Technical-economic analysis of the impact of post-harvesting systems and subsidized loans for coffee farms in Minas Gerais (Brazil)

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Abstract

This study aimed to assess the economic feasibility and financial risks in a post-harvesting process center to provide services to small coffee producers. This is quantitative financial modeling, where were compared two investment alternatives, which are wet and dry processes with the possibility or not of loan support, in a rural property in the south of Minas Gerais. Initially, did the process mapping of the two alternatives, seeking to detail the steps for surveying the project costs. Subsequently, were modeled the cash flows of the two alternatives and the uncertainties regarding operational variables, the CAPEX, and the price of a coffee per bag were incorporated. The study resort on the estimative of the stochastic Net Present Value from a Monte Carlo Simulation for both dry and wet processing scenarios, with and without subsidized loans. Then, using ANOVA and the Levene test, we compared the returns and risks for the four scenarios. The results showed that, although wet processing had higher CAPEX values, operational efficiency and market premiums paid per coffee bag can compensate for higher investment costs. The statistical comparisons for the scenarios allowed us to identify that there was a significant difference in returns, but no significant difference in risk. Furthermore, subsidized loans improved returns, regardless of the adopted process.

Keywords: Economic Viability. Stochastic Analysis. Coffee Processing. Pos-Harvest Coffee. Process Improvement.

1. Introduction

Commodities are very relevant to the economy of emerging countries since they are sources of foreign exchange, and help maintain international trade balances (Novada et al., 2018). However, an economy that is heavily dependent on exporting commodities, especially agricultural commodities, is potentially subject to increased economic risks, given price volatility caused by shocks to global supply and demand changes (Lien and Zhang, 2008; Novada et al., 2018; Consuegra, 2017; Cuaresma et al., 2018).

In Brazil, agricultural commodities comprise a large share of the country's economy. From 2010 to 2020, commodity exports represented more than 18% of Brazil's Gross Domestic Product (GDP) (CEPEA, 2022).

In Brazil, coffee is a major agricultural commodity, in terms of production and consumption, both internally and externally. In 2020, Brazil produced approximately 58 million 60kg-bags of coffee, making it a world leader in coffee production, at 35.27% of the total global share, followed by Vietnam (18.47%), and Colombia (8.54%). Minas Gerais state produces 54.93% of all coffee in Brazil, 30.36% of which is grown in the Southern and Midwestern regions of this state (CONAB, 2022; ICO, 2022). From 2010 to 2020, Brazilian coffee exports increased to 10 million 60kg bags, and in 2020 coffee exports reached US$ 5.6

billion. In conjunction with increased exports, domestic consumption also increased between 2010 and 2020 by approximately 3.6 million 60 kg bags (ICO, 2022).

Although Brazil is one of the main coffee producers in the world, coffee prices are set internationally, thereby exposing rural producers to exchange rate risks and fluctuations in supply and demand (Novada et al., 2018). Thus, one alternative for minimizing financial risks to producers is by helping rural properties produce high-quality coffees (Malta et al., 2008; Silva et al., 2011). Specialty coffees are priced 30% to 40% higher than traditionally grown coffee, and in extraordinary cases this difference can exceed 100% of the price of traditional coffees (BSCA, 2016).

As a result, many producers have begun to invest in more advanced technological pre-harvesting and post-harvesting resources, e.g., different planting, handling, and cultivating methods, planting more productive varietals, developing herbicides, fungicides and fertilizers, in addition to using mechanized harvesting processes. This has resulted in increased production and volume for harvested coffee, and this means that, now, the productive bottleneck has been transferred to the post-harvesting stage. (Clemente et al., 2013; Barros et al., 2010; Pedro et al., 2011; Matiello et al., 2010; Garcia et al., 2009; Matiello et al., 2009).

Currently, the post-harvesting stage for coffee is performed via two processing methods, i.e., the dry method, and the wet method. The dry method is mostly used in Brazil, and is based on processing whole coffee beans. In this method, after drying, is obtained the natural coffee (coffee with husk). In the wet method, the coffee husk is removed, and after drying is obtained the parchment coffee (naked beans with silver skin). The wet method results in higher-quality coffee (Borém, 2008; Malta et al., 2008).

Appropriate processing structures require infrastructure, machinery, and equipment investments (Silva et al., 2013; Silva et al., 2011). For this reason, many small producers cannot properly process coffee, since they cannot invest in adequate post-harvesting infrastructure.

Therefore, providing post-harvesting solutions for small producers would be important to making production more competitive. Most rural producers are small-scale producers who generally have a greater capital restriction. Therefore, is essential for small producers focusing on making the optimal decision that creates economic value. In this way, the technical-economic analysis of new technologies and processes help to identify the feasibility and financial risks of different investment alternatives.

This study seeks to analyze the economic feasibility and financial risks of investing in a post-harvesting processing center to provide services to small coffee producers, which would be located on a farm in Southern Minas Gerais. We evaluated the impacts of obtaining subsidized lines of credit for this, and compared the two different harvesting methods to investigate the levels of return and risk for the two types of post-harvesting processes, both with and without subsidized loans.

This study contributes to literature, initially, by mapping the most widely used post-harvesting processes on farms to identify their current financial performance. Then, we will conduct stochastic analysis to evaluate the feasibility and risk of the post-harvesting alternatives, by inserting uncertainties inherent to the processes, along with subsidies, to ascertain the economic-financial impacts of post-harvesting processes.

In addition to this introduction, Section 2 presents a literature review on the economic and financial viability of coffee production. Section 3 presents the case study, the collected data, and the investment analysis techniques. Section 4 presents the results and discussions. Finally, Section 5 presents the final considerations and the recommendations for future studies.

2. Theoretical Framework

2.1. Literature review

High and risky investments are often required during the entire coffee production process, in function of production variation and coffee price volatility. Therefore, economic-financial feasibility analyses are essential in helping decision-makers decide on whether certain production stage investments should be made or not (Cuaresma et al., 2018; Novada et al., 2018; Silva et al., 2011).

