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Original Article

Economic Feasibility in Commercial Egg Production in a Conventional and Cage-Free Systems with Different Stocking Densities

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ABSTRACT

Adapting existing laying facilities to meet animal welfare certifications is not a simple task. It causes higher expenses to producers, who are often hesitant to accept the need for changes. Considerations of their financial situation make them insecure to make assertive decisions in this area, as they seek to maintain the economic efficiency of laying poultry. This study aims to analyze the economic viability of laying systems (conventional cages and Cage-Free) with different housing densities. The data source was a systematized literature review. Five articles were found containing reports on systems. Further data sources were the lineage handbook and a survey with companies specializing in poultry farming. An analysis of economic viability was performed in the multiple scenarios. Densities in each system were used to compose different scenarios: Conventional: 1,500 cm²/bird, 750 cm²/bird, and 398 cm²/bird; and Cage-Free:7 birds/m² and 13 birds/m². The scenarios were evaluated in terms of Net Present Value, Internal Rate of Return, Modified Internal Rate of Return, Discounted Payback Method, Profitability Index, Equivalent Uniform Annual Value, and Monte Carlo Simulation. The best scenario was the Conventional, with 398 cm²/bird, presenting a higher NPV. The Cage-Free system, with seven birds per square meter, had a lower NPV compared to conventional systems. All scenarios had satisfactory chances of success. The risks of negative or null financial return were low according to Monte Carlo simulations. Conventional and Cage-Free production are economically viable when using densities of 1,500 cm²/bird, 750 cm²/bird, or 398 cm²/bird (conventional), and 7 birds/m², or 13 birds/m² (Cage-Free).

INTRODUCTION

The intense consumption of eggs and the demand for high productive indexes and productivity has driven the genetic development of commercial laying lines and the development of better conditions and facilities for production. New studies have aimed to determine densities (Pavan *et al.*, 2005) and the space required per bird. The use of cages was the chosen to increase production per area and strengthen this industry (Cabrelon *et al.*, 2016).

The ban of traditional cages by European Regulation in 1999, which established rules for animal welfare in confinement situations, led to a gradual migration from conventional cages to alternative systems. This situation demands changes in facilities, equipment, and labor employed in the activity. Adapting existing facilities and often financing their purchase are not simple tasks. It leads to further and extended expenses for producers, who are often hesitant to accept the need for changes, considering their financial situation, and makes them insecure to make assertive decisions regarding meeting consumers' desires and maintaining the economic efficiency of laying poultry.

Considering the price competitiveness in the egg market, it is essential that producers and companies have assertiveness in their decisions. Thus, the greatest challenge in making decisions is achieving a balance between animal welfare standards (AW) and a production system that is sustainable and ensures profitability associated with productivity. Blind decisions increase the possibility of errors; in this sense, investments need to be evaluated so that there is prior information on whether projects show positive signs of economic return. Economic feasibility analysis is suitable for this, as it seeks to ascertain the profitability and consistency of investment projects (Guiducci *et al.*, 2012).

Some measures capable of mitigating the effects of hen confinement and serving consumers' animal welfare requirements can be pointed out (Amaral *et al.*, 2016); producers argue for fewer structural changes in poultry facilities, such as reducing the density of birds per cage. When more space is available for birds in cages, there is a reduction in severe injuries, indicating the promotion of well-being (Soares *et al.*, 2018). In order to obtain specific certifications for Cage-Free or *Free-range* systems, which allow for expectations of higher added value in the products, profound changes are needed in the production structure, facilities, equipment, as well as the training of employees.

Empirically, eggs have a higher sales value to consumers; moreover, to be sure of higher incomes and evaluate the possibility of return on investment in obtaining these products, it is necessary to study different production scenarios using economic feasibility analysis. Demonstrating under which conditions the conventional and Cage-Free systems are economically viable may be a tool in decision-making regarding the implementation of systems considering aspects related to AW. Thus, the objective of this study is to analyze the economic viability of Conventional and Cage-Free systems for laying hens with different housing densities.

