ECONOMIC AND FINANCIAL VIABILITY OF SWEET POTATO ETHANOL PRODUCTION IN MICRODISTILLERIES

Viabilidade Econômica e Financeira da Produção de Etanol de Batata Doce em Microdistilerias

ABSTRACT

Renewable energy demand is expanding worldwide and it is stimulating the biofuel sector. Sweet potato, due to its productivity and edaphoclimatic adaptation, has potential for ethanol generation. This crop also plays an important social role, as it is directly linked to peasant production systems. As every project needs planning before execution, we proposed to analyze the economic and financial viability of sweet potato ethanol production in microdistilleries. Simulations were carried out in twelve scenarios, varying factors such as costs, starch content, taxes, and the sale price. Net Present Value, Internal Rate of Return, and Payback were used as study tools. The most promising scenarios were those with a microdistillery production capacity of 807 L day^{-1} and direct sales to the consumer. Scenario twelve, involving 58 farmers supplying 30 Mg ha^{-1} of sweet potato to the plant, with a starch content of 300 g kg^{-1}, plant operation for 11 months per year, sales price BRL 2.92 L^{-1}, and exemption from PIS/Pasep and Cofins taxes, was the most attractive. It resulted in an NPV of BRL 4,053,178.70, 39% IRR and Payback of 4.43 years. Scenarios with ethanol production of 403 L day^{-1} proved to be unfeasible or unattractive economically.

Wania Kauana Bernardi
Universidade Estadual de Ponta Grossa
kawanna.bernardi@gmail.com

Pedro Henrique Weirich Neto
Universidade Estadual de Ponta Grossa
lama1@uepg.br

Jaime Alberti Gomes
Universidade Estadual de Ponta Grossa
jagmtp@gmail.com

Aghata Cristie Rewa Charnobay
Universidade Estadual de Londrina
aghatacharnobay@hotmail.com

Reginaldo Ferreira Barreiros
Universidade Estadual de Ponta Grossa
rfbarreiros@uol.com.br

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RESUMO

A demanda por energia renovável está se expandindo em todo o mundo, estimulando o setor de biocombustíveis. A batata-doce, por sua produtividade e adaptação edafoclimática, apresenta potencial para geração de etanol. A cultura também desempenha um importante papel social, pois está diretamente ligada aos sistemas de produção camponês. Como todo projeto necessita de planejamento antes da execução, propusemos analisar a viabilidade econômico-financeira da produção de etanol de batata-doce em microdestilarias. As simulações foram realizadas para doze cenários, variando fatores como custos, teor de amido, impostos e preço de venda. O Valor Presente Líquido (VPL), a Taxa Interna de Retorno (TIR) e o Payback foram usados como ferramentas de estudo. Os cenários mais promissores foram aqueles com capacidade de produção de microdestilarias de 807 L dia^{-1} e venda direta ao consumidor. O cenário doze, envolvendo 58 agricultores que fornecem à planta 30 Mg ha^{-1} de batata-doce, com teor de amido de 300 g kg^{-1}, operação da planta 11 meses ao ano, venda realizada por BRL 2,92 L-1 e isenção do PIS/Pasep e da Cofins, foi o mais atrativo. Este resultou em VPL de BRL 4.053.178,70, TIR de 39% e Payback de 4,43 anos. Cenários com produção de etanol de 403 L dia^{-1} mostraram-se inviáveis ou pouco atraentes economicamente.

Keywords: Biofuel; Bioenergy; Peasant Farming.

Palavras-chave: Biocombustível; Bioenergia; Agricultura Camponesa.

1 INTRODUCTION

Predictions regarding the depletion of fossil energy resources and the need to mitigate greenhouse gas emissions have led to the search for alternative sources of energy (Ventorim & Machado, 2008; Lima & Souza, 2015). Starch, saccharine, and lipids are already transformed into liquid biofuels.