The Net Present Value (NPV), Internal Return Rate (IRR), Payback (PB), Cost-Benefit Analysis (CBA), and Real Options (RO), methods are quite appropriate for assessing investment feasibility for different stages of coffee production.

Although the post-harvesting stage increases coffee quality, which can promote small quality producer inclusion, academic literature on economic feasibility studies for investments in technology and post-harvesting processing techniques is lacking. Nonetheless, economic feasibility analyses have been explored in different studies for other production stages.

Gobbi (2000), investigated the feasibility of a process for obtaining biodiversity-friendly coffee certificates, considering five hypothetical farm models in El Salvador. The author used NPV combined with Monte Carlo Simulations (MCS), to incorporate coffee price uncertainty into the model. The study offered sensitivity analysis comparing drops in coffee production, resulting from maintaining tree biodiversity in the vicinity to obtain certifications, and premium sales price levels resulting from these certifications.

Reichhuber and Requate (2012), analyzed a sustainable and viable alternative, from a financial standpoint, to the problem of deforestation in Ethiopia, using NPV, CBA, and sensitivity analysis. They defined the system combining high-quality coffee cultivation, quality, and forestry resources, as being the best alternatives, compared to traditional land conversion techniques and strict forestry conservation.

Fitriani et al. (2020), studied the feasibility of sustainable robusta coffee production in Lampung, Indonesia, using an agroforestry system, planting coffee under various types of shade plants, and intercropped plants, in the Sekampung watershed. The authors used NPV, CBA, IRR, and sensitivity analysis considering three scenarios where coffee prices could be reduced by 10%, 30%, and 50%.

Santiago et al. (2020), investigated the economic-financial feasibility and managerial flexibility value in investments related to producing and selling organic coffees in the municipality of Ixhuatlan, Mexico. They used the RO approach using binomial trees, that included coffee price volatility in the analysis, along with changes to producer decisions. Ihlia et al. (2018), also used the RO approach to study investment decisions considering uncertainty in an experimental environment.

Hein and Gatzweiler (2006), studied the economic value of arabica coffee genetic resources contained in Ethiopian forests. Their analyses sought to consider the main benefits and costs of using genetic information (genome) in creating improved cultivations. The NPV is used to economic valuation, subject to uncertainty related to the program duration needed for transferring the genetic information to new coffee plants, and later by new cultivations.

Alves et al. (2017), compared two systems for semi-mechanized coffee harvesting, via investments in micro-terracing, and in manual labor. The study was carried out for a rural property in São Sebastião do Gama, São Paulo, Brazil using NPV, IRR, and PB calculations to assess the feasibility of investing in micro-terraces. Using the same criteria, Goes and Chinelato (2018), evaluated the economic-financial feasibility of investing in coffee plantations in Alta Mogiana. They evaluated two productivity scenarios for three market prices for a bag of coffee.

Jesus et al. (2017), analyzed the feasibility of Arabica coffee production, using price sensitivity for varying coffee production, and studied the correlation between socio-economic aspects for coffee growers and productivity. The study was carried out at Aldeia de Poetete, in the Ermera District of East Timor, using NPV, IRR, and CBA indicators to analyze economic-financial feasibility, and the Spearman Ranking test to analyze the correlation between productivity and socioeconomic aspects.

Magalhães Júnior et al. (2021), evaluated the costs, investments, and economic performance of three fermentation processes. Fermentation takes place in the post-harvesting stage, and although the costs and investments are high, they are compensated for in the future by sales of high-quality coffee.

Unlike other studies in literature, this study uses stochastic economic viability analysis applied to the post-harvesting stage, highlighting the main uncertainties related to coffee production volumes, coffee prices, and loan impacts on financial returns.

The stochastic analysis results will allow us to compare production alternatives, via statistical tests to compare the mean and variance of returns at the proposed post-harvesting center. This study will use the NPV indicator linked with MCS to obtain a probability distribution for the NPV. The focus is on comparing dry and wet post-harvesting alternatives, support or without subsidized rural loans. Finally, the Analysis of Variance (ANOVA) will be used to compare the average returns for each scenario, and the Levene Test will be used to compare the variances.

2.2. Case study

The case study investigated was a farm located in southern Minas Gerais (Brazil), which has a climate and a structured production chain that is viable for producing quality coffee.

We evaluated alternatives for providing post-harvesting services for wet and dry processes to local production. The processing capacity of the post-harvesting center is 4,000 bags of coffee per year. The main variables for the post-harvesting process are liters of coffee needed for filling a 60kg bag, the processing time, the number of employees, and engine performance for the machines that are used.

The post-harvesting stage is shown in Fig 1. Activities marked with "*" refer to wet processing, and are detailed in Table 1, specifying both optional activities "O" and mandatory activities for each type of process.