MATERIALS AND METHODS

Considering there were no available field data, in order to characterize facilities and equipment, and obtain data on lineages, densities, productive performance, and commercial egg production in the Conventional and Cage-Free *systems*, we adopted previously published works as the main sources of information. A systematized literature review was conducted in two databases (Web of Science and Scopus), using the following strings as search words, which could be present in titles, abstracts, or keywords: "laying hen" "production" and densit* OR "laying hen production" and densit*; "laying hen" "conventional production" and densit* OR "conventional production" and densit*; "cage laying hen" "production" and densit* OR "cages" "production" and densit*; "Cage-Free" "laying hen production" and densit* OR "Cage-Free production" and densit*; "performance laying hen production" and densit* OR "performance production" and densit*; "housing densit*" and hen OR "housing densit*" and "laying hen"; "laying poultry" and "laying hen" and "performance" and "consumption" OR "laying poultry" and "laying hen" and "performance" and "conversion"; "laying poultry" and "laying hen" and "performance" and densit* OR "laying poultry" and "laying hen" and "performance" and "accommodation" OR "laying poultry" and "laying hen" and "performance" and "housing"; and "laying hen" and "system" and "housing densit* OR "laying hen" and "system" and densit*.

We considered Portuguese and English articles published between 2010 and 2020 in peer-reviewed journals that presented empirical data addressing housing densities of laying hens in the Conventional and/or Cage-Free system.

The search in *Web of Science* resulted in 230 articles and *Scopus* produced 78 articles in English. The databases did not return any articles in Portuguese. Inclusion criteria adopted for the selection and evaluation of studies were articles published and fully available for download; articles regarding housing densities of laying hens in the Conventional system; articles regarding housing densities of laying hens in the Cage-Free system; articles providing laying housing density, performance, and production of laying hens in the Conventional system; and articles providing data related to housing density and performance and production of laying hens in the Cage-Free system. Exclusion criteria were articles unavailable for view or download; articles presenting or evaluating housing densities without considering the Conventional or Cage-Free laying hen production systems; texts published as posters or expanded abstracts; articles published in languages other than Portuguese or English; articles with no specific relationship with the topic analyzed here; and articles presenting data or evaluations without demonstrating the sources or methods.

Considering the criteria proposed in this study, only five articles met the criteria. Papers were identified by titles (Table 1). After selecting the material, the articles within the scope were fully read to select characteristics to compose the studied scenarios.

Table 1 – Selected articles.

Authors	Year	Title
Guo, Y. Y. *et al.*	2012	The effect of group size and stocking density on the well-being and performance of hens housed in furnished cages during summer
Şekeroğlu, A. *et al.*	2014	Effect of cage tier and age on performance, egg quality and stress parameters of laying hens
Abdel-Azeem, N.M., Emeash, H.H.	2016	Hyline-white behaviour, laying performance and egg quality in two conventional caging systems with different densities
Kang, H. K. *et al.*	2018	Effect of stocking density on laying performance, egg quality and blood parameters of Hy-Line Brown laying hens in an aviary system
Cheon *et al.*	2020	Adaptational changes of behaviors in hens introduced to a multi-tier system

Based on the literature findings, the characteristics of each scenario and the expected performance and egg production results were established and included in the economic feasibility analyses.

Housing densities found were 1,500 cm²/bird, 750 cm²/bird, (four and eight birds in each cage, respectively), and seven birds per m² in the alternative system. The densities found in the literature are in accordance with the findings reported in the literature for the construction of the scenarios. In addition to the densities above, densities of 398 cm²/bird (15 birds per cage) for the conventional system and 13 birds per m² for the alternative system were established. These densities are higher than those recommended by animal welfare regulations; nevertheless, they were considered in order to enrich the discussion proposed in the present study.

The densities of each system used to compose the scenarios were: conventional 1,500 cm²/bird (four birds per m²), conventional 750 cm²/bird (eight birds per m²), conventional 398 cm²/bird (15 birds per m²), Cage-Free 7 birds/m², and Cage-Free 13 birds/m².

The selected articles on Conventional and Cage-Free systems presented the following performance and egg production data: average daily feed intake (kg), feed conversion per dozen birds, feed conversion per mass (g/g), production (%), egg weight (g), egg mass (g), and non-saleable eggs (%). The means between each set of data were calculated so that they could be used to estimate values needed to prepare the cash flow. In addition to the five articles presenting data, a lineage manual was analyzed (Hyline, 2016) to include missing expected performance information.

To obtain the prices of facilities and equipment, a survey was carried out with companies specialized in poultry farming that supply birds, equipment, and supplies in the Midwest region of Brazil. After conducting the surveys, commercial egg production scenarios were developed and the economic viability of each of these scenarios was evaluated using the cash flow and Monte Carlo methods.

