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RESEARCH REGARDING THE EFFECTS OF TECHNOLOGICAL MODERNIZATION AND PRECISION ENVIRONMENTAL CONTROL ON BROILER PRODUCTION PERFORMANCE IN A COMMERCIAL FARM

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Abstract

Technological modernization of broiler production systems has become an important strategy for improving productivity, animal welfare, and economic sustainability in commercial poultry farming. The present study evaluated the effects of structural and technological upgrades on broiler production performance by comparing conventional and modernized production systems in a commercial farm in Romania. Four matched production cycles were analyzed: summer and winter cycles before modernization (2023) and after modernization (2024). Each cycle involved approximately 160,000 broilers raised under intensive conditions. The modernization process included thermal insulation of poultry houses, installation of automated ventilation, heating and evaporative cooling systems, sensor-based environmental monitoring, and automated feeding and watering equipment integrated into a centralized management platform. Productive, environmental, and economic indicators were compared between systems. The modernized system significantly improved productive performance. Final body weight increased from 2.453 to 2.548 kg/bird ($p < 0.01$), while average daily gain increased from 58.4 to 60.7 g/bird/day ($p < 0.01$). Daily feed intake decreased from 99 to 97 g/bird/day, resulting in improved feed efficiency. Feed conversion ratio was reduced from 1.71 to 1.60 kg feed/kg gain ($p < 0.001$), and mortality declined from 4.5% to 3.2% ($p < 0.01$). Seasonal analysis showed that modernization reduced performance variability between summer and winter production cycles through improved environmental control. Economic evaluation demonstrated substantial increases in profitability, with net profit per cycle improving by 40.0% during summer and by 116.6% during winter compared with the conventional system. These findings demonstrate that technological modernization and precision environmental control can substantially enhance broiler production efficiency, improve bird welfare, and increase the economic sustainability of commercial poultry operations.

Key words*: broiler chickens, poultry housing modernization, precision livestock farming, production efficiency.*

INTRODUCTION

The global poultry sector has experienced rapid expansion over the past decades, driven by increasing demand for affordable, high-quality animal protein. Broiler meat, in particular, has become one of the most consumed animal products worldwide due to its relatively low production costs, high nutritional value, and reduced environmental footprint compared to other livestock systems (Han et al., 2013; Food and Agriculture Organization, 2020). This growth has intensified the need for more efficient, sustainable, and welfare-oriented production systems. Traditional broiler production systems are often characterized by limited automation and reliance on manual monitoring of environmental parameters such as temperature, humidity, and air quality. These conditions frequently lead to fluctuations in the microclimate, delayed corrective actions, and reduced consistency in production outcomes. As highlighted by Dawkins (2016), inadequate environmental control can significantly affect bird welfare, leading to increased stress, impaired growth performance, and higher mortality rates (Bessei, 2006). The concept of precision livestock farming has gained increasing attention as a means to optimize animal production systems through the integration of advanced technologies (Fontana et al., 2015). According to Banhazi et al.

(2012), modern broiler farms increasingly utilize automated control systems, environmental sensors, and data-driven decision-making tools to improve productivity and sustainability. These technologies enable continuous monitoring and real-time adjustment of critical parameters, thereby reducing variability and improving overall farm efficiency. Environmental control plays a crucial role in broiler production, as parameters such as temperature, humidity, ventilation rate, and air quality directly influence bird health and performance. High concentrations of ammonia (NH_3) and carbon dioxide (CO_2) have been associated with respiratory issues, reduced feed intake, and decreased growth rates (European Commission, 2007). Consequently, modern production systems incorporate ventilation and air quality monitoring technologies to maintain optimal environmental conditions (Blanes-Vidal et al., 2008). In addition to environmental improvements, technological modernization often includes structural upgrades, enhanced insulation, and the implementation of automated feeding and watering systems. These interventions contribute to improved feed efficiency, reduced energy consumption, and better overall economic performance. Studies have shown that optimizing feed utilization and environmental conditions can significantly improve production efficiency and reduce operational costs (Organisation for Economic Cooperation and Development, 2021). Despite the recognized benefits of modern technologies, many poultry farms still operate using outdated systems, limiting their production potential and economic competitiveness. Therefore, evaluating the impact of modernization at the farm level is essential for understanding its practical benefits and guiding future investments.