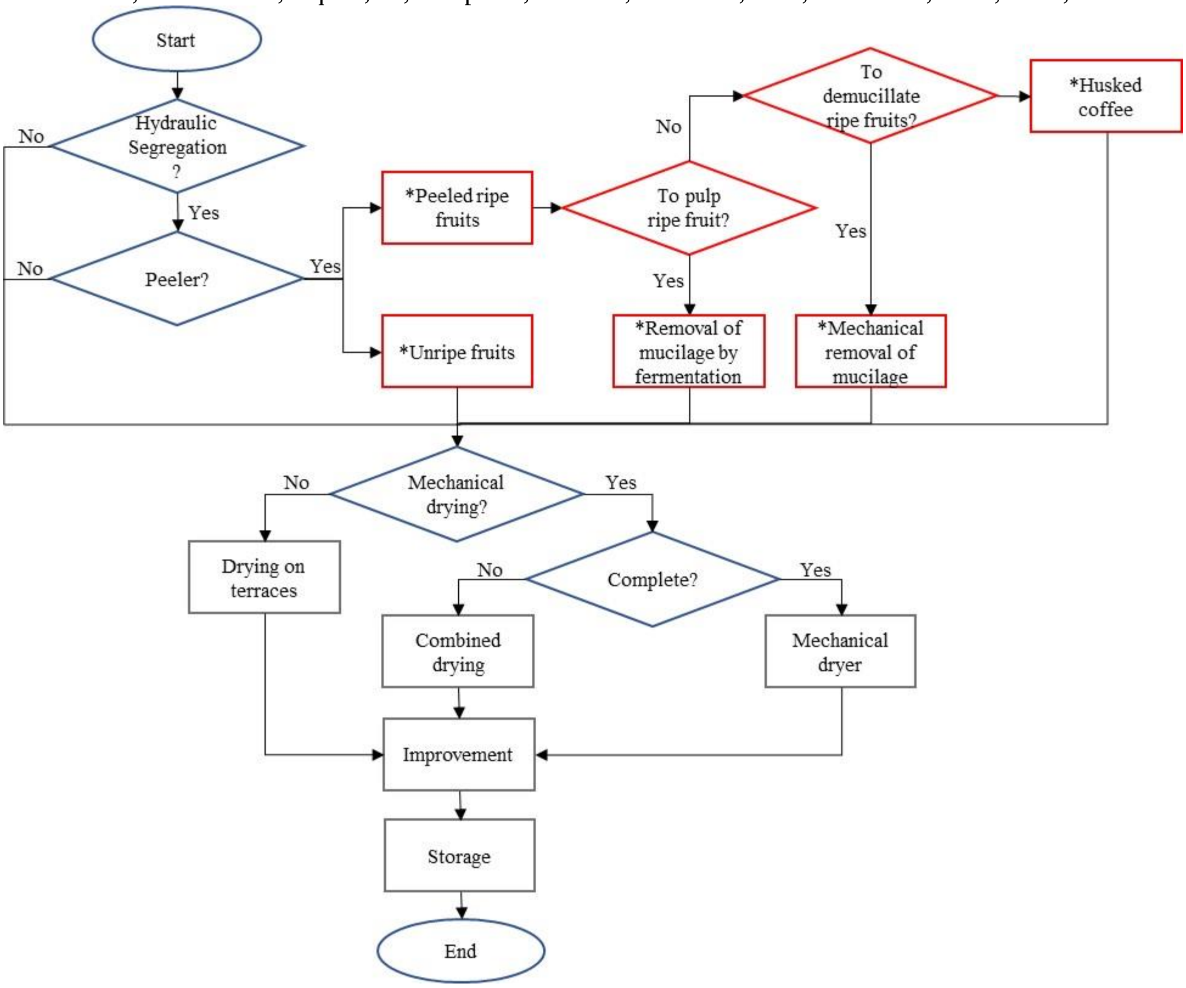


Fig 1: Post-harvesting process mapping.

Source: Adapted from Malta et al., 2008 and Pimenta, 2003.

Table 1: Post-harvesting process steps.

Steps	Dry process	Wet process	Description
Start	X	X	Coffee arrives from the farm.
Hydro segregation	O	X	This occurs on harvest day to avoid quality losses. In this stage, washer devices are used to segregate heavy and ripe fruits from light and defective ones.
Peeling	-	X	By means of a mechanized process, only the husk is removed, while keeping the bean mucilage, resulting in husked coffee.
Pulping	-	O	After dehulling, the coffee may have the mucilage removed in fermentation tanks, resulting in pulped coffee.
Demucillation	-	O	In this step, mucilage is mechanically removed, obtaining demuciladed coffee.

Steps	Dry process	Wet process	Description
Drying on terraces	O	O	Most producers use a drying method on terraces for at least one of the stages of the drying process. Terrace drying requires large areas, intensive labor, and longer drying time, which can vary according to the product characteristics, type of terrace, type of management method used, and specific climatic conditions in each region. Under favorable conditions, dry processed coffee takes an average of 15 to 20 days to dry, or up to 30 days under unfavorable conditions. Wet processed coffee takes an average of 8 to 12 days to dry.
Drying on terraces and mechanical dryers	O	O	Using mechanical drying or pre-dryers in aerated silos accelerates the drying process. This practice consists of drying coffee in terraces or pre-dryers until reaching the semi-dry phase (35 to 40% wet basis - b.u.). After this, the coffee is subjected to mechanical drying where it will be stored (11 to 12% b.u.). It can also be dryed at first on terraces or in pre-dryers up to 22% b.u., with subsequent complementary drying in an aerated silo until it is stored.
Drying in mechanical dryers	O	O	In this method, heated air passes through the grain mass by forced ventilation, either in motion or static. This process is complex, due to maturation differences and the high water content in the fruits at harvest (60% bu), which means several factors (temperature, relative humidity, air flow, drying rate, time of product in the drying chamber, and initial and final water content) must be monitored during drying.
Beneficiation	X	X	The transformation of natual or parchment coffee in green coffee beans is called beneficiation. Using processing machines, the beans are separated and the husk is removed. This operation must occur right before commercialization, so the product maintains its original characteristics.
Storage	X	X	Lots of coffee in natural or parchment can be stored in bulk in bins or silos, but this type of storage is costly due to the large volumes involved. Coffee is processed before storage in producer countries, and traditionally, green coffee beans are stored in 60 kg jute bags.

Source: Borém, 2008; Borém et al., 2008a; Borém et al., 2013; Brandão Junior et al., 2002; Donzeles, 2002; Embrapa, 2005; Greco, Campos e Klosowski, 2010a; 2010b; Malta et. al., 2008; Reinato et al., 2012; Reinato e Borém, 2006; Resende et al., 2009; Rigueira, 2005; Revista Rural, 2002; Silva et al., 2001; Silva et al., 2008.

There is more than one processing option that can characterize dry vs. wet processing methods. In this study, the dry method will be simulated via hydraulic segregation with combined drying using terraces and mechanical dryers. The wet method will be simulated using demucillators to remove mucilage, along with a combined drying stage. This way of processing improves processing coffee quality via the dry process, and reduces processing time, and consequently costs for the wet process.