Based on the needs bird flocks in each production situation, poultry house dimensions (civil area) were estimated as follows: area 15 x 150 m = 2,250 m² and ceiling height of 2.80 m (capacity of up to 30,000 birds). Thus, the total number of birds in each scenario was estimated at Conventional 1,500 cm²/bird – 8,100 birds; conventional 750 cm²/bird – 16,200 birds; Conventional 398 cm²/bird - 30,375; Cage-Free 7 birds/m² - 15,750 birds; and Cage-Free 13 birds/m² - 29,250 birds.

The lineage chosen was *Hy-Line Brown*, as it is the one studied in the five analyzed papers. The information related to breeding was indicated by the lineage manual (Hyline, 2016). To calculate the annual cost of bird acquisition, the laying cycle of this lineage was considered for both production systems, since different cycles are reported in the handbook for the two types of breeding, i.e., in cages and cage-free (594 and 524 days, respectively). For the breeding time, hens with approximately 120 days (16 weeks), close to the beginning of the laying phase, were purchased. The cost of purchasing each bird was US$ 5.27, a value obtained through a supplier from the company *Hy-Line*.

Bird feed costs vary according to the type of production, as free-range birds consume more food than caged birds. Birds raised in the Cage-Free system must also be dewormed every six months via feed.

Calculations regarding feed costs were performed considering a ten-year historical average price (2010 to 2020) of each ingredient included in the diet. Working with historical data allows for taking into account products with a high variation between harvests. For all prices in the historical series, databases such as the Institute of Agricultural Economics - IEA, National Supply Company - Conab, Center for Advanced Studies in Applied Economics – CEPEA, and National Service for Rural Learning - SENAR were considered. The calculated cost for the feed was US$ 0.292 per kilogram.

Annual feed consumption costs were calculated considering a feed consumption of 106 g/bird/day for the Conventional system and 130 g bird/day for the Cage-Free system. These figures were the mean values among the analyzed articles (Şekeroğlu *et al.*, 2014; Kang *et al.*, 2018; Guo *et al.*, 2012; Cheon *et al.*, 2020; Abdel-Azeem & Emeash, 2016) and lineage manuals (Hyline, 2016). The waste of 5 g/bird/day was added to total feed consumption (Hyline, 2016). Values were converted into kilograms, totaling a consumption of 0.111 kg/bird/day in the Conventional system and 0.135 kg/bird/day in the Cage-Free system. The values were multiplied by 365 days to compute the total consumption of each bird per year. Then, a calculation was performed considering the flocks, as well as a reduction of 6% reflecting the bird mortality ratio (Hyline, 2016).

The data provided by the companies specialized in poultry breeding refer to facilities that have an egg selection room, a silo, and a compost bin; and for the Cage-Free system, bedding, perches, and nests. The conventional system is characterized by being automated, that is, it has a food distribution line, while Cage-Free distribution is manual. Both systems have an air conditioning system. Conventional poultry houses employ two people, while Cage-Free ones employ three.

It is important to note that, for the cash flow calculation of the Cage-Free production system, expenses with the necessary certification were also included, considering data from Certified Humane® (2021); three tariffs for animal welfare certification were considered: Application Fee, Inspection Fee, and Certification Fee.

The sales value of the eggs produced was calculated considering the commercial classification of eggs produced by the *Hy-Line Brown* lineage. The average egg weight expected for this lineage is 62.5 g (Hyline, 2016), classified in the Extra category (60>egg≤65 g).

The year of 2019 was considered for the quotation, since there was a change in the prices of agricultural/livestock items with the onset of the new Coronavirus pandemic in 2020, thus justifying not using current values, as they do not represent reality satisfactorily. According to the Cepea, a box containing thirty dozens of red eggs was sold for US$ 29.25 in April 2019.

The manure produced by birds is part of the revenue in the cash flow. Calculations were based on the determination of the amounts produced by each system, as well as the manure value of US$ 5.27 per 20 kilograms. Regarding the revenue from the sales of discarded birds, a calculation was performed considering the production cycle of animals, the number of birds, and the value of US$ 0.26 for each discarded bird. Subtracting 6% due to mortality, the unit price of discarded birds was US$ 0.24.

Economic feasibility study

The production scenarios were modeled according to values for individuals, that is, considering an investor without a company, using their own resources.

The economic feasibility analysis was performed by the cash flow method (Bordeaux-Rêgo *et al.*, 2006). The cash flow method is based on an accounting concept that considers cash inflows and outflows at the time they occur. The unit used in cash flow is the period, which may be expressed in days, months, or years, depending on the project. In the present study, the period of ten years was the best option. The USD exchange rate was BRL 3.79, calculated based on the average dollar exchange rate between January 2015 and December 2020, according to the Central Bank of Brazil.