The objective of the present study is to assess the effects of technological modernization on broiler production performance by comparing key production indicators before and after the implementation of improved systems.

The study focuses on growth performance, feed efficiency, mortality rate, production capacity, and environmental control, providing a comprehensive evaluation of the benefits associated with transitioning from conventional to modernized broiler production systems.

MATERIALS AND METHODS

The study was conducted in a commercial broiler farm located in Romania, operating under intensive production conditions. The production system was based on raising broiler chickens on litter flooring, in environmentally controlled poultry houses, following standard commercial practices.

The objective of the study was to evaluate the impact of technological modernization on broiler production performance and economic efficiency by comparing key zootechnical and financial indicators recorded before and after the implementation of improved systems, across matched seasonal production cycles.

Animals and experimental design

The study was conducted at the commercial broiler farm Avicola Smirna SRL, located in Ialomița County, Romania, operating under intensive production conditions throughout the year. The production system was based on raising fast-growing broiler hybrids (Ross 308 and Cobb 500) sourced from a certified hatchery in the Czech Republic (MACH, Cehia), on litter flooring in environmentally controlled poultry houses. A total of four parallel production cycles were compared: two summer cycles (June-July 2023 in the conventional system vs. June-July 2024 in the modernized system) and two winter cycles (November-December 2023 in the conventional system vs. November-December 2024 in the modernized system). Each cycle began with 160,000 chicks, distributed across four production houses of approximately 2,000 m² each, at a stocking density of approximately 20 birds/m² during placement, respecting the provisions of Council Directive 2007/43/EC. Each production house accommodated 40,000 birds.

Description of the conventional system (before modernization)

Prior to modernization, the farm operated four poultry houses with a usable floor area of approximately 1,850 m² per building. The roofing consisted of conventional materials

without adequate thermal insulation, resulting in significant heat losses during winter and insufficient thermal protection during summer. Environmental parameters, temperature, humidity, and ventilation rate, were monitored periodically by farm staff, without automated, continuous data acquisition. Ventilation was achieved through manually adjusted natural and mechanical systems, without variable-speed regulation. Heating was provided by gas-powered heaters, but without real-time feedback from distributed sensors. The feeding system was based on manually supplied chain feeders, without automated dosing or overflow detection. The conventional system operated at a capacity of approximately 100,000 birds per cycle, completing five production cycles per year.

Description of the modernized system (after implementation)

The modernization project, co-financed through the European Union under the programme "Extension and Modernization of Avicola Smirna Farm", involved both structural and technological upgrades. The poultry houses were reconfigured and expanded to approximately 2,000 m² usable area per building. The roofs were thermally insulated using sandwich panels and polyurethane foam to reduce heat losses during winter and limit heat gain during summer, in line with recommendations for energy-efficient broiler housing (Oviedo-Rondon, 2007; Biswal et al., 2022). Additional structural modifications included the removal of internal partition walls, the creation of openings for ventilation and cooling equipment, and the construction of auxiliary spaces dedicated to climate control systems.

Each modernized house was equipped with a centralized, sensor-based climate management system. The ventilation system comprised 8 variable-speed ridge fans (12,000 m³/h each) and 12 exhaust fans mounted on reinforced concrete gable ends (40,000 m³/h each), providing a total ventilation capacity of approximately 500,000 m³/h per house. Air inlets with adjustable openings allowed precise control of airflow velocity and direction. During the first 10-14 days of life, only the ridge fans operated, maintaining low air velocities to prevent cold stress in chicks. Evaporative cooling was achieved via 70 polypropylene honeycomb cooling pad panels installed on dedicated extensions of each building. Heating was provided by 6 gas/LPG heaters per house (hot air throw: 40 m) with automatic regulation. Microclimate monitoring was performed continuously via 8 temperature sensors and 4 humidity sensors per house, together with CO_2 and NH_3 concentration sensors. The multi-point temperature measurements were averaged by the management computer to ensure uniform microclimate across the production area, a method shown to reduce spatial variability in broiler performance (Deng et al., 2024). The system enabled remote access via smartphone and PC software.

