R. Bras. Zootec., 53:e20230043, 2024
https://doi.org/10.37496/rbz5320230043

Animal production systems and agribusiness
Full-length research article

Revista Brasileira de Zootecnia

Brazilian Journal of Animal Science
e-ISSN 1806-9290
www.rbz.org.br

Economic viability analysis of mechanization in broiler chicken harvesting

Fábio Mascarenhas Dutra[1], Rodrigo Garófallo Garcia[1], Rafael Martins Noriller[1], Erlaine Binotto[1], Maria Fernanda de Castro Burbarelli[2], Claudia Marie Komiyama[2], Fabiana Ribeiro Caldara[2], Jean Kaique Valentim[3]*

[1] Universidade Federal da Grande Dourados, Programa de Pós-Graduação em Agronegócios, Dourados, MS, Brasil.
[2] Universidade Federal da Grande Dourados, Programa de Pós-Graduação em Zootecnia, Dourados, MS, Brasil.
[3] Universidade Federal de Viçosa, Departamento de Zootecnia, Viçosa, MG, Brasil.

***Corresponding author:**
kaique.tim@hotmail.com

Received: April 8, 2023
Accepted: December 17, 2023

How to cite: Dutra, F. M.; Garcia, R. G.; Noriller, R. M.; Binotto, E.; Burbarelli, M. F. C.; Komiyama, C. M.; Caldara, F. R. and Valentim, J. K. 2024. Economic viability analysis of mechanization in broiler chicken harvesting. Revista Brasileira de Zootecnia 53:e20230043.
https://doi.org/10.37496/rbz5320230043

Editors:
Marcos Inácio Marcondes
Valdir Ribeiro Junior

ABSTRACT - This study aimed to analyze the economic viability of the implementation of a mechanized harvesting of broilers where the activity is carried out entirely manually. The viability indicators used were net present value (NPV), net future value (NFV), net uniform value (NUV), discounted payback (DP), and internal rate of return (IRR). Scenario analysis, sensitivity, and Monte Carlo simulation were performed in the present study. The results showed that the initial investment was US$ 1,868,302.76. The average price paid by the slaughterhouse to third-party manual harvesting companies was US$ 18.17 per thousand broilers, which was converted into revenue in the cash flow of the project. The cash flow result was positive at US$ 22,256.14 over the entire study period considering a daily catch of 144 thousand broilers. The results of the economic viability analysis were NPV of US$ 64,786.23, NFV of US$ 333,382.11, NUV of US$ 735.19, DP of 13.82 years, IRR of 0.965 monthly, and modified IRR of 0.933 monthly. These values prove the economic viability of implementing the project considering the market conditions at the time of the study. The analysis of scenarios showed great sensitivity to the exchange rate and the price of fuels. The Monte Carlo simulation highlighted a moderate risk of negative NPV, emphasizing the importance of considering this variable when making decisions. Despite these challenges, the potential benefits of mechanized harvesting, such as increased efficiency and reduced labor costs, make it a promising alternative to manual harvesting, even for small to medium-sized poultry industries.

Keywords: exchange rate, fuel, Monte Carlo analysis, poultry raising, scenario, sensitivity

1. Introduction

The harvesting stage has always been an inefficient and unhealthy activity due to the lack of adequate working conditions and the low level of labor qualification. The combination of these factors has generated a high cost for industries. Thus, this activity needs new methods and equipment aiming to reduce losses with carcass disposal, new loading and transport techniques, and techniques to reduce competitiveness among chickens, reducing stress and the refused animals (Wolff et al., 2019).

An alternative to minimize the effects of this bottleneck, which has already been adopted in the Netherlands and the United States, is the mechanization of broiler harvesting. Two major advantages of mechanized broiler harvesting are the lack of contact between animals and humans and the transport in a horizontal position, both of which reduce animal stress. In addition, the risk of injury to both broilers and workers during mechanized harvesting is lower compared with that of manual harvesting (Mönch et al., 2020). Mechanization in the harvesting process offers benefits such as reduced operational costs and a lower risk of injuries to both operators and animals (Werner et al., 2023); however, manual harvesting remains the major approach in the broiler production industry (Dutra et al., 2021). The comparison between these methods is relevant to assess the return on investment and the economic impact on the poultry industry.

Nevertheless, research on the economic feasibility, considering the specificities of each production context, is scarce or nonexistent. This gap in the literature emphasizes the importance of dedicated studies to shed light on the economic aspects related to the adoption of mechanized harvesting, providing valuable insights to guide the poultry sector towards a more efficient and sustainable approach.

When analyzing the viability of a project, the first important point is time, that is, the determination of the time frame required to recover the invested capital. In this study, the time analyzed for the return on the invested value was the useful life of a 15-year-old harvesting machine; at the end of this period, the machine will be sold as scrap. For Sinden (2016), the economic viability analysis is the systematic process of comparing benefits and costs to assess the suitability of a project. Riegg Cellini and Edwin Kee (2015) define cost-benefit analysis as a process of identifying, measuring, and comparing the benefits and costs of a project.

Thus, the methodology used was the survey of all costs due for the project implementation followed by a calculation to define operating revenue. Based on this, this study developed cash flow and the investment analysis techniques such as net present value (NPV), internal rate of return (IRR), modified internal rate of return (MIRR), discounted payback (DP), and net uniform value (NUV). Finally, a scenario and a Monte Carlo analysis were conducted.

In this scenario, the question that guides this study is: what are the results of economic viability analysis in the mechanization of broiler harvesting? To answer this question, the present economic feasibility study was carried out through a survey of all direct and indirect costs, the possibilities for generating revenue, and the main variables of this activity which can influence the possible results.

2. Material and Methods

The information and data needed for the calculations represent the reality of Brazilian companies in the period between January 2015 and December 2019. This study does not use data from 2020 due to the volatility caused by the Corona Virus (Covid-19) pandemic.

Two main aspects should be considered: the cost of manual harvesting carried out by an outsourced company and the cost of mechanized harvesting carried out by the company itself. This study took as a reference any slaughterhouse plant with a slaughtering capacity of 144 thousand birds/day, as it is the maximum capacity of the harvesting machine.

The calculations considered the implantation of a complete mechanized harvesting system. From this base scenario, it was possible to analyze possible scenarios because of possible variations in the market and daily production.