The financial indicators hereby used were:

Minimum Acceptable Rate of Return (MARR) – Consists of analyzing the cash flows of the investment project, defining its respective economic and financial viability. This rate may be based on the opportunity cost of applications that exist in the market or on the organization’s cost of capital through the average among sources of funds (Camargos, 2013). The MARR was established for a five-year period considering the rate of the Special Settlement and Custody System (SELIC), as practiced in the Brazilian financial market. For the estimated Beta, data from the meatpacking plant of JBS were used, since it is the largest protein seller in Brazil. The pre-fixed treasury bond was used as the Risk-Free Bond. The indicators used in the analyses are organized by financial institutions; in this case, the Ibovespa is an indicator calculated by the B3 (São Paulo Stock and Merchandise Exchange); another index the IPCA (Consumer Price Index), applied in financial transactions. Thus, taking into account the IPCA, an index determined at 1.01% per month, that is, 12% per year, the Minimum Rate of Attractiveness was 12%.

Net Present Value (NPV) - The positive difference between revenues and costs corrected at a given discount rate. The project is considered viable when the value of this method is greater than zero (Rezende & Oliveira, 2008). The NPV is the sum of the inflows and outflows of a cash flow at the start date (Hoji, 2012).

Internal Rate of Return (IRR) - It is the discount rate (interest rate) that equals inflows to outflows at a single moment. It is the interest rate that generates a NPV equal to zero. IRR generally assumes all values corresponding to the cashflow to be updated to the moment zero (Assaf Neto, 1992).

Modified Internal Rate of Return (MIRR) – It is an analysis method that improves the IRR, reducing whatever limitations of this technique. This method consists of projecting positive cash flows into the future, in which the same IRR is reinvested and leads to present negative cash flows, which results in a new cash flow composed of different rates (Casarotto Filho & Kopittke, 2010).

Discounted Payback - Considers the time value of money and, for this reason, it should be considered the most appropriate indicator since, when disregarding the consequences of holding money over time, one may be associating a lower risk to the investment proposal (Assaf Neto & Lima, 2009).

Profitability Index (PI) - Determined by dividing the present value of net cash benefits by the present value of capital disbursements, consisting in the ratio between the present value of cash inflows and the value of cash outflows (Ross *et al.*, 1995; Brigham & Houston, 1999).

Equivalent Uniform Annual Value (EUAV) - Used in renewable investments in order to build an uniform annual series that portrays the discounted cash flow for a given MRA. The scenario resulting in the highest EUAV values will be the best (Ross *et al.*, 1995).

Monte Carlo Method – Random and pseudo-random numbers are used to sample a probability distribution. This method supports the administrator in her/his decision-making since the results achieved with its execution indicate probabilistic values rather than binary responses. The Monte Carlo simulation can define several scenarios and their probability of happening (Galvão, 2005). The simulation starts with the conversion of random numbers into variable observations, subsequently defining a probability arrangement that is close to the real distribution of the variable. There are three fundamental steps for simulating an investment option, namely: defining the essential variable equations for modeling cash flows; determining the probabilities of the occurrence of forecast errors for each parameter and the ratio of forecast errors; and performing random combinations with numbers of distributions of forecast errors of variables and, through this step, performing the resulting cash flow calculations.

RESULTS AND DISCUSSION

Regardless of the results obtained in this study, it is important to emphasize that each system has unique characteristics. Comparisons may be made, but it is not possible to state that one production model is better or worse than the other since, according to Lay Jr *et al.* (2011) and Janczak & Riber (2015), animals may experience stress in all production systems and no system is exempt from events that affect animal welfare standards. Thus, there is consensus regarding stress reduction during the breeding of laying hens, and consequently greater welfare. The adoption of each type of housing has considerable impact on the welfare of animals. Correct handling, feeding, and environment conditions are essential to improve the comfort of birds and egg production.

After economic feasibility analyses, positive results were observed in all scenarios, showing that they are economically viable and have the potential for return of the investments (Table 2). The results of the Cage-Free production system may be considered attractive scenarios, as they show economic returns.This scenario meets the requirements of several national laws that require animal welfare and of consumers who prefer products originating from animals bred in proper welfare conditions.

Table 2 – Indicators of economic feasibility analysis for different scenarios of production systems for *Hy-Line Brown* laying hens and different housing densities.