Sweet potato (*Ipomoea batatas*) is a crop with high starch content, high productivity, great rusticity, and genetic variability, characteristics that make it one more option for biofuel production in Brazil (Silveira, 2008). This crop can be an alternative for generating energy and income for peasants. These represent 77% of Brazilian agricultural producers (Altieri, MA, Funes-Monzote, FR & Petersen, P., 2012); IBGE, 2019). Strengthening this group of farmers is necessary and the diversification and transformation of products, as well as the use of co-products and differentiated marketing can be alternatives (Weirich Neto, Delafoulhouze, Vriesman, Souza & Rocha, 2016).

Many crops might present potential for generating income for peasants. Sweet potato, given its characteristics, is a crop that can integrate the production system of these farmers (Silveira, 2008). Ethanol production from sweet potatoes through associations and the implementation of microdistilleries might be an option to add value to this crop (Silveira, 2007). Cooperativism is seen as a solution to the economic development of groups of individuals. This type of association seeks not only the common well-being of members but also the aggregation of values within the social and organizational parameters of a society (Delha, Gabriel & Nunes, 2015).

However, sweet potato is still a poorly researched crop in Brazil, both for fresh consumption and for the industry. Although there is little interest in this tuber, the significant amount of its starch content raises its potential to be a source for ethanol production. Ethanol can be used, in addition to biofuel, as solvents, antiseptics, food preservatives, drugs, drinks, among others (Rizzolo, 2014).

In any type of enterprise, it is important to perform an economic and financial feasibility assessment of the investment. This analysis will guide decision making according to the period necessary for the investment to be recovered and the financial return on the capital invested (Gitman, 2001). In this context we propose to analyze the feasibility of sweet potato ethanol production in peasants' systems in the Central Eastern and Southeastern Paraná State mesoregions (southern Brazil), taking into account "the knowledge of local farmers, food security for families, and market demands" (Almeida, Martins, Palheta, & de Paula, 2016). From this perspective, the analysis will be based on the family farming system, which is an important sweet potato supplier in different Brazilian regions.

2 SWEET POTATO CHARACTERISTICS AND PRODUCTION

Sweet potato (*Ipomoea batatas*) is a dicotyledonous plant of American origin, which belongs to the family *Convolvulaceae* and is well adapted to the climate of tropical countries. It is a root tuber crop with stems, leaves, and roots of very different shapes, sizes, and colors (Filgueira, 2013). Sweet potato is considered a rustic crop, growing easily in poorly fertile and degraded soils, presents tolerance to water stress, and is highly resistant to pests, which implies low production costs (Miranda, França, Carrijo, Souza, Pereira, Lopes, & Silva, 1995; Silva, Lopes, & Magalhães, 2002).

Sweet potatoes are grown in 115 countries, with 66% production in Asia, 28% in Africa, and approximately 6% in the rest of the world (Feltran & Fabri, 2010; FAO, 2019). China currently accounts for more than half of the global sweet potato production (58%) with over 53 million Mg year^{-1} (FAO, 2019).

Brazil is 16th in the world ranking of sweet potato production, producing 741 Mg in 2018, with a 13.98 Mg ha^{-1} average yield (FAO, 2019; IBGE, 2019). Paraná State is the 4th largest Brazilian producer, with a 22.29 Mg ha^{-1} average productivity (IBGE, 2019).

Sweet potato is a crop that presents low production costs (Miranda, et al. 1995). However, its production process can vary these costs significantly (Melo, Costa, Brito, Aguiar Netto & Viégas. 2009; Suyama, Ieiri &Tarsitano, 2010; and Furlaneto, Firetti & Montes, 2012). In these studies, the main expenses were inputs (fertilizers and pesticides), and also mechanized and manual operations with harvest and classification.

About 40% of the sweet potato tuber roots that are produced do not reach market standards and are usually discarded. These could be destined for the production of ethanol (Servino, Nalin, Godinho, Marques, Benincasa, Pinto, & Cristina, 2011), avoiding waste, and also helping with the problem of competition of areas for the production of food and biofuels, an existing discussion when considering raw materials from plant biomass for energy production.

3 SWEET POTATO ETHANOL

Ethanol or ethyl alcohol is a chemical substance, formed by carbon, hydrogen, and oxygen (CH_3CH_2OH), which can be obtained through the distillation of fermented products from biological sources (Oliveira, Valdés Serra, & Magalhães, 2013; ANP, 2018).