The necessary information for elaborating the cash flow and calculating viability indicators was provided by two companies in the poultry harvesting sector located in the state of Santa Catarina, Brazil. The companies were selected for their extensive performance and representativeness in the sector, as well as for their availability to collaborate with this research. The interviews took place between June and December 2020 via telephone to identify the description of the equipment, labor, and of costs for implementing manual and mechanized harvesting.

The calculation considered that the initial investment is fully financed by the company, and it was not necessary to obtain third-party loans. Gross revenue was obtained from the amount saved with labor and fuel.

The exchange rate and the price of the fuel (Diesel S10) were calculated based on the average price of the Euro and the average fuel market values between January 2015 and December 2019 (Agência Nacional do Petróleo, 2020; Banco Central do Brasil, 2020).

To calculate the capital asset pricing model (CAPM), the monthly returns obtained in the period from January 2015 to December 2019 (60 observations) of the company JBSS3 (i.e., a prominent company in agribusiness and meat marketing on B3) were considered and for the market return the IBOVESPA (i.e., the most relevant index of B3). Through the covariance of the variables and the variance of the market return, it was possible to establish the CAPM Beta. In time, the P-value found of the CAPM Beta was 0.00101. The formula used to calculate Beta is:

$$\beta_i = \frac{Cov(R_i, R_m)}{\sigma^2(R_m)}$$

The minimum attractiveness rate (MAR) was calculated using the CAPM. This model considers an average risk-free rate (Selic rate: 9.26%), the Beta index (20.15% or 0.2015), and finally the market rate of return (Ibovespa: 20.59%). In this case, the calculation presented a MAR of 11.54% per year.

2.1. Mechanized harvesting, transport, and unloading system for broilers

The harvesting phase is one of the stages that most demands attention and care when it comes to animal welfare. It may also cause economic losses for both industry and producers. This stage occurs inside poultry houses, beginning with the pre-slaughter fasting and ending with the loading of boxes on the transport truck (Benincasa et al., 2020).

There are several methods of manual collection: by the animal's back, paw, wings, and neck. All of them cause some damage to animal welfare and the quality of the products (Alonso et al., 2020). The literature highlights that among the current manual harvesting methods, the one with the lowest percentage of injury is harvesting by the back. However, this process takes longer and requires much physical effort by workers (Kittelsen et al., 2018). This scenario generates studies on the mechanization of this activity for almost 40 years in search of economically viable solutions to minimize losses and consider animal welfare (Nelson, 1984; Kettlewell and Turner, 1985; Mitchell and De Boom, 1986; De Koning et al., 1987).

In this sense, a Dutch company (Peer System) in partnership with a Danish company (JTT Conveying JSC) developed in 2002 an automated harvesting system that involved all stages of pre-slaughter, from the harvesting of animals, boarding, passing through transportation, disembarking, up to washing, and disinfecting transport trailers (Figure 1) (Zezula, 2020).

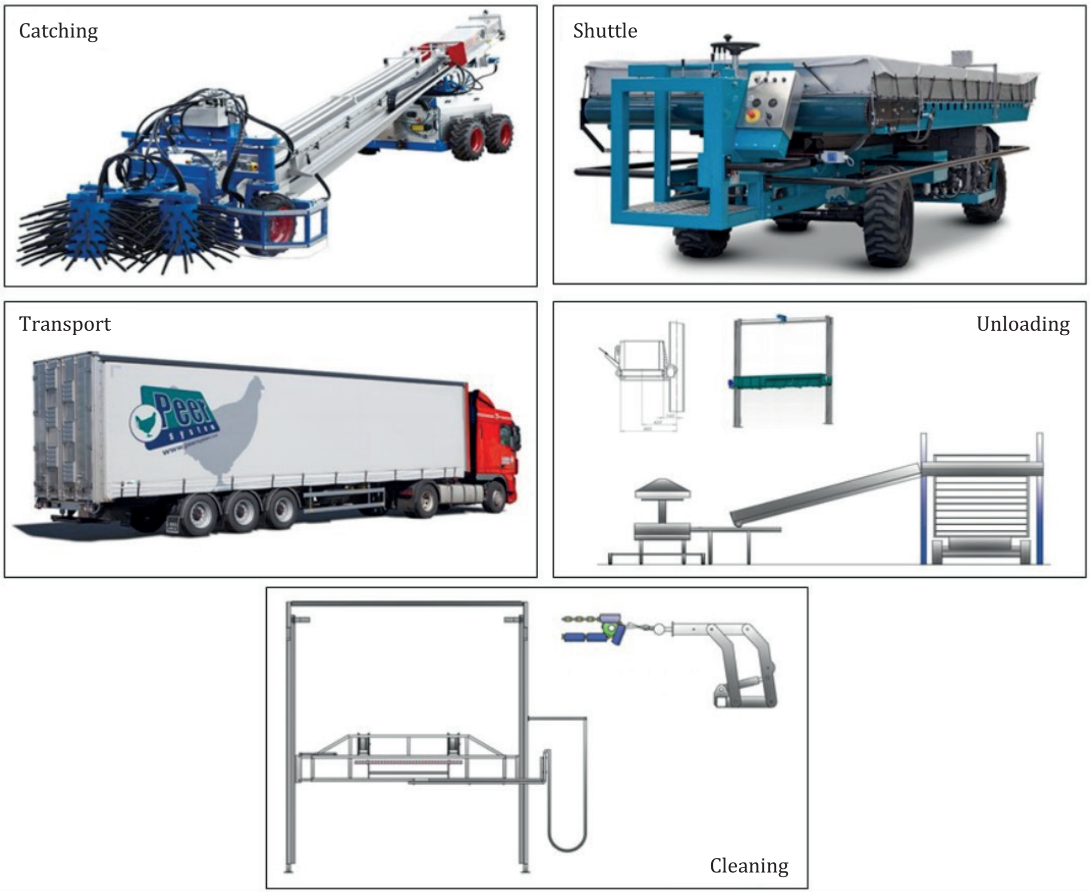
The first stage of the system is performed by a harvesting machine that has a frontal collection unit containing three hydraulically driven rotating cylinders. The surface of the cylinders is covered with long, flexible rubber fingers that force the birds to climb on a conveyor belt and then accommodate in a shuttle where the second loading stage happens. The harvesting machine can collect 9,000 birds per hour, making work more efficient and reducing the physical damage and stress of animals. In addition, it requires only one operator to do all of its movement at a distance using a remote control (Peer System, 2012).