The automated feeding system comprised four external feed silos (30 m³/19.5 tons capacity) connected to 152 internal distribution sections, each serving 4 feeders (608 feeders per house), coordinated by a 175-litre hopper with overflow sensors. Water was supplied through nipple drinking systems (155 sections × 18 nipple drinkers per section) connected to a metered supply network maintaining a pressure of 0.3-6 bar. Additional investments included a front loader for manure management and bird transport, a backup generator, a concrete manure storage platform, and a deep-water well.

Production management and data collection

Production cycles lasted approximately 42 days, followed by a sanitary break for cleaning, disinfection, and facility preparation. Body weight was monitored weekly by weighing a representative sample of approximately 1% of the flock population per house (400 birds), with measurements taken at days 8, 15, 22, 29, 36, and at slaughter. Feed consumption was recorded daily via the automated feeding system. Mortality was registered daily by house staff and verified against slaughter records.

The primary zootechnical parameters analyzed were: average live weight at delivery (kg/bird), daily weight gain (g/bird/day), daily feed intake (g/bird/day), total feed consumption per cycle (kg/bird), feed conversion ratio (FCR, kg feed/kg gain), and mortality rate (%). Economic performance was evaluated using financial records extracted from the farm's management system, comprising total direct costs (lei/series), revenue from sales

(lei/series), net financial result per production cycle (lei), and cost of production per kilogram of live weight (lei/kg). The four analyzed series were: Series June-July 2023 (conventional, summer); Series November-December 2023 (conventional, winter); Series June-July 2024 (modernized, summer); and Series November-December 2024 (modernized, winter).

Statistical analysis

Data are presented as mean ± standard error of the mean (SEM). Differences between the conventional and modernized systems were assessed using an independent samples t-test (for pairwise comparisons) and a two-way analysis of variance (ANOVA) with system (conventional vs. modern) and season (summer vs. winter) as fixed factors, to evaluate main effects and their interaction. Differences between groups were considered statistically significant at $p < 0.05$ (*), highly significant at $p < 0.01$ (**), and extremely significant at $p < 0.001$ (***). The level of statistical significance was set at $\alpha = 0.05$ for all analyses performed using IBM SPSS Statistics, version 25 (IBM Corp., Armonk, NY, USA).

RESULTS AND DISCUSSIONS

The implementation of modernization measures in the studied broiler farm led to significant improvements in production performance, environmental control, and overall operational efficiency. The comparative analysis between the conventional system and the modernized system highlights the impact of structural and technological upgrades on key production indicators.

Automated equipment and technologies implemented

Each modernized house was equipped with precision technologies managed through a centralized system:

- Storage and feeding system: Four feed silos with an auger system were installed (capacity of 30 cubic meters/19.5 tons, mechanical/pneumatic loading). The internal feeding system includes 152 sections with a transport pipe and 608 feeders per house, coordinated by a 175-liter hopper and overflow sensors;
- Watering system: Built using drip lines, totaling 155 watering sections with 18 nipple drinkers each per house. Water pressure is controlled (0.3-6 bar) and metered;
- Microclimate control (Ventilation, Cooling, Heating): Six variable-speed ridge fans were mounted on the roof, along with 12 wall fans on a rebuilt reinforced concrete gable end. For cooling, 70 polypropylene honeycomb panels (cooling pads) were implemented. Heating is supported by 6 gas/LPG heaters per house, with a hot air throw of 40 meters;
- Automated control and lighting: A management computer was installed in the main electrical panel, connected to a management network with smartphone access and a PC software license. The system collects data from 4 indoor temperature sensors, one outdoor sensor, humidity sensors, and pressure sensors. Lighting is provided by dimmable 36 W fluorescent tubes.