Evaluation criterion	Production System				
	Conventional 1,500 cm²/bird	Conventional 750 cm²/bird	Conventional 398 cm²/bird	Cage-Free 7 birds/m²	Cage-Free 13 birds/m²
Discounted payback	6 years	3 years	2 years	3 years	2 years
NPV	US$ 69,911.54	US$ 664,518.72	US$ 1,685,088.80	US$ 552,795.57	US$ 1,398,977.75
EUAV	US$ 11,636.04	US$ 110.602.21	US$ 422,945.67	US$ 92,007.06	US$ 232,845.25
IRR	14.02%	39.99%	76.99%	42.22%	78.16%
MIRR	12.19%	21.27%	28.99%	21.77%	29.19%
PI	1.16%	2.52%	4.68%	2.63%	4.74%

Net Present Value (NPV), Equivalent Uniform Annual Value (EUAV), Internal Rate of Return (IRR) Profitability Index (PI), Modified Internal Rate of Return (MIRR).

The end of the period was considered for the analysis of discounted payback. It was five-six years for Conventional 1,500 cm²/bird, two-three years for Conventional 750 cm²/bird, one-two years for Conventional 398 cm²/bird, two-three years for Cage-Free 7 birds/m², and one-two years for Cage-Free 13 birds/m².

In the analysis of discounted payback, the best result was for the Cage-Freesystem with 13 birds/m² and for the Conventional system with 398 cm²/bird. The return of the initial investment was after two years. Such results may be explained by the greater number of animals housed in this system, which results in a greater number of eggs for the same space, thus resulting in a greater revenue per area unit. As for the Conventional system with 750 cm²/bird and the Cage-Free system with seven birds, the result was a period of three years for the return on invested capital, which was an intermediate result. The longest period was that of the Conventional system with 1,500 cm²/bird, which corroborates Petek *et al.* (2014), who observed that the greater the number of animals housed per unit of space, the greater the revenue per unit and the shorter the time for the return of investment.

The period for return on investment, i.e., Discounted Payback, considers the time-value of money and should thus be considered the most appropriate indicator, since when disregarding the consequences of holding money over time, one may be associating a lower risk to the proposed investment (Assaf Neto & Lima, 2009).

Taborda *et al.* (2022), considering a density of seven birds per m², similarly to this study, concluded that the production of laying hens is feasible. However, the authors found a longer investment payback period than that of this study (seven years). This shows that, in addition to density, other factors may affect the economic viability of the Cage-Free system.

Alternative production systems in accordance with animal welfare use capital goods that have high costs, such as a the large space offered to animals. This implies a higher capital per animal ratio, thus increasing production costs (Gameiro *et al.*, 2017) and consequently the investment recovery period. This greater investment must be offset by a greater revenue at the end of the production process (Gameiro *et al.*, 2017) to ensure the economic viability of the activity.

Although high density produces attractive results to investors, its use should be avoided, as it is contrary to the precepts of animal welfare and causes stress to animals. Therefore, according to the Brazilian Aviculture Union (2008), restrictions of high density determine that the housing density of birds must allow for the movement of animals without crowding. According to the FAWC (2009), animals must be free to manifest their natural behavior: birds must have freedom to perform movements and express a natural behavior typical of each species. Laying hens reared in high densities constantly have little space available and end up not displaying their usual behavior.

The positive value of the Net Present Value and revenue calculations within a period of ten years indicate that the analyzed project is economically viable. Evaluating the scenarios of the present study, all of them have a positive NPV, indicating that any of the chosen situations will have a return on invested capital. Taking the NPV as a criterion for comparison between scenarios, the one that presented the lowest return for the implementation of a project was the conventional system with 1,500 cm²/housed bird. The best scenario was the conventional system with 398 cm²/bird, which presented an NPV of US$ 1,685,088.80, followed by Cage-Free with 13 birds/m² with a NPV of R$ 1,398,977.75. The Cage-Free system with seven birds per m² presented a lower NPV compared to conventional systems, possibly because it is linked to higher costs of execution and maintenance. The NPV depicts revenues in absolute numbers of investment, which is measured by the difference between the present value of cash inflows and the present value of cash outflows (Assaf Neto, 1992).