The shuttle is the equipment responsible for the second stage of the system. It receives birds from the first stage and then conducts and packs them in the transport trailer. Its load capacity is 900 kg of birds at a time. The chickens are automatically weighed. At least two shuttles are required for each harvesting machine to avoid interruption of the process.

The transport of the birds to the slaughterhouse is the third stage of the system. It is composed of a transport trailer with a load capacity of 18 tons. Inside, the animals are accommodated in ten internal layers that provide a greater load capacity per vehicle. During the trip, the birds are calm due to a mechanical ventilation system that controls the humidity and internal temperature of the trailer.

The fourth stage of the process consists of landing the birds in the slaughterhouse using an automated conveyor belt. This process requires the presence of only one operator to monitor the discharge, which prevents the birds from heap causing scratches and other types of bruising.

In the transport trailer, the slaughterhouse does not need machines to stack, unstack, or wash the boxes and containers since the conventional boxes are no longer used, requiring only cleaning and disinfection of the transport trailer using a system developed for this purpose. This is the fifth and final stage of the system (Figure 1).



Source: Peer System (2012).

Figure 1 - Model of machines and equipment used in the study.

2.2. Investment valuation methods

According to Ross et al. (2015), among the techniques used for economic feasibility analysis, the first is discounted payback. It is an application widely used in investment analysis that translates the time needed to recover the value of the investment made. This indicator is compared with the maximum period of recovery of invested capital previously defined by the investor. If the discounted payback is shorter than this period, the project must be accepted; if it is longer, it must be rejected. Finally, if the discounted payback is equal to the term stipulated by the investor, the decision is indifferent, and the investment is at the discretion of the decision-maker.

The NPV considers the value of money over time and also the opportunity cost of capital, allowing a direct comparison with alternatives to it. The NPV is the algebraic sum of the cash flow balances discounted from the interest rate for a given date (Woiler and Mathias, 1996; Ross et al., 2015).

The calculation of NPV is, in a simplified way, the difference between the total revenue generated by a project and its total costs, all at present value, that is, a project is viable or not upon deducting the cost of the initial investment from the current value of a uniform series of future capital by discounting an appropriate interest rate. The equation used to calculate the NPV is:

$$NPV = \sum_{j=1}^{n} \frac{CF_J}{(1+k)^J} - Inv \quad (1)$$

in which CF_j is the cash flow (benefit) for each period; k is the cost of capital or MAR, represented by the minimum required return; *Inv* is the expected investment at time zero; and n is the number of periods analyzed (Ross et al., 2015).

To analyze the NPV, it is possible to consider revenues greater than costs; therefore, NPV > 0. Thus, the investment will be recovered and will generate extra profit on the present date (t = 0) (Assaf Neto, 2010). In this case, it can be concluded that the project is economically viable and must be implemented. If NPV < 0, the project is economically unfeasible and should not be carried out. Finally, if the NPV = 0, the feasibility of the project is considered neutral.

Another way to assess the viability of a project is through the NUV, also known as equivalent uniform worth (EUW). The NUV consists of finding through the MAR a uniform annual series equivalent to the cash flow of the investment, that is, the costs and benefits of a cash flow are transformed into an annual, uniform, and equivalent values, so that they can be compared. Therefore, if the NUV > 0, the benefits will outweigh the costs, and the project is considered viable. When the benefits are less than the costs, the NUV is negative, thus making the project unfeasible. Finally, when costs and benefits are equal, it is indifferent to the decision-maker whether or not to invest. The equation used to calculate the NUV is:

$$NUV = \text{NPV} \times \left[\frac{(1+i)^n \, x \, i}{(1+i)^n - 1}\right] \quad (2)$$

in which i is the minimum attractiveness rate and n is the analyzed period.

The IRR or MIRR is important for analyzing high initial investments that contribute to production over various periods, such as in agricultural and industrial enterprises (Yates et al., 2007). The IRR is the discount rate that equates, at a given moment, the inflows with the outflows provided for in cash. The equation used to calculate the IRR is:

$$IRR = I_0 + \sum_{t=1}^{n} \frac{I_t}{(1+k)^t} \quad (3)$$

in which I_0 is the investment amount at time zero (project start), I_t is the investment amount expected at each subsequent moment, and k is the periodic equivalent annual rate of return.

As a criterion for selecting the viability of the project, it is necessary to compare the IRR with a MAR, that is, with a minimum interest rate that the investor intends to obtain with its investment, i.e., the rate from which the investor considers that it is making financial gains. Therefore, if IRR (or MIRR) is greater than MAR, the project is considered economically viable and can be accepted; if IRR (or MIRR) is less than MAR, the project must be rejected; lastly, if IRR (or MIRR) is equal to MAR, it is irrelevant to carry out the project since the return is null (Casarotto Filho and Kopittke, 2010).

The most widely used method for calculating the MAR is the CAPM, which determines a certain rate of return for each level of risk assumed (Póvoa, 2007; Ross et al., 2015). The equation to calculate MAR using CAPM is:

$$E(R) = Rf + \beta(Rm - Rf) \quad (4)$$

in which $E(R)$ is the minimum expected return calculated by the CAPM model, Rf is the risk-free rate, β is the Beta index that indicates the risk associated with the investment, and Rm is the market rate of return.

The CAPM method was used to evaluate the economic viability in projects of replacing incandescent lamps with led lamps in dark house aviaries, determining the shareholder rate of return of a commercial real estate enterprise, evaluating viability in milk-producing goats, and assessing the viability of cattle confinement (Leal et al., 2018; Cerávolo and Hochheim, 2022).

2.3. Risk analysis involving scenario analysis and Monte Carlo simulation

Due to possible fluctuations in the company or the market, which may change project costs, some factors directly affect the projected cash flow. This indicates why it is necessary to carry out a risk analysis to measure the extent of the effects. For this, two methods are the most used, the first is the analysis of scenarios and the second is the Monte Carlo simulation (Souza and Brandalise, 2020).