Brazil and the United States are the world's largest ethanol producers, mainly from sugarcane and corn (Dias et al., 2012). In 2018, 33.1 million m³ ethanol were produced in Brazil, 15.6% more than in the previous year (ANP, 2019), when sugarcane was the raw material used for the production of approximately 32 million m³ (SEAB, 2019). The Southeast region is the largest national producer of ethanol, with 19.7 million m³ (59.6% of the national production) (ANP, 2019). In the Southern region, the Paraná State is the main producer, with 1.6 million m³ (ANP, 2019).

The flex distilleries showed greater viability in regions producing starch raw materials, where low prices and demand for animal feed, a co-product of ethanol production, are essential components (Masiero, 2012; Milanez, Nyko, Valente, Xavier, Kulay, Donke, Matsuura, Ramos, Morandi, Bonomi, Capitani, Chagas, Cavalett & Gouvêia, 2014). The insertion of starch crops, such as cassava, corn, and sweet potato, puts in perspective the participation of small entrepreneurs in the biofuel market, enabling the expansion of social, environmental, and economic policies in peasants' communities (Masiero, 2012; Taborda, Jahn, Lovato & Evangelista, 2015).

Sugarcane provides an average of 86 L ethanol per Mg of biomass (Castro, Emygdio, Abrantes & Rocha, 2008). Studies report alcohol yields varying between 89 and 181 L Mg^{-1} of sweet potato root (Castro et al., 2008; Santana, Martins, Silveira, Santos, Gonçalves, Souza, Resplandes, & Lima, 2013). In general, sweet potatoes have between 160 to 400 g kg^{-1} of dry matter at the time of harvest, depending on the genotype. Of this mass, 750 to 900 g Kg^{-1} are carbohydrates composed of starch, sugar, cellulose, pectin, and hemicellulose. The starch content, the main element of interest in sweet potatoes aiming at the transformation into ethanol, presents great variability, following the wide genetic variety of the crop (Table 1).

Starch is a polysaccharide formed by amylose and amylopectin chains. Amylose is a macromolecule, formed by glucose units joined by alpha-1,4 glycosidic bonds, creating a linear chain. Amylopectin, on the other hand, is less water-soluble than amylose and is formed by glucose units linked in alpha-1,4 and alpha-1,6, forming a branched structure. This constitutes about 80% of the polysaccharides found in the starch grain (Tester & Karkalas, 2004).

TABLE 1 – Starch contents from different varieties of sweet potato

Starch content (Wet basis)	Study
220.7 to 296.8 g kg^{-1}	(Leonel, Sarmento, Franco, Oliveira, & Cereda, 2004)
115.6 to 270.7 g kg^{-1}	(Alves, Andrade, Oliveira, Santana, Pinto & Blank, 2014)
160 to 239 g kg^{-1}	(Andrade Júnior, Viana, Pinto, Ribeiro, Pereira, Neiva, Azevedo, Andrade, 2012)
300 g kg^{-1}	(Silveira, 2008; Ray & Ramachandran, 2018)

Source: Adapted by the author

In this case, three processes are necessary to produce ethanol. Hydrolysis, usually performed by enzymes, is initially necessary to fragment the starch chain. Then, fermentation of the sugars generated occurs, and finally, the product from the previous steps is distilled, aiming to separate the ethanol from the must (Silveira, 2008). These are mechanical, thermal, chemical, and biochemical processes that makeup and burden the industrial process.

4 METHODS

The study was carried out considering edaphoclimatic conditions, peasants' typology, and farming system, as well as the cultural reality in the Mid-East and Southeast mesoregions of Paraná state, Brazil. The region is 11,761 km² long, "located between the coordinates 23° 45 ' and 26 ° 15' S and 49 ° 15 ' and 50 °45' W " (Melo & Moro. 2014).

Cash flow was elaborated and financial feasibility analysis was carried out simulating the conditions of production and transformation of sweet potato into ethanol (92.5 to 94.6% ethanol – w/w), as well as commercialization (Viana, Hoeflich, Morozini & Schwans, 2014). The basic premise was agroecological systems with family farming in the region of the study.