The highest IRR values found were in the scenarios of higher densities, namelyCage-Free with 13 birds/m² and Conventional with 398 cm²/bird. The lowest IRR was observed in the Conventional system with 1,500 cm²/bird, as result of the increase in production costs per bird and the low revenue due to low egg production. For the MIRR, the results found in all scenarios showed higher values in comparison to those of the MRA, established at 10.52% according to the SELIC-based calculation criteria, indicating that all scenarios are feasible.

Maas *et al.* (2020) analyzed a production system for laying hens in an automated poultry house with characteristics similar to those defined for the scenarios in the present study. The authors found a payback result of 7.44 years for the return on investment, a value that is higher than the one found in this study. An IRR of 14.12% was found by Maas *et al.* (2020), which is above the MRA value and results in a higher-than-expected return on investment. The NPV resulted in US$ 25,178.15, which demonstrates the feasibility of the project in face of the results for the scenarios of conventional systems analyzed in this study.

The Profitability Indexes indicate that the Cage-Free scenario with 13 birds/m² and the Conventional scenario with 398 cm²/bird have the best operational efficiency, in percentage. The findings are related to higher investments in these systems, and the amount of return (annual profitability) will also be higher in absolute values.

Regarding the values of EUAVs, the annual expectation of gains from the investment in the Conventional system with 398 cm²/bird will be the highest, followed by the Cage-Free system with 13 birds/m². The Conventional system with 750 cm²/bird is the third best result, followed by the Cage-Free system with 7 birds/m², which are the best results observed here.

Simulations of NPV were performed using the Monte Carlo Method. The NPV was used as an indicator in the Monte Carlo Method. The standard deviations of revenues, costs, operation, and MRA were considered.

The analyses resulted in 14,000 simulations for each of the five scenarios. All showed a satisfactory probability of success. The different possibilities of results indicate that there is a high chance of good financial returns in all scenarios, since the possibility of the NPV being greater than zero is very high. For almost all simulations performed in all scenarios, the probabilities of repeating these results of financial return are greater than 90% (Table 3).

Table 3 – Monte Carlo Method Results (14,000 Simulations).

Scenario	Birds/m²	NPV>0	SD	Average NPV
Conventional	04	93.3%	US$ 26,987.36	US$ 70,064.17
Conventional	08	100.0%	US$ 1,865.50	US$ 644,723.42
Conventional	15	100.0%	US$207,973.99	US$ 1,685,797.88
Cage-Free	07	100.0%	US$ 19,897.73	US$ 555,095.41
Cage-Free	13	100.0%	US$ 34,515.69	US$ 2,145,913.47

NPV: Net present value. SD: Standard error.

The average NPV for the scenario of cages with four birds per m² (1,500 cm²/bird) was US$ 70,064.17; for the scenario of cages with eight birds per m² (750 cm²/bird) it was US$ 644,723.42; for the scenario of cages with 15 birds per m² (398 cm²/bird) it was US$ 1,685,797.88; for the Cage-Free scenario with seven birds per m² it was US$ 555,095.41; and for the Cage-Free scenario with 13 birds per m² it was US$ 2,145,913.47.

According to the evaluation of economic viability, despite variations in indicators, the results of all scenarios were positive. Conventional systems showed superiority in terms of NPV, which is related to the lower production cost in these systems. Schwartz & Gameiro (2017) observed similar results. It is important to highlight that the most attractive scenarios for investments were those that extrapolated the recommended densities to maintain animal welfare. This shows that increasing the density of birds promotes greater revenues in relation to a same area, but this reality is not in accordance with animal welfare directives. Therefore, we emphasize that densities that are in accordance with animal welfare must be respected. The adoption of this practice, according to the results of the present study, creates positive results to the investor, that is, an economically viable activity. In this sense, eggs from hens raised in accordance with welfare principles are niche markets for consumers who are often willing to pay a higher price for the products. Thus, even if production costs are higher, it is possible that this profit margin allows for the recovery of most of the initial investment.

CONCLUSION

Conventional and Cage-Free production systems for laying hens are economically viable at densities of 1,500 cm²/bird, 750 cm²/bird, and 398 cm²/bird (conventional), as well as 7 birds/m² and 13 birds/m² (Cage-Free). According to the production scenarios analyzed here, there is a faster return on investment at higher densities. However, higher densities are less suitable of laying hens' well-being, which may support a decision of adopting intermediate densities for both systems. As this is a simulation work, there may be variations in the results in the implementation of both systems. Even when considering possible variations, all scenarios show a possibility of return on investment to the investor, indicating that this study may be used as an auxiliary tool in decision-making regarding the implementation of conventional and Cage-Free systems.

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