The analysis of scenarios studies a series of different situations that the project may confront considering relations between variables and their simultaneous changes. This technique compares favorable and unfavorable circumstances with the real situation; however, it allows for examining the feasibility of investment in pessimistic, realistic, and optimistic scenarios (Correia Neto, 2009; Damodaran, 2009).

The pessimistic scenario is when there is an unfavorable combination of variables that compound the cash flow and leads to a result that is less than realistic and maybe even negative. The optimistic scenario is a possibility of the simultaneous occurrence of a series of favorable behaviors of cash flow variables. Its result is more interesting than the result of a more realistic scenario, leading to a higher project value. From the elaboration of these two scenarios, it is possible to find the indicators for feasibility analysis and compare them with the realistic scenario (Correia Neto, 2009).

However, the creation of different scenarios is limited due to the existence of many possibilities. Therefore, to assist in the creation and analysis of these scenarios, the Monte Carlo method is used. This method uses computational tools to simulate future scenarios based on variables whose values are randomly generated within a probability of distribution. These random variables are called stochastic (Souza and Brandalise, 2020).

According to Correia Neto (2009), the NPV can be used as a stochastic variable. However, other accounts whose future behaviors are certain and predictable with more assertiveness can be used without considering a random behavior.

The main contribution of the Monte Carlo simulation is that the decision-maker can evaluate scenarios through various interactions between the most important variables of the project (Damodaran, 2009; Assaf Neto, 2010; Ross et al., 2015).

3. Results

3.1. Initial investment

As some of the equipment is imported from the Netherlands and its price is quoted in Euro, it was necessary to determine the average exchange rate for the period analyzed to convert it into Real between January 2015 and December 2019. The average value of one Euro for the analyzed period was R$ 3.97. After performing all calculations in Brazilian Reais, the respective values were converted into US Dollars at an exchange rate of R$ 3.52.

In addition to the unit value of the equipment, freight costs, taxes, and fees are also part of the calculation. The only item with an import tax is the transport trailer; the other items do not have this tax. Each harvesting machine costs US$ 97,140.44 plus 30% freight and taxes. The final value is US$ 126,282.57 per machine (Table 1). The shuttle platform has a unit cost of US$ 112,954.00 plus 30% shipping and taxes, but two shuttles are required, which totals US$ 293,680.40.

Table 1 - Vehicles, machines, and equipment necessary for the mechanization of harvesting

Description	Unit value	Total value	Freight + taxes = 30%	Grand total + charges	Grand total
1 - Harvesting machine	US$ 97,140.44	US$ 97,140.44	US$ 29,142.13	US$ 126,282.57	US$ 126,282.57
2 - Shuttle platform	US$ 11,2954.00	US$ 225,908.00	US$ 67,772.40	US$ 293,680.40	US$ 293,680.40
3 - Transport trailer[1]	US$ 248,498.80	US$ 745,496.40	US$ 313,108.49	US$ 1,058,604.89	US$ 1,058,604.89
1 - Unloading station	US$ 62,124.70	US$ 62,124.70	US$ 18,637.41	US$ 80,762.11	US$ 80,762.11
1 - Washing tower	US$ 33,886.20	US$ 33,886.20	US$ 10,165.86	US$ 40,052.06	US$ 40,052.06
1 - Sider trailer	US$ 38,890.87	US$ 38,890.87	-	-	US$ 38,890.87
4 - Truck tractor	US$ 107,872.48	US$ 431,489.94	-	-	US$ 431,489.94
1 - Popular car	US$ 11,355.00	US$ 11,355.00	-	-	US$ 11,355.00
4 - Sale of trucks	US$ 42,581.24	US$ 170,324.98	-	-	US$ −170,324.98
2,500 - Shipping boxes	US$ 17.03	42,581.24	-	-	US$ −42,581.24
					US$ 1,872,211.62

[1] In addition to the 30% freight and taxes, the transport trailer still has a 12% import tax.

3.2. Fixed and variable costs

To calculate the fixed cost, two shifts per day were considered. This study considered four truck drivers, four harvesting operators, a truck washer, an extra employee to cover the holidays of the entire team, and lastly a team supervisor. In this format, the company had a fixed monthly cost of US$ 10,653.49 including salaries, labor charges, thirteenth salary, and holidays, generating an annual fixed cost of US$ 127,841.83 (Table 2).

Table 2 - Calculation of fixed cost

Description	No.	Monthly salary	13th salary	Holidays	FGTS	INSS	Total unit	Grand total
Drivers	4	529.17	44.10	58.78	50.56	169.39	852.00	3,408.02
Technical operator in harvesting	4	709.69	59.14	78.83	67.81	227.17	1,142.65	4.570.60
Washer	1	357.50	29.79	39.71	34.16	114.44	575.61	575.61
Extra employee[1]	1	576.51	48.04	64.04	55.09	184.54	928.23	928.23
Supervisor	1	709.69	59.14	78.83	67.81	227.17	1,142.65	1,142.65
Feeding	10							28.39
-	-	-	-	-	-	-	Monthly fixed cost	10,653.49
-	-	-	-	-	-	-	Annual fixed cost	127,841.83

FGTS - Fundo de Garantia do Tempo de Serviço (Length-of-Service Guarantee Fund); INSS - Instituto Nacional do Seguro Social (National Institute of Social Security.)
[1] The extra employee is needed to replace those on holidays.

3.3. Cash flow

In the preparation of the cash flow, this study considered a productive timeline of 180 months, which is equivalent to fifteen years of the useful life of the harvesting machine.

For the sources of revenue, this study used the calculation of how much the industry would save by not paying for the work of outsourced companies that until then carried out the manual harvesting of birds. In a previous survey of the last five years, the average value was US$ 18.17 per thousand birds.

As an employee is no longer necessary to wash the shipping boxes, this cost is considered revenue. Similar to Zaroni et al. (2019), there was a difference in fuel cost, with the number of trips decreasing considering that the transport trailer has a capacity for 6,668 birds and a four-axle truck has a capacity for 5,555 birds. Thus, with the mechanization of harvesting, a slaughterhouse that slaughters 144,000 birds/day saves US$ 61,089.84 per month, which enters the cash flow as revenue (Table 3). The cash flow shows the values related to the initial investment in year zero and other forecasts for the following months until the fifteenth year of the project.