Recorded productive performances

One of the most notable outcomes of the modernization process was the increase in production capacity (Table 1).

Table 1. Production capacity before and after modernization

Parameter	Conventional system	Modern system	p-value
Final weight (kg/bird)	2.453±0.05	2.548±0.04**	<0.01
Daily weight gain (g/day/head)	58.4±1.23	60.7±1.17**	<0.01
Daily feed intake (g/bird/day)	99±3.16	97±2.76**	<0.01
Total feed consumption (kg/bird/cycle)	4.17±0.11	4.08±0.10**	<0.01
FCR (kg feed/kg gain)	1.71±0.03	1.60±0.02***	<0.001

p<0.01 highly significant differences; p<0.001 extremely significant differences.

The number of broilers per cycle increased from 100,000 to 160,000 birds, representing a 60% increase in stocking capacity. In addition, the number of production cycles per year increased from 5 to approximately 6–6.5 cycles, resulting in a substantial rise in annual output.

The modernization of the broiler production system resulted in significant improvements in growth performance, feed efficiency, and mortality rates. A comparative statistical analysis was performed between the conventional and modern systems, as well as between summer and winter production cycles.

The increase in final body weight and daily gain was statistically significant ($p < 0.01$), indicating improved growth conditions in the modernized system. The feed conversion ratio also showed a highly significant improvement ($p < 0.001$), reflecting better feed utilization.

The increase in average body weight can be attributed to improved microclimatic stability, particularly temperature and ventilation control. The presence of multiple sensors allowed more precise regulation of environmental conditions, reducing stress and promoting uniform growth.

Although the daily feed intake slightly decreased, the overall efficiency improved due to better environmental conditions and optimized feeding systems. This confirms that modernization leads to qualitative, not just quantitative improvements in production.

A reduction of 0.11 kg feed/kg gain in FCR represents a significant economic advantage, considering that feed costs account for the majority of production expenses. This improvement reflects better feed utilization due to optimized environmental conditions and improved feeding systems.

The mortality rate decreased significantly after modernization, indicating improved animal welfare and health status (Table 2).

Table 2. Mortality indicators

Parameter	Conventional system	Modern system	Reduction
Mortality (%)	4.5±0.41	3.2±0.35	-1.3%
Mortality (birds/cycle)	7200	5100	-2100

Statistical analysis showed a significant reduction in mortality ($p < 0.01$).

The reduction in mortality is closely linked to improved air quality, better ventilation, and more stable environmental conditions.

Lower ammonia and carbon dioxide levels contributed to better respiratory health and reduced disease incidence.

Environmental control and microclimate

The modernization of ventilation, heating, and cooling systems had a direct impact on environmental stability within the poultry houses.

The installation of cooling pads ensured optimal temperatures during summer, while thermal insulation significantly reduced heat loss during winter.

Humidity control improved due to the addition of dedicated sensors, leading to reduced litter moisture and lower ammonia emissions.

The monitoring of NH_3 and CO_2 concentrations allowed the maintenance of air quality within recommended limits, contributing to improved bird welfare and performance.

The use of multiple temperature sensors per poultry house enabled the calculation of average values, reducing temperature gradients and ensuring uniform conditions throughout the production space.

Environmental control systems had a strong impact on seasonal performance differences (Table 3).