3. Materials and Methods

3.1. Investment analysis

We used NPV analysis in this study to estimate the present value of future cash flows, discounted at a given rate representing the cost of capital (Eq. 1). Positive NPV values indicate investment feasibility, while negative values indicate unviable projects (Fernández, 2015).

$$NPV = \sum_{j=1}^{n} \frac{CF_j}{(1+i)^j} - CF_0 \qquad \text{Eq.1}$$

where, CF_0 is the cash flow on date zero; CF_j is the cash flow for each time interval j; i is the discount rate; n is the planning horizon.

The cost of capital is obtained using the Capital Capital Asset Pricing Model (CAPM) as per Sharpe (1964), Lintner (1965), and Mossin (1966) (Eq. 2). Since the financial expenses are considered in the cash flow, the discount rate of future cash flows in the NPV comprises only the cost of equity.

$$k_e = r_f + \beta \times PRM \qquad \text{Eq.2}$$

where, r_f is the risk free rate; β is the risk coefficient relative to the market; PRM is the premium risk market.

The reference risk-free rate (rf) was a Brazilian government bond (NTN-B), with a maturity of 25 years (Brazilian Treasury, 2022). Furthermore, the sectoral beta (β) of farms and livestock was used in the calculation to show the risk for the sector (Damodaran, 2022).

The premium risk market (PRM) is 5.21 % per year, discounting for inflation at 4.52% per year (FGV, 2022; IBGE, 2022). The CAPM data are estimated from data from the end of 2020, and are shown in Table 2.

Table 2: Discount Rate Parameters

Parameter	Value
r_f	3.52% per year
B	0.63
PRM	5.21% per year

k_e (i)	6.81% per year

The risks inherent to the project for each scenario are considered in the NPV estimate via MCS. Thus, probability distributions are modeled to attribute uncertainty to the main cash flow input variables. Finally, the cumulative NPV distribution allows us to assess the probability of positive NPV (Eq. 3) (Hacura et al., 2001).

$$P(X > x) = 1 - \int_{-x}^{x} f(u)du \quad \text{Eq.3}$$

where, *P(X > x)* = the cumulative distribution of the NPV results; *x* is the minimum NPV (in this case, zero); *f(u)* is the probability density function of the NPV (represented by the probability distribution of the NPV results).

Finally, the average NPV returns are compared using Analysis of Variance (ANOVA) (Montgomery et al., 2009), and the variance of the NPV results from the MCS was compared using the Levene Test (Carrol, 1985).

3.2. Methodological procedures

The research methodology used is modeling and simulation, since are modeled the process mapping of two post-harvest processing alternatives and, subsequently, and the modeling and simulation of the NPV results of the alternatives, considering the uncertainties associated with the main variables. As for the study approach, are used a quantitative approach. According to Bertrand and Fransoo (2002), quantitative studies analyze causal relations of control and performance variables. In this study, are quantifiable the variables, and the results analyzes are based on simulations and statistical analyses.

This research was carried out on a rural property in the south of Minas Gerais, where after mapping the two post-harvest processing alternatives, were modeled the cash flows for the different investment scenarios. In this study, were analyzed dry and wet post-harvesting alternatives, both with and without subsidized loans, resulting in four scenarios. Fig 2 shows these four analyzed scenarios. For all scenarios, were collected the data about investments, operating costs, expenses, taxes, and revenues for each type of post-harvesting process.

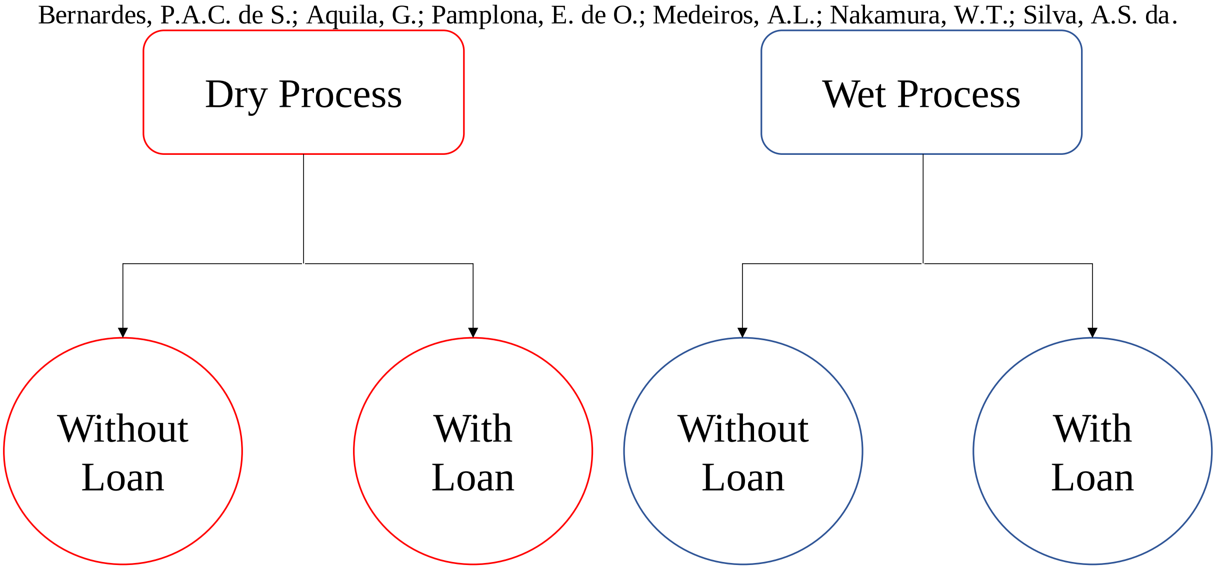


Fig 2: Scenarios for the post-harvesting project.