To obtain the entries, receipts were listed as cash sales and installment sales. For the outputs, we considered payments to suppliers, bank and financial expenses, salaries and employee charges, maintenance, accounting assistance, taxation and contributions, administrative consumables, investments, and amortization of loans and debts.

Elaboration of cash flows considered the sale of ethanol and the co-product (ANP, 2020; BCSP, 2019) as revenues. As expenses, the initial investment was presented, which includes pre-operating expenses; initial fixed investments and working capital, expenses with legislation; equipment; and expenses incurred before the start of activities. The initial investment comprises the total expenditure on equipment and installations for the microdistillery. These values were obtained from the company Limana Poli Servios Eireli, located in Jaguari, Rio Grande do Sul. This company has over thirty years of experience in the field of distillation. It commercially makes available a range of equipment for obtaining ethanol from different raw materials and processing capacity, including what is currently called flex ethanol plants, which process different raw materials (Limana, 2019). These expenses would be paid by the partners taking into account the Pronaf value.

Values related to outputs, regarding the legalization of operation, such as land use and occupation certificate, preliminary license and environmental licensing were used according to the Henrique Luís Roessler State Environmental Protection Foundation (FEPAM, 2019). The fire safety permit by the Fire Department (Paraná, 2018), the environmental permit by the municipal environment agency (Ponta Grossa, 2016), and the Municipal Sanitary License (Ponta Grossa, 2008) were requested from the Ponta Grossa City Hall. These may change depending on the municipality. The values are approximate, since for specific values, it would be necessary to submit a project for internal procedures at the city hall.

Consumables and office supplies were also planned (paper, pen, toner, envelope, printer, computer, tables, chairs, cabinets, among others). The estimated working capital took into account the cost of products for the production of a batch of ethanol (according to the production capacity of the microdistillery) in one month.

Raw material, inputs, fees, and taxes were the variable costs considered. Fixed costs included labor and conservation of the physical structure (Gitman, 2001; Bornia, 2002) as fixed administrative expenses, and other expenses that are diluted per batch produced (Bornia, 2002; Moura, 2005).

Some of the materials required to start activities are presented as fixed, such as office supplies, internet access, electricity, telephone service, security, cleaning materials in general, and employee remuneration and charges. Based on the proposed volume, the remuneration of one employee was considered. Production costs, such as raw material and inputs, as well as the hiring of temporary personnel are also considered variable costs. These include expenses with raw materials, acquisition of sweet potatoes, inputs (biomass for boiler, nutrients (Zn, N, Cu, P, K, among others), yeast, CaO (Calcium Oxide), detergent, Enzyme A (Liquozyme Supra 2.2X (alpha-amylase)), Enzyme B (AMG 300L - glucoamylase), diesel, water for dilution and processes, defoamer and electricity (Limana, 2019).

The information on inputs (yeasts, enzymes, nutrients, and others) was based on recommendations from equipment companies for ethanol production, such as Limana Poli Servicos Eireli, input suppliers, and Latino Americana and Fermentec (LNF), as well as bibliographic search. For the cost of sweet potato, raw material for ethanol production, the value of BRL 250.00 Mg^{-1} was considered, which is practiced by farmers in the region (Guanabara, 2018). Spreadsheets from the Microsoft Excel® for Windows, Microsoft operating programs were used.

Net Present Value (NPV), Internal Rate of Return (IRR), and Payback or Recovery Period (RP) of the investment (Casarotto & Kopittke, 2010) were used to measure the project economic and financial viability.

Net Present Value (NPV) determines the value of the flow of financial resources in the current period, discounting the interest rate i and the cost of the initial investment (Jerônimo,2013; Viana et al., 2014). The higher the NPV is, the more profitable the project will be (Santana, 2005).

To discount the cash flow, the Minimum Attractiveness Rate (MAR) was used, which refers to the lowest interest rate that the investor expects to achieve when investing (Souza & Clemente, 2004). For the NPV calculation, the MAR used was the Selic interest rate (Special System of Settlement and Custody) of 4.25% p.a. (referring to February 2020), an index on which the interest rates charged by the market are based in Brazil (BCB, 2020).