Table 3 - Cash flow for a daily slaughter of 144 thousand birds

Bills	Jan 2021	Feb 2021 to Nov 2036	Dec 2036
Gross sales revenue	-	US$ 61,089.84	US$ 61,089.84
(−) Total variable costs and expenses	-	US$ 22,671.31	US$ 22,671.31
(=) Margin of contribution	-	US$ 38,418.53	US$ 38,418.53
(−) Total fixed costs and expenses	-	US$ 10,653.42	US$ 10,653.42
(−) Depreciation	-	US$ 11,562.26	US$ 11,562.26
(=) Profit before income tax	-	US$ 16,202.85	US$ 16,202.85
(−) Income tax and social contribution (34%)	-	US$ 5,508.97	US$ 5,508.97
(=) Net operating income	-	US$ 10,693.88	US$ 10,693.88
(+) Depreciation	-	US$ 11,562.26	US$ 11,562.26
(=) Operating cash flow	-	US$ 22,256.14	US$ 22,256.14
(+) Fixed investment	US$ −1,868,314.57	-	-
(+) Working capital	US$ −28,174.07	-	US$ 28,173.89
(=) Free cash flow	US$ −1,896,488.64	US$ 22,256.14	US$ 50,430.04

3.4. Economic viability indicators

After applying investment evaluation techniques on the amounts presented by the cash flow, the economic viability indicators (Table 4) were obtained.

Table 4 - Results of economic and financial viability indicators for a daily slaughter of 120 thousand birds

Indicator	Result
Net present value (NPV)	64,786.23
Net future value (NFV)	333,382.11
Equivalent uniform annual worth (EUAW)	735.19
Discounted payback (DP)	13.82
Internal rate of return (IRR)	0.965%
Modified internal rate of return (MIRR)	0.933%

3.5. Analysis of scenarios and Monte Carlo simulation on NPV

Considering the risks and sensitivity of the project according to Zaroni et al. (2019), this study simulates different scenarios about the number of broilers slaughtered per day according to the harvesting capacity by the machine; therefore, this study evaluated the conditions under which the project is economically viable to carry out the investment (Table 5).

Considering the base scenario (144 thousand birds/day), the minimum and maximum variations found between 2015 and 2019 were evaluated both for exchange rate and fuel price. In this case, the pessimistic and optimistic scenarios were considered concerning the realistic scenario. Ben and Aimi (2017) highlighted the importance of monitoring the exchange rate, since this variable may turn import operation unfeasible when it presents high values for foreign currency that increase the acquisition costs (Table 6).

If the price of a liter of diesel cost US$ 0.85, the NPV would be US$ 165,479.35; on the other hand, if the value of the fuel rises to US$ 1.04, the maximum value found in the period analyzed, the NPV would be US$ −38,344.80, thus, a 10% increase in the price of fuel causes a 123% decrease in NPV (Table 5).

Table 5 - Simulation based on the number of birds captured by machine and slaughtered per day

No. of machines	Birds/day[1]	NPV	NFV	EUW	DP	IRR	MIRR
1	144	64,786.23	333,382.11	735.19	13.82	0.96536	0.9331
2	288	56,405.55	290,248.47	640.08	14.47	0.93626	0.92241
3	432	90,300.73	464,676.67	1,024.72	14.44	0.93761	0.92291
4	576	536,020.79	2,758,298.32	6,082.69	12.72	1.02309	0.95397
5	720	623,447.10	3,208,183.58	7,074.79	12.86	1.01478	0.95099
6	864	646,345.03	3,326,013.54	7,334.64	13.13	1.0004	0.94582
7	1,008	1,092,065.08	5,619,635.19	12,392.61	12.39	1.04183	0.96065
8	1,152	1,125,960.27	5,794,055.72	12,777.24	12.62	1.02841	0.95587
9	1,296	1,171,110.72	6,026,394.49	13,289.60	12.78	1.01944	0.95266
10	1,440	1,659,106.64	8,537,562.64	18,827.32	12.26	1.05029	0.96365

NPV - net present value; NFV - net future value; EUW - equivalent uniform worth; DP - discounted payback; IRR - internal rate of return; MIRR - modified internal rate of return.
[1] Number of birds caught per day multiplied by 1000.

Table 6 - Simulation of changes in the Euro exchange rate and the price of fuel per liter based on 144 thousand birds/day

Scenario	NPV	NFV	EUW	DP	IRR	MIRR
Realistic	64,786.23	333,382.11	735.19	13.82	0.96536	0.9331
Exchange rate: US$ 1.04	167,522.72	862,051.72	1,901.02	12.21	1.05326	0.9647
Exchange rate: US$ 1.25	−91,684.78	−471,798.83	−1,040.43	ND	0.84694	0.88892
Fuel: US$ 0.85	165,479.35	851,536.78	1,877.84	12.37	1.04319	0.96113
Fuel: US$ 1.04	−38,344.80	197,317.69	−434.85	ND	0.88362	0.9028

NPV - net present value; NFV - net future value; EUW - equivalent uniform worth; DP - discounted payback; IRR - internal rate of return; MIRR - modified internal rate of return.

After identifying that sensitivity affects the exchange rate and the fuel, the Monte Carlo analysis aimed to verify how the NPV and the profitability index (PI) behave when there are variations in the price of diesel, in exchange rates, and in the increase in the number of birds slaughtered per day (Table 7).

The mechanization of harvesting is feasible in all analyses. However, there are some differences between the scenarios. In the case of the acquisition of a machine (scenario 1), there is economic viability, and the probability of the NPV being negative is 30.80% (Table 7). When the analysis considers two sets of machines (scenario 2), the number of birds/day doubles; however, the PI and NPV decrease, and the probability of being negative rises to 41.59%.

In contrast, the opposite occurs between scenarios 3 and 4. There is a considerable increase in NPV and PI, but the chances of NPV being less than zero drops to 15.01%. These variations in two scenarios occur due to the fuel savings obtained after the mechanization of the harvesting system, directly affecting cash flow. The same situation occurs between scenarios 6 and 7, as well as between scenarios 8 and 9.