Sequentially, were collected the data for each post-harvest processing alternative referring to investments, fixed costs, and variable costs, in addition to coffee bag prices and the loan conditions. It is worth noting that these variables directly reflect on the inputs and outputs of cash flow values, giving rise to the financial modeling of the investment. From this, it is possible to estimate the NPV of each investment scenario from 10,000 iterations of the Monte Carlo Simulation.

Although dry processing requires fewer investments in processing machines, since it does not use a dehuller nor a dehusker, it does have higher values in terms of investments in land for drying. Mature coffee that is not dehulled, takes up a lot of space, and requires longer drying times. The other investments were taken as being the same for the two processing types (Table 3).

Table 31: Investments

Investments (US$)	Dry Process	Wet Process
Post-harvesting machines	95.779,85	107.002,23
Drying grounds	34.770,09	23.180,06
Vehicles etc.	18.943,10	18.943,10
Furniture	199,30	199,30
Shipping and installation	12.707,95	12.707,95
Cost of the area used	8.471,97	8.471,97
Total	**170.872,26**	**170.504,60**

The structures needed to house the machines were said to have already been built, and only investments in drying grounds are required. A concrete drying area was considered for the analysis, and although this is more expensive, it lasts longer relative to other options.

Gains from local production are taxed via the Brazilian Simple National Tax System. In this system, production between US$ 34,658.04 and US$ 69,316.08 is taxed at 5.97% levied on revenue. For the MCS, revenue over US$69,316.08 results in higher tax rates. Thus, depreciation does not impact tax payments, as tax is levied on revenue rather than profit.

The number of employees needed at the post-harvesting plant varies according to the adopted process. Employee monthly salaries are equal to one Brazilian minimum wage, which is equivalent to US$ 201,21. Salaries, including labor charges and other fixed costs, are shown in Table 4.

Table 4: Fixed costs

Variable (US$)	Dry Process	Wet Process
Number of employers	8	6
Salaries	11,992.07	9,175.14
Labor charges	3,477.70	2,660.79
Hiring costs	92.42	69.32
Protective Equipment	172.48	133.44
Tools	727.51	574.64
Total	**16,462.18**	**12,613.32**

The variable costs for the project are electricity costs, coal consumption, diesel oil, and maintenance (listed in Table 5). The coffee chaff resulting from post-harvest processes, is burned as fuel in the dryers, at no additional cost. Coal is only consumed after chaff consumption.

Table 5: Variable costs

Variable costs (US$)	Dry Process	Wet Process
Electricity	6,510.42	6,825.05
Coal	0.00	0.00
Diesel oil	62.77	62.77
Maintenance	770,18	962.72
Total	**7,343.37**	**7.850,54**

Post-harvesting expenses are reduced due to the size of activities, requiring only one supervisor to monitor operations. Thus, the supervisor will be said to be one of the post-harvesting owners, resulting in a *pro-labore* salary at US$ 577.63 as a fixed cost, with variable expenses at US$ 19.25 per year for office supplies. Expenses will be the same for both dry and wet processes.

Revenues from post-harvesting processes are based on historical Arabica coffee prices (CEPEA, 2022). Thus, the estimated price for a bag of coffee is multiplied by a post-harvesting fee at 12%, practiced by regional producers. The dry and wet processes adopted in the study result in higher-quality coffees, and the only difference is that wet processing generates a US$ 9.63 premium on 60% of all processed bags for husked coffee production. Taking an average price per bag at US$ 157.09 and 3,500 processed bags per year on average, annual revenue would be approximately US$ 65,978.36 for the dry process and US$ 68,405.12 for the wet process.

Furthermore, post-harvesting processing scenarios will be simulated with loans to finance post-harvesting machines. These loans are granted via the National Support Program for Medium-sized Rural Producers, through the Brazilian Development Bank (BNDES). Loans can be financed up to US$ 82,794.21, with loan rates at 2.37% per year, discounting inflation at 4.52% per year, over an 8-year payment period, with a 3-year grace period (BNDES, 2022). The projected cash flow is shown in Table 6 for both dry and wet processing.

Table 6: Project cash flows

Gross revenue
- Taxes
- Fixed costs
- Variable costs
- Expenses
- Financial expenses
- Loan amortization
- Initial Investments (CAPEX)
+ Loan release
= Cash flow

After defining the size of the post-harvesting coffee processing center, we carried out stochastic feasibility analysis, which is illustrated step by step in Fig 3.

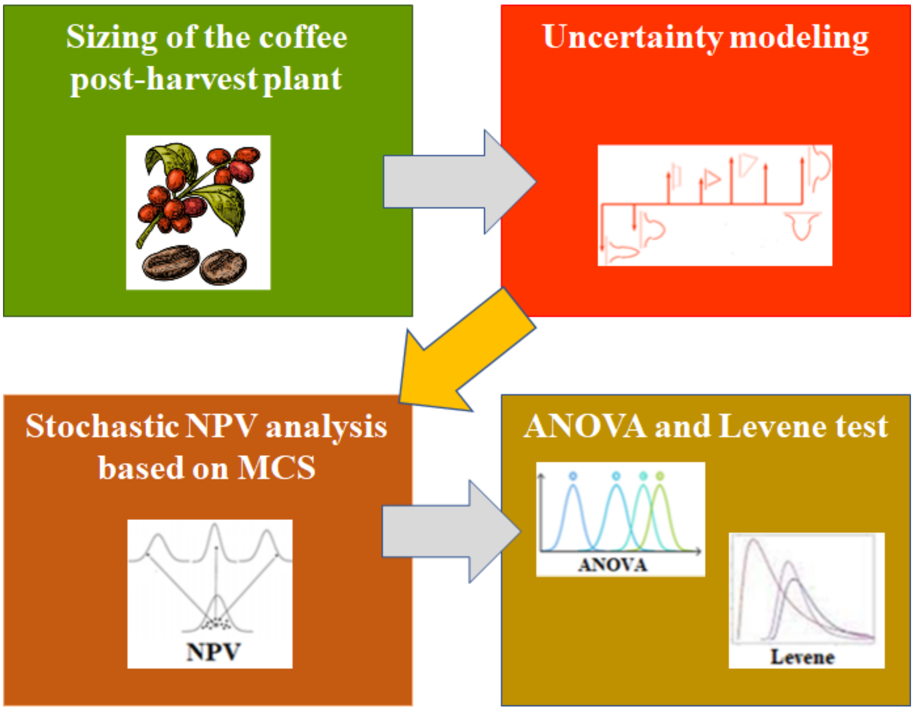


Fig 3: Steps for the stochastic economic analysis.