The Internal Rate of Return (IRR) is the interest rate that equates, at a given point in time, the present value of inflows with that of cash outflows, considering that when the NPV is zero, the return on invested capital occurs. The IRR is used as an investment analysis method, in which the investment will be economically attractive if the IRR is greater than the MAR (Puccini, 2012).

Payback is an indicator that determines the number of periods to recover the investment. The lower the payback, the more attractive the investment (Rasoto, Gnoatto, Oliveira, Rosa, Ishikawa, Carvalho, Lima, Lima, Trentin, & Rasoto, 2012).

4.1 Scenarios

Simulations were performed in several scenarios, varying quantitatively the factors that may influence the project viability. Among the alternatives for future planning, the scenarios provide a range of possibilities, based on a set of assumptions about the uncertainties that can influence the enterprise and its structure (Schoemaker, 1995; Porter, 1996). Therefore, the simulation of scenarios is one of the ways to minimize or predict possible risks of an investment.

NPV (Net Present Value), IRR (Internal Rate of Return), and Payback (Period of Return) were calculated for 12 scenarios of sweet potato ethanol production, in which costs with raw materials and inputs were simulated, as well as starch content, taxes, and ethanol price. The cash flow was determined for 10 years.

Some factors remained fixed in all scenarios. The microdistillery would operate for 11 months a year, with one month for maintenance. Financing was calculated with an interest rate of 4.6% per annum, referring to Pronaf Agroindustry (BCB, 2019), a 10% depreciation on equipment (Brasil, 1998), taxation (ICMS 18%, PIS BRL 23.38 per m³ and COFINS BRL 107.52 per m³, CSLL 9%, and IPI 8%) (Paraná, 2007; Brasil, 2017a; Brasil, 2008; Brasil, 2016), and a 15% income tax on presumed profit (Brasil, 2017b).

The co-product sale price (protein must) also remained the same in all scenarios - BRL 780.00 Mg^{-1}. This value was based on the protein content, or 56% of the price practiced for soybean meal, with the soybean meal average selling price in 2019 (Parente, Rodrigues, Vieira, Albino, Siqueira, & Paiva, 2014; BCSP, 2019).

Due to the variation in the capacity of the microdistillery, as well as some characteristics of the raw material in some scenarios, the number of farmers included in the process varied from 29 to 58. The smallholders, organized in associations/ cooperatives, would produce the raw material and would own the microdistillery, with the sale of raw material and participation in investments and profits (Delha, et al. 2015).

Two sizes of microdistillery production capacity were stipulated, 403 L day^{-1} or 807 L day^{-1}. These values were adopted because they are the smallest microdistilleries commercially available. For production above 800 L day^{-1}, a larger number of farmers involved is required to provide sweet potatoes as raw material. Besides, these farmers' production area must be located close to the industry, since the study seeks the logic of small local enterprise and small cooperatives.

The agricultural area to be used for sweet potato production would be 1 hectare. The average land of family farms in the region is 10.2 ha (Okuyama, Rocha, Weirich Neto, Ribeiro, & Almeida, 2018). In this case, there would be no competition with food production, but optimization of the area, which makes it possible to maintain food sovereignty and at the same time explore a new option for land use, namely, bioenergy production.

Regarding the scenarios, a 30 Mg ha^{-1} sweet potato yield was considered (Taborda et al., 2015). In studies (unpublished) carried out by the Agricultural Mechanization Laboratory of the State University of Ponta Grossa, yields ranging from 20 to 38 Mg ha^{-1} were found, with agroecological management, without the use of synthetic molecules (fertilizers and pesticides), a productive system that fits the peasant profile in the study region.

For organization purposes, odd numbers were used to identify the scenarios representing the microdistillery capacity of 403 L day^{-1}, while the scenarios numbered by even numbers represent the 807 L day^{-1} ethanol production.

In the first scenario, ethanol sale prices were simulated using: average sale price to distributors in Paraná, in 2019, that is BRL 2.61 L^{-1}, and variations around it (+ 5% and + 10%), plus average sale price to the final consumer BRL 2.92 L^{-1} in 2019 (Table 2)(ANP, 2020), and variation in the sale price until reaching the break-even point, with a 403 L day^{-1} production capacity. In the second scenario, the same simulations were carried out taking into account a micro distillery capacity of 807 L day^{-1}.