Table 7 - Monte Carlo simulation based on NPV variations

Scenario	No. of birds/day	Average NPV	Standard deviation	NPV < 0	PI	Diff.
1	144	67,177.42	133,909.50	30.80%	1.03	−1
2	288	57,929.12	272,836.86	41.59%	1.01	−1
3	432	86,292.71	412,253.21	41.71%	1.02	−1
4	576	523,668.02	505,502.67	15.01%	1.07	−2
5	720	638,022.90	647,515.40	16.22%	1.07	−3
6	864	641,779.76	792,215.58	20.89%	1.06	−3
7	1,008	1,116,970.30	893,708.05	10.57%	1.09	−4
8	1,152	1,166,959.85	1,035,826.96	13.00%	1.08	−4
9	1,296	1,162,951.99	1,165,699.03	15.92%	1.07	−5
10	1,440	1,682,912.95	1,283,940.97	9.50%	1.09	−6

Scenario - number of harvesting machines; average NPV - average net present value; NPV < 0: probability of the NPV being less than zero; PI - profitability index; Diff. - difference in the number of transport trailers and four-axle trucks after mechanization.

4. Discussion

To prepare the cash flow, this study calculated the total value of the initial investment, which consists of the acquisition of vehicles, machines, and equipment for the mechanization of broiler harvesting in Brazil. Artuzo et al. (2015) warned about the importance of dimensioning machines and equipment in the correct quantity so that there is no increase in final production costs.

According to Ben and Aimi (2017), importing can be an alternative to reduce costs for companies, but it requires much dedication and knowledge on the part of those who execute it. For the authors, it is a complex process, and special attention must be paid to the costs involved so that decision-making is carried out efficiently and generates economic benefits for the company.

In addition to the transport trailer being the highest value item to be imported, three units are required at a unitary cost of US$ 248,498.80 plus import, shipping, and tax fees, totaling US$ 1,058,604.89.

The poultry unloading station in the slaughterhouse has a unit cost of US$ 62,124.70 plus freight and taxes, which totals US$ 80,762.11. The washing tower of trailers has a unitary cost of US$ 33,886.20 plus the amount of freight and taxes, which totals US$ 40,052.06.

The sider semitrailer is a vehicle necessary for the transportation of the harvesting machine and shuttles between industry and properties. It must have a minimum length of 15 m and a minimum width of 2.50 m. This item can be purchased in Brazil at a unitary cost of US$ 38,890.87, including freight and tax. In addition to the trailers and the sider semitrailer, four trucks (tractors) are required, which can also be purchased in Brazil for US$ 107,872.48 each, totaling US$ 431,489.94. These items were quoted in October 2020.

A popular vehicle costs US$ 11,355.00. It is used to transport operators and the team supervisor between the poultry farms and the slaughterhouse. When finalizing the initial investment items, there is a need to sell the trucks and poultry transport boxes that will be replaced by the new system. Four trucks were quoted on 02/20/2021 at US$ 170,324.98 each and 2,500 transport boxes at US$ 17.03 each, totaling US$ 42,581.24 which will be used as a source of capital for initial investment.

An investment project can be financed in two ways: through the investor's capital or third-party capital through bank financing, and loans, among others (Hastings, 2017). In this study, the investment was made with only equity capital.

When calculating variable costs, only three items are considered: electrical energy used by the landing station and washing tower; fuel used by the picking machine, shuttles, transport trucks, and support car; and the cost of maintenance of machinery and equipment. We considered 400V 16A electric motors to work for two shifts of 8 h each.

The average daily distance traveled by trucks is 1,900 km, with a range of 2.8 km/L. The average cost of diesel between 2015 and 2019 was US$ 0.94. The company's average variable cost per month is US$ 22,671.31, considering an average price of energy in Kw/h of US$ 0.18, the average price of fuel, and the average maintenance cost of 1% per year on the value of the machines.

According to Artuzo et al. (2015), fixed costs allow the investor to quantify the participation of fixed capital, in the long term, in his activity; however, if compared to other projects, there may be a considerable variation depending on performance.

The MAR obtained considered the average of treasury bills between 2015 and 2019 as the risk-free rate and the CAPM beta was attributed based on the return obtained by JBS SA (*i.e.*, JBBS3) and the market return (*i.e.*, Ibovespa). This study adopted JBS SA because it is the largest representation among the meat processing industries in the world (JBS, 2019). In other words, MAR with a risk-free return of 9.26% per year + a premium of 2.27% per year, totaling 11.54% per year.

Considering a MAR of 0.914% per month, that is, 11.54% per year, the NPV found was US$ 64,786.23, the NFV was US$ 333,382.11, and the EUW was US$ 735.19. Considering that all indicators were positive in the current market and production conditions, the investment project is considered economically viable.

In addition to these three indicators, another evaluation technique can also certify this result. This method is called the IRR. According to the calculations, the IRR was 0.965% per month, which is higher than the MAR of 0.914% per month. This shows that the project must be accepted, as it will produce positive values for the investor.

In addition to the IRR, there is the MIRR, which is a method of analysis consisting of bringing negative cash flows to the present value and bringing positive cash flows to the future value. This technique results in a new cash flow that eliminates some of the problems of IRR when estimated traditionally. According to the data presented, the MIRR was 0.933% per month, even higher than the MAR of 0.914% per month. This reinforces that the project must be accepted by the investor under the presented market conditions.

Regarding the period for return on investment, the time required for the sum of net revenues to equal the value of the initial investment over fifteen years was 13.82 years, the number of years in which the sum of cash flow minus the cost of capital over time when the investment becomes null (DP) was sufficient to reach the amount invested within the analyzed period. This indicator is easy to interpret, but it provides important information to the decision-maker. Silva et al. (2019) reinforced that the shorter the time required to recover the invested capital, the lower the risk of the project not funding itself.

As previously mentioned, by the analysis of the economic viability indicators, it is feasible to acquire a mechanized harvesting system with a capacity for 144 thousand birds/day under the market conditions described in this study. Although there is a drop in the NPV value in the second scenario (two harvesting machines) about the first one, there is an increasing evolution from the acquisition of the third machine, and as the number of birds caught increases, the NPV also increases.

Among the various techniques that allow the analysis of economic viability, Zaroni et al. (2019) suggested that the Monte Carlo method assists in calculations and analyses using Microsoft Office Excel spreadsheets. This method creates several scenarios in addition to the optimistic, pessimistic, and realistic ones.