The sensitivity analysis helps identify variables with the uncertainty that most impacts the NPV results. Subsequently, uncertainties are inserted into these variables to perform the MCS for each scenario. The MCS results provide an NPV distribution that will be evaluated by the ANOVA and Levene tests.

4. Results and Discussions

4.1. Sensitivity analysis and break-even point

After sizing the system and surveying the variables for the cash flow, we conducted sensitivity analysis to identify the variables with the greatest uncertainty in the NPV results. The NPV result for the post-harvesting process is more sensitive to price per bag of coffee variations, to the number of bags processed at the post-harvesting center, and to the service fee charged, as shown in Fig 4.

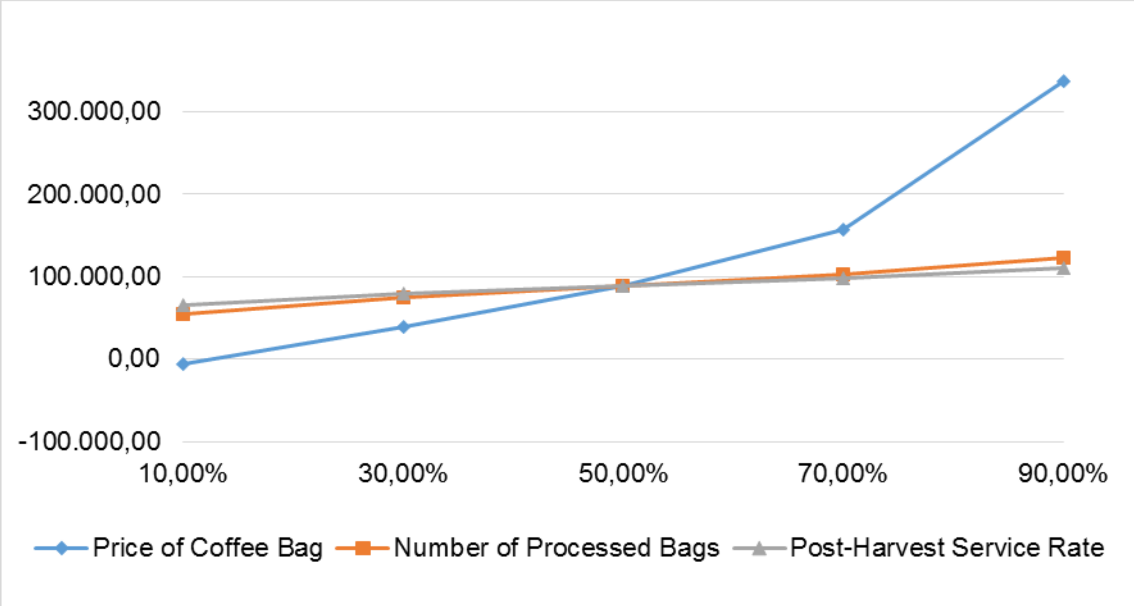


Fig 4: Sensivity analysis for NPV.

Of the three selected variables, the price of coffee per bag stood out as the most important variable, since it significantly influenced project feasibility. Thus, a more detailed analysis of this variable was necessary. To determine the lower price limit for a bag of coffee, we calculated the Break-Even Point (BEP) for each simulation.

The BEP shows the lowest admissible price for a bag of coffee without compromising project feasibility, i.e., the price at which the NPV is equal to 0. The minimum price results for each scenario are given in Table 7.

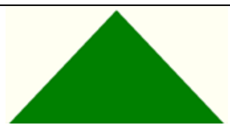
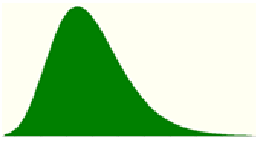
Table 7: Breakeven Point

	Dry Process Without Loan	Dry Process With Loan	Wet Process Without Loan	Wet Process With Loan
Minimum price per bag of coffee (US$)	123.45	117.22	108.73	102.50

Although the project is sensitive to price variations for a bag of coffee, the lower limit analysis for this variable shows that there are good margins to support price drops for all scenarios. Emphasis can be given to the wet process with loans, where margins were US$ 54.59.

After defining the main variables for the project cash flows, we assigned uncertainties to each. A triangular distribution was used for the number of bags processed and the service fee charged. A monthly historical data series, from 2011 to 2020, was used for the price per bag of coffee, using the Anderson Darling (AD) test. The goodness-of-fit results showed that the lognormal distribution was more appropriate in representing the price uncertainty per bag of coffee, at a 5% significance level. Due to the COVID-19 pandemic, there was a gradual reduction in demand for coffee, made worse by difficulties in exporting coffee, resulting in atypical prices in the market from 2021. Therefore, prices from 2021 were excluded from the sample, since they were very atypical for the coffee market. The distribution parameters are shown in Table 8. It is worth mentioning that the probability distributions were the same for all scenarios.

Table 8: Probability distributions

Variables	Distributions	Parameters
Number of bags	 Triangular	(Minimum; Mean; Maximum) (3,000; 3,500; 4,000)
Service tax	 Triangular	(Minimum; Mean; Maximum) (11%; 12%; 13%)
Price per bag of Coffee	 Lognormal	(Local; Mean; Standard Deviation) (86.40; 158.20; 67.04)

Using the uncertainties from Table 8, we performed 5,000 MCS iterations for the dry and wet scenarios, with and without bank financing. We obtained the NPV distributions for the four scenarios from the MCS, allowing us to compare the means among the scenarios via ANOVA. In turn, we made comparisons among the variances using the Levene test, at a 95% confidence level ($\alpha = 0.05$).