As regards financing, the financing of 50% of the initial investment, for the microdistillery acquisition, with an interest rate of 4.6% per annum was considered as standard. Thus, scenarios 3 and 4 simulated interest rates applied to the initial investment. In scenario 3, the interest rate was reduced by 4.6% p.a. (the value used in the other simulations) up to 0% p.a., for a 403 L day^{-1} production. As for scenario 4, for a 807 L day^{-1} production, the interest rate changed from 4.6% p.a. to 23% p.a., which is the break-even point.

Among the costs, those related to raw materials (sweet potatoes) and inputs represent approximately 55% of the total costs of the ethanol production industry. Therefore, in scenario 5 (403 L day^{-1} microdistillery), variations were simulated with cost reductions of -5%, -10%, -15%, -20%, -50%, and -71%. In scenario 6 (807 L day^{-1} microdistillery), -5%, -10%, -15%, -20% cost reductions were considered in the simulation, and up to 9% of the costs with raw materials and inputs was added until the break-even point was reached.

Sweet potato starch content is directly proportional to the ethanol yield. In this study, 300 g kg^{-1} starch content was considered the standard value (Ray & Ramachandran, 2018). In Spain, when studying 30 varieties, Suárez, Hernández, Galdón, Rodríguez, Cabrera, Mesa, Rodríguez, & Romer (2016) determined starch values ranging from 120 to 470 g kg^{-1} (dry basis). In New Guinea and Australia, when evaluating 25 varieties, Waramboi, Dennien, Gidley, & Sopade. (2011) found starch values between 300 and 580 g kg^{-1} (dry basis). These values vary according to genetic and management characteristics and can be achieved with post-harvest drying processes. Therefore, scenarios 7 and 8 show variation in starch contents.

Another simulated scenario is related to the reduction of Brazilian taxes, such as PIS /PASEP, Cofins, ICMS, IPI, and CSLL. These values influence directly the production costs, accounting for approximately 30% of costs. The simulations (scenarios 9 and 10) were based on the law Project 9625 of 2018, which provides for the exemption of these taxes for small ethanol producers (Brasil, 2018).

In addition to the reduction and exemption from PIS/PASEP and Cofins, direct sales are also a relevant factor in the viability of the project, generating an increase in revenues, thus, scenarios 11 and 12 show the reduction of taxes and direct sales to the final consumer.

5 RESULTS

To simulate the ethanol sale values in the first scenario, production values were set at 403 L ethanol day^{-1}, a 30 Mg ha^{-1} sweet-potato yield, a 300 g kg^{-1} starch content (wet basis), 29 farmers, financing 50% of the initial investment, and an interest rate of 4.6% per annum (Table 3).

Regarding the base price or following the current legislation, which would be the sale price of ethanol for supply to distributors practiced at auctions, that is, BRL 2.61 L^{-1}, which was the average value in 2019 in Paraná State (ANP, 2020), the NPV value was negative (BRL -1,471,278.40). Thus, in scenario 1, when selling to distributors the investment would not be economically interesting. Considering the direct supply to the consumer or even own use by the association/ cooperative, the break-even point for this scenario would be above BRL 3.00 L^{-1}, where the NPV becomes positive. With the sale at BRL 3, 01 L^{-1}, the NPV becomes positive with a value of BRL 35,166.53, an IRR of 11.47% p. a., and a payback of 9.85 years.

In scenario 2 the microdistillery processing capacity is 800 L day^{-1}, and consequently, the number of farmers increased from 29 to 58 (Table 4). The other variables were fixed in the same values as in scenario 1. More attractive values compared to the first scenario were verified in simulation 2, as the cost of implementing the plant per unit of fuel produced became smaller. Scenario 2 is attractive when evaluating the investment with a sales price to the distributor, with NPV of BRL 337,061.58, IRR of 14.44% p. a., and Payback in 8.91 years. The viability of the project is verified with an ethanol sale price of BRL 2.57 L^{-1}, obtaining an NPV of BRL 35,772.59, IRR 11.38% p. a., and Payback of 9.86 years; however, with the sales below BRL 2.57 L^{-1}, the NPV is negative (BRL - 39,550.66).