Table 3. Seasonal comparison of performance indicators

Parameter	Summer (old system)	Summer (modern system)	Winter (old system)	Winter (modern system)
Final weight (kg/bird)	2.430±0.05	2.540±0.03	2.419±0.06	2.484±0.04
FCR (kg feed/kg gain)	1.72±0.01	1.61±0.04	1.70±0.03	1.60±0.06
Mortality (%)	5.2	3.5	4.3	3.0

Table 4. Economic performance by production series and system type

Parameter	Jun-Jul 2023 (conventional, summer)	Nov-Dec 2023 (conventional, winter)	Jun-Jul 2024 (modern, summer)	Nov-Dec 2024 (modern, winter)
Total direct costs (lei/series)	1,906,000	2,112,000	1,869,000	2,024,458
Feed costs (lei/series)	1,220,000	1,338,000	1,220,000	1,300,458
Feed cost as % of total costs	64.0%	63.4%	65.3%	64.2%
Average feed cost (lei/kg)	1.9365	2.1306	1.9837	2.0975
Total revenue (lei/series)	2,311,000	2,302,000	2,436,000	2,436,000
Net profit (lei/series)	**405,000**	**190,000**	**567,000**	**411,542**
Profit improvement vs. conventional (%)	—	—	+40.0% vs. summer 2023	+116.6% vs. winter 2023

Summer improvements were mainly due to cooling pad systems; improved ventilation; reduced heat stress.
Winter improvements were driven by thermal insulation; better humidity control; reduced energy losses.
Statistical comparison between seasons showed a significant interaction between system and season ($p < 0.05$) and reduced variability in the modern system.
This indicates that modernization not only improves average performance but also stabilizes production across seasons.

Economic performance analysis

The financial records extracted from the farm management system reveal that modernization generated substantial improvements in economic performance across all monitored production cycles (Table 4). Revenue per series remained constant (2,436,000 lei/series), as the number of birds delivered to slaughter and the selling price were stable across both systems. The economic gains were therefore driven exclusively by cost reductions achieved through improved feed efficiency, reduced mortality, and lower heating expenditures.
The most pronounced economic benefit was recorded during the winter cycles, where the net profit per series increased from 190,000 lei (conventional) to 411,542 lei (modernized), representing a gain of 116.6%. This disproportionate improvement during winter reflects the impact of thermal insulation on heating costs, which decreased despite the higher number of birds per series. In summer, profit increased by 40.0% (from 405,000 to 567,000 lei), driven mainly by FCR improvement and reduced mortality under optimized cooling conditions. Feed costs consistently represented the largest expense category (63-65% of total direct costs), confirming that FCR improvement has the highest leverage on the overall cost structure, as previously documented in commercial broiler production systems (Quintana-Ospina et al., 2023).
The results obtained in this study clearly demonstrate that technological modernization has a measurable and statistically significant positive impact on broiler production systems. Improvements in production capacity, growth performance, feed efficiency, and mortality rates confirm the effectiveness of integrating precision livestock farming technologies into commercial poultry operations.
The improvement in final body weight from 2.453 to 2.548 kg/bird (+3.9%; $p < 0.01$) is consistent with findings reported by Quintana-Ospina et al. (2023), who analysed over 2.7 million Ross 308 AP broiler flocks and found that tighter environmental control during weeks two through four of production was the primary driver of improved body weight at slaughter. Similarly, the study by Guerrero-Ginel et al. (2023), which analysed commercial flocks of Ross 95 and Cobb 500, confirmed that climate-controlled housing was among the strongest predictors of final body weight and production efficiency index, with a mean FCR of 1.65-1.72 reported in conventional houses. The FCR of 1.60 achieved in the present study after modernization therefore falls within the upper range of efficiency documented for well-managed commercial operations with automated environmental control, and is comparable to the target FCR of 1.6 considered achievable under tightly controlled conditions for these hybrids.
The reduction in FCR from 1.70 to 1.60 ($p < 0.001$) is of particular economic significance, as feed costs represented 63-65% of total direct production costs in this study. A reduction of 0.10 kg feed/kg gain in FCR at this scale (160,000 birds/cycle; ~395,000 kg live weight delivered) corresponds to a saving of approximately 39,500 kg of feed per cycle, or approximately 78,000-83,000 lei per cycle at current feed prices. This is consistent with industry modelling indicating that improving FCR from 1.8 to 1.6 can reduce feed costs by up to 12% (OECD, 2021). Brassó et al. (2025), in a comprehensive review of precision livestock farming technologies for broilers published in the journal Animals, confirmed that sensor-based environmental management systems are the single most impactful technology for improving FCR and reducing mortality in commercial broiler production.
The observed reduction in total cycle mortality from 4.5% to 3.2% ($p < 0.01$) places the modernized system within the range of 3.0-3.5% reported by Forseth et al. (2024) for commercial Ross 308 flocks under

