were received. Data was exported from Qualtrics and analysed using SPSS. Respondents were classified by their role (consultant, researcher) and specialisation (animal scientist, engineer, veterinarian). Analysis was conducted using the chi-square test, frequency analysis, and the Monte Carlo method to account for the small sample size. Results showed that 92% of scientists agreed that the cost of production influences a farmer's decision to implement PLF. Additionally, 92% of researchers were familiar with the term PLF, but only 55% of them had or used these technologies.

G. Li *et al.* (2020) developed and tested image analysis algorithms for the automated monitoring of feeding and drinking behaviour in group-housed broiler chickens to improve farm management. The study used 60 Ross 708 broiler chickens aged 26-28 days, housed in a 2.9×1.4 m pen with a tubular feeder and five nipple drinkers. The developed algorithms demonstrated a high level of accuracy (on average over 90%) for analysing broiler behaviour, making them promising tools for automated image-based poultry behaviour monitoring systems. I. Chan *et al.* (2022) note that with the increasing demand for poultry meat, concerns about chicken welfare and the harms caused by the current technology of raising fast-growing broilers are also growing. In this regard, the scientists considered the option of raising chickens on pasture and using slower-growing crosses and breeds. However, they noted that this requires a significant additional 43.8-60.1% land use.

J. Smith (2019) notes that the US Food and Drug Administration's restrictions on antibiotic use in broiler production should not significantly impact broiler performance and health. Instead, marketing programs that significantly restrict or completely prohibit the use of antibiotics, including ionophores, in broiler production are becoming increasingly important. The main consequences of such programs include: difficulties in controlling necrotic enteritis and coccidiosis, problems with litter moisture management and associated diseases, and an increase in neonatal infections due to the removal of antibiotics from Marek's disease vaccines. To address these issues, significant changes in poultry feeding and treatment are required, as well as the application of alternative nonantibiotic agents, such as chemically synthesised coccidiostats. However, such changes can only partially compensate for the negative impact of antibiotic-free programs.

E. Ornelas-Eusebio *et al.* (2020) identified two key challenges facing the Mexican poultry industry: the responsible and effective use of antimicrobial drugs and the risk of infectious disease outbreaks. For instance, since the first detection of the highly pathogenic avian influenza H7N3 subtype in Mexico in 2012,

outbreaks have repeatedly occurred among domestic poultry. Both of these threats can be minimised through the implementation of good management practices and enhanced biosecurity on farms. The study aimed to analyse the biosecurity measures applied to different types of poultry farms in Mexico and to obtain data on the use of antimicrobial drugs. Using agglomerative hierarchical cluster analysis, three clusters of farms were identified. Each cluster was dominated by a specific type of farm.

The key biosecurity measures that significantly differentiated the farms and formed the basis for their clustering were: the use of personal protective equipment (including masks, hairnets, and safety goggles), adherence to hygiene protocols before entering and after leaving the farm, the use of dedicated workwear by staff and visitors, the presence of disinfectant foot baths at the entrance to the premises, and methods for disposing of dead birds. The stricter the biosecurity measures within a cluster, the less frequently farms use antimicrobial drugs. On farms with less stringent biosecurity, antimicrobial drugs critical for public health were used more often. The researchers also provided recommendations for improving biosecurity on farms. Overall, scientists from South American universities are conducting numerous studies that are highly relevant to the current state of broiler production.

Conclusions

A comprehensive analysis of broiler production in North America reveals certain distinctions between countries such as the USA, Canada, and Mexico, as evidenced primarily by an analysis of statistical data on stocks chickens and meat production. American companies such as Tyson Foods, Bell & Evans, and Cargill are leaders not only in North American production but are also renowned worldwide. An analysis of sources regarding the use of chicken crosses for broiler production indicates that Cobb and Ross crosses are the most common in North America. The Cobb-500 and Cobb-700 crosses differ in both live weight and feed conversion. Broilers of the Cobb-500 cross have a higher live weight, reaching 3,278 g at 42 days of age, exceeding the Cobb700 cross (2,847 g) by 431 g. Overall, Cobb-700 broilers grow more slowly and can be raised to 9 weeks of age. The Cobb-700 broilers reach a live weight similar to Cobb-500 broilers a week later. Therefore, depending on the end goal, poultry farmers in North America choose the appropriate cross.

Broilers are predominantly housed on litter floors in industrial conditions. In North American poultry farms, air chilling of carcasses is a common practice at slaughter. Additionally, an analysis of the reviewed literature indicates that scientists from North American universities are conducting a variety of studies that are highly relevant to the current state of the broiler meat industry. The majority of research focuses on solving problems related to broiler nutrition. Future research prospects include an analysis of the state of egg production in EU countries.

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Conflict of Interest

None.

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Сучасні тенденції виробництва м’яса бройлерів у Північній Америці: огляд літератури

Вікторія Мельник

Доктор історичних наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0003-2491-757X

Наталія Прокопенко

Доктор сільськогосподарських наук, професор
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0001-7967-884X

Світлана Базиволяк

Кандидат сільськогосподарських наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0003-1656-5754

Анотація. Світове виробництво м'яса бройлерів зростає швидше, ніж будь-якого іншого м'яса. Сполучені Штати є найбільшим виробником бройлерів у світі. У 2022 р. США разом з Канадою й Мексикою забезпечили 20 % загального виробництва м’яса бройлерів. Мета дослідження – проаналізувати та узагальнити літературні джерела щодо сучасних тенденцій технології виробництва м'яса курчат-бройлерів у США, Канаді та Мексиці. У дослідженні використовували методи аналізу й синтезу, контент-аналізу. Встановлено, що серед країн Північної Америки США посідають перше місце як за поголів’ям курей, так і за виробництвом м’яса бройлерів. Загалом у світі у 2022 році поголів’я курей становило 26,561,634,0 тис. голів. При цьому перше місце належить Китаю (5,185,477,0 тис. голів), США посіли п’яте місце (1,528,000,0 тис. голів), Мексика – восьме (611,202,0 тис. голів), а Канада – 29-е (173,942,0 тис. голів). У світовому рейтингу серед виробників м’яса бройлерів у 2022 р. на першому місці – США, Мексика – на сьомому, Канада – на 22-му. У динаміці виробництва м’яса бройлерів у країнах Північної Америки упродовж 2018-2022 рр. спостерігалася тенденція до збільшення даного показника. У 2022 р. у США було вироблено 20,652,970,91 т м’яса бройлерів, у Канаді – 1,332,967,57 т та у Мексиці – 3,668,552,28 т. Провідними виробниками м’ясної продукції у США, а також у всій Північній Америці є «Tyson Foods», «Cargill» та «Bell & Evans». Найпоширенішими кросами у птахогосподарствах Північної Америки є «Кобб» і «Росс». Порівняльний аналіз продуктивності кросів «Кобб-500» та «Кобб-700» засвідчив, що бройлери кросу «Кобб-500» мають перевагу за живою масою. Загалом бройлери кросу «Кобб-700» ростуть повільніше, і їх можна вирощувати до 63-добового віку. Найбільш поширеним є метод утримання бройлерів на підлозі з використанням підстилки. Вчені з університетів Південної Америки проводять різноманітні дослідження, котрі є актуальними на сучасному етапі розвитку м’ясного птахівництва. При цьому науковці розв’язують проблеми щодо утримання, годівлі, благополуччя, здоров’я бройлерів, якості тушок тощо

Ключові слова: США; Канада; Мексика; м'ясо птиці; крос; жива маса; годівля