4.2. Stochastic analysis

We obtained probability distributions for each scenario after running the simulations for each scenario. Based on the boxplots shown in Fig. 5, without bank loans, the wet process had an NPV equal to US$93,193.40, with a probability of NPV > 0 at 98.04%. In turn, the dry process, without loans, had an average NPV at US$ 111,681.00, with a probability of NPV > 0 at 99.69%.

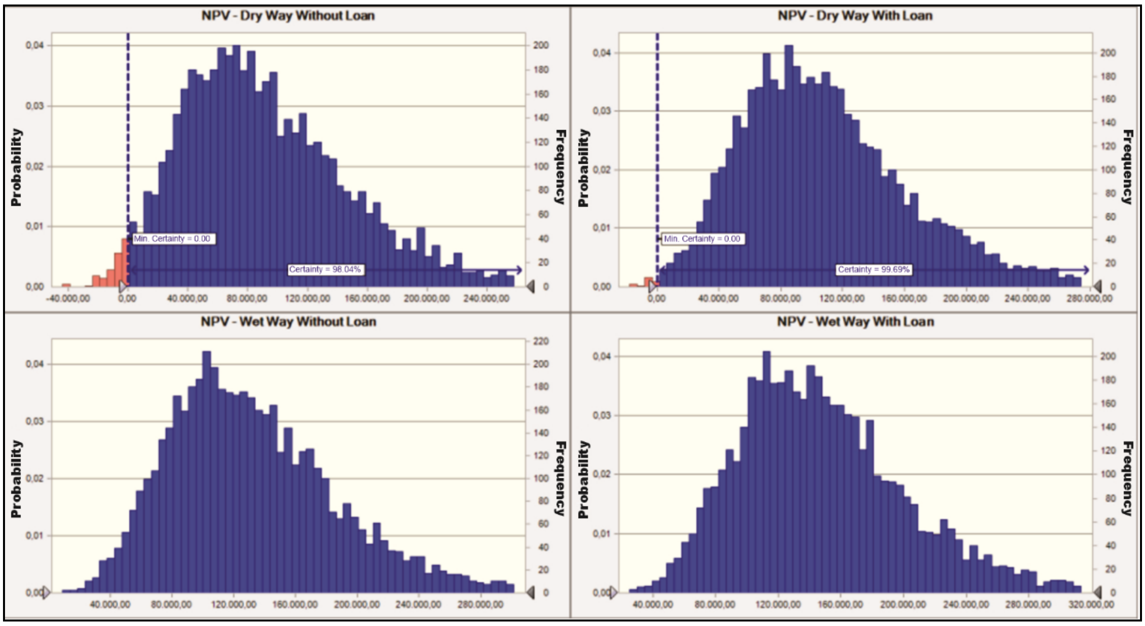


Fig 5: NPV results for each scenario.

The statistical analyses on both wet and dry scenarios with loans, as illustrated in Table 9, resulted in an ANOVA test p-value < 0.05, and an F-value > 3,84, indicating that there is a statistically significant difference between the returns for these scenarios. The Levene test results, which are shown in Table 9, show that there was no statistically significant difference between the variances, meaning there is no advantage for any scenario, with respect to financial risks among the two scenarios. Via this comparison, we observed that the average NPV for the dry process was higher and more financially attractive than the wet process, since it resulted in better returns, without greater financial risk, relative to the wet process.

Table 9: Statistical Analysis

	ANOVA		Levene Test	
	P-Value	F-Value	P-Value	F-Value
Dry Process - Without Loan x With Loan	0.000	248.870	0.313	1.020
Wet Process - Without Loan x With	0.000	148.740	0.104	2.640

Loan				
Dry Process x Wet Process - Without Loan	0.000	1264.040	0.819	0.050
Dry Process x Wet Process - With Loan	0.000	1079.170	0.392	0.730

Regarding the impacts of loans on risks and returns for the wet process, we observed that without loans, the mean NPV was US$ 135,265.00, while with loans, the mean NPV was US$ 149,416.00, and for both scenarios, the probability of NPV > 0 was 100%. The ANOVA test indicated a p-value < 0.05, and an F-value > 3.84, meaning that the loan resulted in significant increases in average returns for the wet process. However, the Levene test showed that there was no significant difference between the two scenarios, meaning that the loans did not bring about significant impacts in reducing financial risk for the wet process.

Loans for post-harvesting process are offered by the National Development Bank at a subsidized interest rate to encourage project development in rural areas. The results show that this loan fulfills its role of leveraging NPV results for post-harvesting activities, since the investment naturally has little unfeasibility risk, but can leverage the NPV results with loans.

Finally, the NPV results were also compared for each type of post-harvesting process, both with and without loan support. The mean NPV values without loans were US$ 93,193.40 for the dry process, and US$ 135,265.00 for the wet process. The statistical ANOVA test comparison for these scenarios indicated a p-value < 0.05, and an F-value > 3.84, showing that the average returns for the wet process are significantly higher than returns for the dry process with no loans.

Comparing the two process types with funding support, the mean NPV was US$ 111,681.00 for the dry process, and US$ 149,416.00 for the wet process. The ANOVA test for the two scenarios resulted in a p-value < 0.05, and an F-value > 3.84, showing better returns for the wet process. This result can be explained by the fact that the wet process has fewer operating costs, i.e., it is more efficient than dry processing. Furthermore, husked coffee bags (mature coffee) processed via the wet method can be sold at a US$ 9.63 premium, contributing to the difference in the returns.