The lowest value of the exchange rate found in the period analyzed was US$ 1.04. If these values were considered in Euro with other market conditions, the project would have even more expressive viability because of the realistic scenario for the slaughter of 144 thousand birds/day. The DP in this scenario is 12.21 years, the period that the investor will need to recover the invested capital.

The opposite is true, with the Euro at US$ 1.25, which was the highest value found between 2015 and 2019. In this scenario, the project is not viable for all the indicators analyzed, in which NPV was negative (US$ 91,684.78) and there was no return on the invested capital in 180 months. Both analyses showed the extent to which the project can be affected and are sensitive to the financial market. These findings are extremely important because the machines are imported from the Netherlands and their acquisition is negotiated in Euro.

A variable that does not influence the viability of the project is the fuel used by the harvesting machine, the shuttle, and the trailers for transportation. However, an analysis made considering the value of diesel oil, in the same period, showed the importance of this variable.

The present study contributes to the evolution of poultry science in several ways. It broadens the understanding of the mechanized harvesting process of broilers, assists in the identification and description of machines and equipment used for this purpose, and provides relevant information for the preparation of strategic planning related to broiler harvesting in Brazil.

The study also provides evidence that the net profit attributed to the mechanization of harvesting is flexible to changes in exchange rates and the fuel used in the process. The investor needs to be attentive when buying machinery and equipment since this is the main cost of the business, directly and significantly affecting the economic viability of the project. In addition to the price paid for the equipment, it is essential to correctly plan broilers transport; if this stage is overestimated and if the trucks consume fuel beyond the necessary daily limits, there will be negative pressures on the cost of harvesting and, consequently, the economic viability of the project.

The potential for implementing the project is restricted not only to large slaughterhouses but also to those that have a daily slaughtering capacity of 140,000 birds. The investor needs to be attentive to market conditions, especially in constant observation of the most sensitive variables. When they are similar to those in this study, the investor should opt for the mechanization of harvesting.

This study shows that for the market conditions described for the Brazilian poultry industry, there is economic viability in the implementation of mechanized harvesting of broilers. However, it was also possible to identify how sensitive the activity is to investment and execution costs.

In addition to their contributions, this work provides limitations and possibilities for future research. In this study, revenues from the elimination of eventual expenses with labor processes, constant replacement of personnel, and the need for professional qualification through training were not considered. In this study, the manual harvest considered was carried out by an outsourced company, and these costs fell on it. This study did not consider the cases of companies that need to borrow financing to carry out the project and that it may directly affect the period of return on investments and even the economic viability.

Finally, this study only considered the replacement of a manual harvesting system with a mechanized harvesting system; the economic feasibility of implementing the system in an industry that is starting operations has not been evaluated.

Further studies can explore economic viability using data from other mechanized harvesting systems to compare which would be more attractive to the investor while considering the carcass quality, quality of life of workers, and animal welfare. It is also necessary to carry out a complementary marketing study to assess the perception of Brazilian consumers about current and potential methods of harvesting broilers.

5. Conclusions

The study shows that mechanized broiler harvesting is economically feasible based on the calculated indicators, such as positive net present value and profitability index. However, the success of the project depends on factors such as exchange rates and fuel prices, as highlighted in different scenarios and Monte Carlo simulations. Monitoring and managing these variables are crucial for maintaining economic viability. Implementing mechanization offers benefits such as increased efficiency, reduced labor costs, and improved animal welfare, making it a promising choice for sustainable and profitable poultry industries.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: Dutra, F. M.; Garcia, R. G.; Noriller, R. M.; Burbarelli, M. F. C. and Komiyama, C. M. **Data curation:** Dutra, F. M.; Garcia, R. G.; Burbarelli, M. F. C. and Komiyama, C. M. **Formal analysis**: Dutra, F. M.; Garcia, R. G.; Binotto, E.; Burbarelli, M. F. C.; Komiyama, C. M. and Caldara, F. R. **Funding acquisition:** Dutra, F. M.; Garcia, R. G.; Burbarelli, M. F. C. and Komiyama, C. M. **Investigation:** Dutra, F. M.; Garcia, R. G.; Binotto, E.; Burbarelli, M. F. C. and Komiyama, C. M. **Methodology:** Dutra, F. M.; Garcia, R. G.; Burbarelli, M. F. C. and Caldara, F. R. **Project administration:** Dutra, F. M. **Resources:** Dutra, F. M. **Software:** Dutra, F. M. **Supervision:** Binotto, E. and Caldara, F. R. **Validation:** Dutra, F. M. and Noriller, R. M. **Visualization:** Dutra, F. M.; Garcia, R. G. and Valentim, J. K. **Writing – original draft:** Dutra, F. M.; Garcia, R. G.; Noriller, R. M.; Caldara, F. R. and Valentim, J. K. **Writing – review & editing:** Dutra, F. M.; Garcia, R. G.; Noriller, R. M.; Binotto, E. and Valentim, J. K.

Acknowlegdments

Authors thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the funding by the Research Productivity Grant and Fundação de Apoio ao Desenvolvimento do Ensino, Ciência e Tecnologia do Estado de Mato Grosso do Sul (Fundect) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Capes) for financial support under the Fundect/Capes Special Call No. 2/2023 - PDPG 2023.

References

Agência Nacional do Petróleo. 2020. Sistema de levantamento de preços. Available at: <http://preco.anp.gov.br/include/Resumo_Mensal_Index.asp>. Accessed on: Dec. 21, 2020.

Alonso, M. E.; González-Montaña, J. R. and Lomillos, J. M. 2020. Consumers' concerns and perceptions of farm animal welfare. Animals 10:385. https://doi.org/10.3390/ani10030385

Assaf Neto, A. 2010. Finanças corporativas e valor. 5.ed. Atlas, São Paulo.

Banco Central do Brasil. 2020. Cotações e boletins. Available at: <https://www.bcb.gov.br/estabilidadefinanceira/historicocotacoes>. Accessed on: Dec. 21, 2020.

Artuzo, F. D.; Jandrey, W. F.; Casarin, F. and Machado, J. A. D. 2015. Tomada de decisão a partir da análise econômica de viabilidade: estudo de caso no dimensionamento de máquinas agrícolas. Custos e @gronegócio online 11:183-205.