When analyzing scenario 2 using the sale price to the final consumer (2.92 L^{-1}), an NPV of BRL 2,672,050.23, 31.52% IRR per annum, and 5.36 years Payback are obtained. From the economic standpoint, these are better values when compared to those found by Masiero (2012) and Magalhães, Rodrigues,& Silveira, (2012). When investigating sorghum and sweet potato ethanol production, Masiero (2012) obtained an NPV of BRL 35,861.15, 13.4% IRR p. a., and a 7.2-year Payback.

TABLE 2 – Average ethanol prices charged to consumers and sales to distributors in the five Brazilian regions and in the southern states in 2019

	Consumer price (BRL)			Sales to distributors (BRL)		
Regions	Average price	Minimum price	Maximum price	Average price	Minimum price	Maximum price
North	3.72	3.46	4.28	3.24	2.99	3.53
Northeast	3.50	3.17	4.01	3.07	2.72	3.40
Southeast	3.22	2.71	3.99	2.85	2.40	3.32
Midwest	3.06	2.73	3.52	2.70	2.40	2.98
South	3.41	2.97	4.08	2.98	2.57	3.38
Paraná	2.92	2.54	3.56	2.61	2.26	2.98
Santa Catarina	3.55	3.04	4.05	3.08	2.68	3.38
Rio Grande do Sul	4.05	3.57	4.96	3.52	3.00	4.07

Source: Adapted from ANP, 2020

TABLE 3 – Summary of the results from the scenarios of the ethanol production from sweet potato in microdistilleries with 403 L day^{-1} capacity, with Net Present Value (NPV) values, Internal Rate of Return per annum (IRR) and Payback

Scenario	Sale price variation	NPV (BRL)	IRR (%) p.a.	Payback (years)
1	2.61	- 1,471,278.41		
	2.74	- 981,683.80		
	2.87	- 492,089.20		
	2.92	- 303,783.58		
	3.00	- 2,494.59		
	3.01	35,166.53	11.42	9.85
	Interest Rate Variation (% p.a)	NPV (BRL)	IRR (%) p.a.	Payback (years)
3	4.6	- 1,471,278.41		
	4.4	- 1,468,001.37		
	4.1	- 1,463,085.80		
	3.9	- 1,459,808.76		
	3.7	- 1,456,531.72		
	2.3	- 1,433,592.42		
	0.00	- 1,395,906.44		
	Variation in costs with inputs and raw materials	NPV (BRL)	IRR (%) p.a.	Payback (years)
5	270,832.62	- 1,471,278.41		
	257,290.99	- 1,367,220.40		
	243,749.36	- 1,263,162,385		
	230,207.73	- 1,159,104.37		
	216,666.10	- 1,055,046.36		
	135,416.31	- 430,698.29		
	81,249.79	- 14,466.24		
	78,541.46	6,345.36	13.81	9.94
	Starch content variation	NPV (BRL)	IRR (%) p.a.	Payback (years)
7	300	- 1,471.278.41		
	320	- 1,082,360.71		
	330	- 820,346.59		
	350	- 528,471.17		
	360	- 411,646.13		
	380	- 91,032.34		
	450	831,992.14	19.89	7.53
	Tax variation	NPV (BRL)	IRR (%) p.a.	Payback (years)
9	138,432.32	- 1,471,278.41		
	131,510.70	- 1,418,090.61		
	124,589.09	- 1,364,902.81		
	117,667.47	- 1,311,715.01		
	110,745.85	- 1,258,527.20		
	69,216.16	- 939,400.40		
	0.00	- 407,522.39		
11	Direct sale and exemption from PIS / PASEP and Cofins (403 L day^{-1})	NPV (BRL)	IRR (%) p.a.	Payback (years)
		386,780.65	15.44	8.62

Source: The authors

TABLE 4 – Summary of the results from the scenarios of the ethanol production from sweet potato in microdistilleries with 807 L day^{-1} capacity, with values of Net Present Value (NPV), Internal Rate of Return per annum (IRR) and Payback