Regarding the financial risk comparisons between the two processes, the Levene test showed a p-value at 0.819 (>0.05), and the F-value was 0.050 (< 3,84). For comparisons without loans the p-value was 0.392 (>0.05), and the F-value was 0.730 (< 3.84), with loans. Thus, we can see that there is no significant difference between the financial risk of the two processes, even with loans. This can be explained by the fact that the base price of a bag of coffee for both the dry and wet processes is the same. Additionally, the sensitivity analysis showed that the price of a bag of coffee is the main variable for the NPV results. Thus, price variance for a bag of coffee results in the most variance for the scenarios.

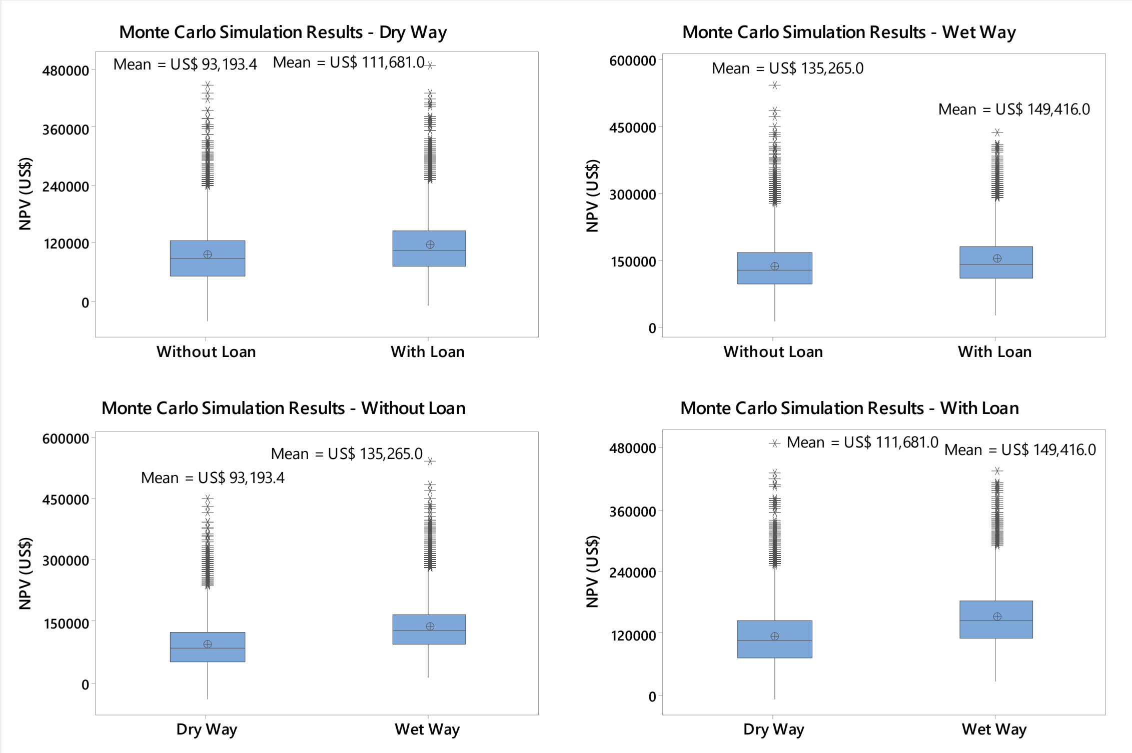


Fig 6: Comparison between scenarios.

Therefore, the results show that the wet processing alternative is more economically feasible since the processing efficiency compensates for the incremental CAPEX value of this alternative. The loan also contributes to greater financial gains with investment, regardless of the process alternative. From the risk point of view, the risk profile is similar in all scenarios. In this way, the study fulfills the objective of identifying the best decision-making related to the implementation of new post-harvest processing, contributing to the economic creation of value for the small coffee producer, at the same time that it favors the implementation of processes that improve the process, improving the final quality of the product.

5. Conclusions

This study investigated post-harvesting options for coffee processing, and if financial incentives, offered via subsidized loans, impact post-harvesting projects for small producers.

Accurately sizing processed coffee volume and simulating, mainly, the uncertainties inherent to the market price of a bag of coffee are essential in guaranteeing reliable viable results. The processing type, be it dry or wet, influences the results of post-harvesting processes, adding value to investors.

Regarding the financial incentive, both the dry and wet processes showed increased average returns, but did not present significant differences related to financial risk. Subsidized loans offered by the National Development Bank help leverage both processes, reducing CAPEX amounts in the present period and installments with low-interest rates and grace periods for payments, increasing project attractiveness.

Comparisons between the dry and wet processes showed a difference in the average NPV, with the average NPV for wet process being higher than the dry process. Higher CAPEX values for the wet process are offset by operational efficiency and the premium paid on husked coffee. However, the risk was not significantly different for the processes. When including funding in the comparisons made between the post-harvesting processes, we saw an increase in averages that were statistically different, while variance results not present significance statistically differences.

Since the price base for a bag of coffee is the same regardless of the process adopted, and since this is the main variable in the NPV results, the variance for the dry and wet processes was essentially represented by the price variance for a bag of coffee, explaining the statistically equal variances from the Levene test. In turn, the returns were statistically different. The wet process has lower operating costs, and a market premium is paid for husked coffee.

Thus, wet processing showed better results than dry processing, for this specific case evaluated. However, the results may vary from one rural property to another, depending on the technologies and types of drying methods used. Furthermore, subsidized lines of credit expanded project results, and were important incentives for rural production.

The study complies with the objectives of help the rural producer in the decision-making between investment alternatives that have particular risks and uncertainties. Therefore, it was able to indicate the optimal investment alternative, the importance of the loan, and identify that there is no greater risk in any of the alternatives. Thus, the results obtained fulfill the objective of clarifying to the rural producer the decisions that allow the creation of economic value, and contributes to the productive processes improvement.

Post-harvesting coffee processing is a field that warrants further study. Future studies could address biodigester feasibility for producing biogas, electricity, and biofertilizers produced from coffee husks coming from the dehulling step in the wet process. Studies could also address experimentally analyzing positive fermentation for hulled coffees, and the feasibility of producing coffee via fermentation, considering different fermentation process types for hulled coffee.

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