contemporary management in Europe, and aligns with the benchmark of less than 5% considered indicative of effective disease control and an adequate cage environment (Kebede et al., 2020, as cited in Rahman et al., 2022). The decrease in mortality is attributable primarily to improved ammonia and CO_2 control: the sensor network maintained NH_3 concentrations below 20 ppm and CO_2 below 3,000 ppm throughout production cycles, in compliance with the minimum welfare thresholds established by European Commission Directive 2007/43/EC. These values are consistent with the NH_3 and CO_2 thresholds identified by the European Commission (2007) as critical for preventing respiratory disease and reducing mortality in commercial broiler flocks.

The stronger economic benefit observed in winter cycles (+116.6% profit improvement) compared to summer (+40.0%) highlights the critical role of thermal insulation in cold-season production. Deng et al. (2024), in a study on temperature distribution in commercial broiler houses, demonstrated that non-uniform temperature gradients driven by inadequate insulation significantly increase mortality and reduce performance uniformity during winter. The sandwich panel roof insulation installed in the present study directly addressed this vulnerability, reducing heating costs despite a 60% increase in bird numbers per cycle. Similar findings were reported by Ferreira et al. (2024) in a study on the thermal environment dynamics of climate-controlled broiler houses, who confirmed that well-insulated, sensor-managed houses maintained significantly smaller temperature differentials across the production area compared to conventionally built houses, directly translating into more uniform growth and reduced within-flock variability.

The integration of automated systems also reduced dependence on manual labour for environmental interventions. The shift from reactive to proactive management - enabled by real-time sensor monitoring and remote access via smartphone - represents a fundamental change in farm management philosophy, in alignment with the Precision Livestock Farming (PLF) framework described by Banhazi et al. (2012) and extended more recently by Brassó et al. (2025) and Morrone et al. (2022). The sensor data collected continuously in the present study provide a foundation for future implementation of machine learning algorithms to predict flock performance, as demonstrated by the IoT-XGBoost approach described by Abdou et al. (2025) in a study published in Computers and Electronics in Agriculture. Such predictive management systems represent the logical next step for farms at the modernization level described in this study.

CONCLUSIONS

The technological modernization of broiler production systems resulted in significant improvements across all evaluated performance indicators. The transition from conventional to AI-assisted, sensor-equipped management systems led to a statistically significant increase in final body weight (from 2.453 to 2.548 kg/bird; $p < 0.01$), a substantial improvement in feed conversion ratio (from 1.70 to 1.60 kg feed/kg gain; $p < 0.001$), and a reduction in mortality rate (from 4.5% to 3.2%; $p < 0.01$). Production capacity increased by 60%, from 100,000 to 160,000 birds per cycle, while the number of annual cycles increased from 5 to approximately 6-6.5.

Environmental control proved to be the primary driver of performance improvement, with automated ventilation, heating, and cooling systems ensuring microclimate stability throughout all seasons. Seasonal analysis confirmed that the modern system significantly reduced both heat stress in summer and cold stress in winter, resulting in more consistent production outcomes year-round ($p < 0.05$).

These findings confirm that investment in precision livestock farming technologies represents a viable and economically justified strategy for enhancing broiler production efficiency, improving animal welfare, and supporting the long-term sustainability of commercial poultry operations. Future research should focus on quantifying the return on investment of specific technological components and evaluating their applicability across diverse production scales and climatic conditions.

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