Ben, F. and Aimi, M. J. 2017. Análise dos custos no processo de importação: viabilidade de compra de matéria-prima no mercado externo para uma indústria de plásticos da serra gaúcha. p.1-13. In: Anais do 24º Congresso Brasileiro de Custos, Florianópolis.

Benincasa, N. C.; Sakamoto, K. S.; Silva, I. J. O. and Lobos, C. M. V. 2020. Animal welfare: impacts of pre-slaughter operations on the current poultry industry. Journal of Animal Behaviour and Biometeorology 8:104-110. https://doi.org/10.31893/jabb.20014

Casarotto Filho, N. and Kopittke, B. H. 2010. Análise de investimentos: matemática financeira, engenharia econômica, tomada de decisão, estratégia empresarial. 11.ed. Atlas, São Paulo.

Cerávolo, E. F. and Hochheim, N. 2022. Simulação de Monte Carlo considerando dependência entre variáveis em análise de investimentos imobiliários. Revista Valorem 1:92-107.

Correia Neto, J. F. 2009. Elaboração e avaliação de projetos de investimento. Elsevier, Rio de Janeiro.

Damodaran, A. 2009. Gestão estratégica do risco: uma referência para a tomada de riscos empresariais. Bookman Editora.

De Koning, K.; Gerrits, A. R. and Migchels, A. 1987. Mechanized harvesting and transport of broilers. Journal of Agricultural Engineering Research 38:105-111. https://doi.org/10.1016/0021-8634(87)90123-5

Dutra, F. M.; Garcia, R. G.; Binotto, E. and Burbarelli, M. F. C. 2021. What do we know about the impacts of poultry catching? World's Poultry Science Journal 77:983-999. https://doi.org/10.1080/00439339.2021.1976056

Hastings, D. F. 2017. Análise financeira de projetos de investimento de capital. Saraiva Educação S.A., São Paulo.

JBS. 2019. Nossa história. JBS - Alimentando o mundo com o que há de melhor. Available at: <https://jbs.com.br/sobre/nossa-historia/>. Accessed on: Mar. 1, 2022.

Kettlewell, P. J. and Turner, M. J. B. 1985. A review of broiler chicken catching and transport systems. Journal of Agricultural Engineering Research 31:93-114. https://doi.org/10.1016/0021-8634(85)90064-2

Kittelsen, K. E.; Granquist, E. G.; Aunsmo, A. L.; Moe, R. O. and Tolo, E. 2018. An evaluation of two different broiler catching methods. Animals 8:141. https://doi.org/10.3390/ani8080141

Leal, G. S.; Sampaio, D. O. and Bessegato, L. F. 2018. Avaliação econômico-financeira de produção de leite caprino na Zona da Mata Mineira. Revista Vianna Sapiens 9:91-114. https://doi.org/10.31994/rvs.v9i1.269

Mitchell, J. R. and De Boom, H. P. A. 1986. Traumatic avulsion of the proximal femoral articular cartilage as a cause of hip dislocation in broiler chickens. Journal of the South African Veterinary Association 57:133-137.

Mönch, J.; Rauch, E.; Hartmannsgruber, S.; Erhard, M.; Wolff, I.; Schmidt, P.; Schug, A. R. and Louton, H. 2020. The welfare impacts of mechanical and manual broiler catching and of circumstances at loading under field conditions. Poultry Science 99:5233-5251. https://doi.org/10.1016/j.psj.2020.08.030

Nelson, G. S. 1984. A mechanized system for harvesting broilers. Transactions of the ASAE 27:41-0044. https://doi.org/10.13031/2013.32731

Peer system. 2012. Leaflets. Available at: <https://peersystem.nl/en/leaflets/>. Accessed on: Jan. 25, 2021.

Póvoa, A. 2007. Valuation: como precificar ações. 2.ed. Globo, São Paulo.

Ross, S. A.; Westerfield, R. W.; Jaffe, J. and Lamb, R. 2015. Administração financeira. 10.ed. AMGH Editora, Porto Alegre.

Riegg Cellini, S. and Edwin Kee, J. 2015. Cost-effectiveness and cost-benefit analysis. p.636-672. In: Handbook of practical program evaluation. Newcomer, K. E.; Hatry, H. P. and Wholey, J. S., eds. https://doi.org/10.1002/9781119171386.ch24

Silva, K. P.; Lima, J. D.; Malacarne, K. and Caricimi, R. 2019. Análise da viabilidade econômica da automação de processo: estudo de caso em uma cooperativa agroindustrial avícola. Custos e @gronegocio online 15:537-555.

Sinden, A. 2016. Cost-benefit analysis. p.295-312. In: Elgar Encyclopedia of Environmental Law. Edward Elgar Publishing.

Souza, V. M. A. and Brandalise, N. 2020. Analysis of economic-financial viability, by the Monte Carlo method, in service provider of non-destructible tests: case study. Independent Journal of Management & Production 11:1454-1469.

Werner, A.; Blaeske, A.; Rauch, E.; Erhard, M.; Unterholzner, J.; Schmidt, P.; Gotthart, M. and Louton, H. 2023. Behavior of broilers and impacts occurring to them during mechanical loading under field conditions. Poultry Science 102:102688. https://doi.org/10.1016/j.psj.2023.102688

Woiler, S. and Mathias, W. F. 1996. Projetos: planejamento, elaboração e análise. Atlas, São Paulo.

Wolff, I.; Klein, S.; Rauch, E.; Erhard, M.; Mönch, J.; Härtle, S.; Schmidt, P. and Louton, H. 2019. Harvesting-induced stress in broilers: comparison of a manual and a mechanical harvesting method under field conditions. Applied Animal Behaviour Science 221:104877. https://doi.org/10.1016/j.applanim.2019.104877

Yates, C.; Dorward, P.; Hemery, G. and Cook, P. 2007. The economic viability and potential of a novel poultry agroforestry system. Agroforestry Systems 69:13-28. https://doi.org/10.1007/s10457-006-9015-8

Zaroni, H.; Maciel, L. B.; Carvalho, D. B. and Pamplona, E. O. 2019. Monte Carlo simulation approach for economic risk analysis of an emergency energy generation system. Energy 172:498-508. https://doi.org/10.1016/j.energy.2019.01.145

Zezula, L. 2020. Efekty zavedení PEER systému k odchytu drůbeže. Thesis. University of South Bohemia, České Budejovice.