Scenario	Sale price variation	NPV (BRL)	IRR (%) p.a.	Payback (years)
2	2.56	- 39,550.66		
	2.57	35,771.59	11.38	9.86
	2.61	337,060.58	14.44	8.91
	2.74	1,316,249.79	22.63	6.98
	2.87	2,295,439.00	29.24	5.71
	2.92	2,672,050.23	31.52	5.36
	Interest Rate Variation (% p.a)	NPV (BRL)	IRR (%) p.a.	Payback (years)
4	4.6	337,060.58	14.44	8.91
	4.8	333,290.59		8.92
	5.1	327,635.62		8.94
	5.3	323,865.63		8.95
	5.5	320,095.65		8.96
	22	9,071.94		9.97
	23	- 9,777.99		
	Variation in costs with inputs and raw materials	NPV (BRL)	IRR (%) p.a.	Payback (years)
6	451,084.16	948,754.91	21.2	7.24
	477,618.52	744,856.80	18.97	7.75
	504,152.88	540,958.69	16.71	8.30
	530,687.25	337,060.58	14.44	8.91
	557,221.61	133,162.47	12.13	9.55
	573,142.23	10,823.60	10.73	9.96
	578,449.10	- 29,956.02		
	Starch content variation	NPV (BRL)	IRR (%) p.a.	Payback (years)
8	290	- 110,082.48		
	300	337,060.58	14.44	8.91
	320	1,114,895.97	21.14	7.27
	330	1,542,256.26	24.31	6.61
	350	2,222,675.06	28.89	5.77
	Tax variation	NPV (BRL)	IRR (%) p.a.	Payback (years)
10	221,491.71	762,562.99	19.16	7.71
	235,334.94	656,187.38	17.99	7.99
	249,178.17	549,811.78	16.81	8.28
	263,021.40	443,436.18	15.63	8.58
	276,864.63	337,060.58	14.44	8.91
	290,707.87	230,684.98	13.24	9.23
	304,551.10	124,309.37	12.03	9.57
	318,394.33	17,933.77	10.82	9.94
	321,162.98	- 3,341.35		
12	Direct sale and exemption from PIS / PASEP and Cofins	NPV (BRL)	IRR (%) p.a.	Payback (years)
		4,053,178.70	39	4.43

Source: The authors

Scenario 3 maintains a fixed yield of 30 Mg ha^{-1}, a 300 g kg^{-1} starch content, a 50% financing of the initial investment, a selling price of BRL 2.61 L^{-1}, and a 403 L day^{-1} production capacity The interest rate varied, currently being 4.6% p.a., (the rate used as the basis for Pronaf Agroindustry). In this scenario, even if the rate was zero, the project would not be viable.

When simulating the interest rate with a 807 L day^{-1} production (scenario 4), a positive NPV value is observed with a 4.6% p.a interest rate. For this scenario, interest rates were simulated increasingly, until reaching the break-even point between 22% and 23% p.a., where the NPV would be BRL 9,071.94 (9.97-year payback) and BRL -9,777.99 respectively. For all simulations in this scenario, the IRR remains 14.44% p.a., since it is not subjected to variations due to the interest rate on the financing, depending only on the project cash flows.

Costs with raw materials and inputs refer to approximately 55% of the ethanol production industry costs (BRL 270,832.62). Therefore, in scenario 5, that is, a 403 L day^{-1} production, costs with raw material (sweet potato), and inputs for ethanol production were simulated. In this case, the NPV value is positive only if there is a 71% reduction in the value of inputs and raw materials (NPV BRL 6,345.36).

Scenario 6 refers to the same values set in the previous scenario, simulating variation in the values of inputs and raw material for microdistilleries with a 807 L day^{-1} production. The variations were -5%, -10%, and -15%, with the addition of 9% to the value of original inputs and raw materials (BRL 530,687.25). With a 15% reduction in these costs, in the 807 L day^{-1} microdistillery, it is possible to reach an NPV of BRL 948,754.91, a 21.20% IRR per annum, and Payback in 7.24 years. With an 8% increase, a NPV value of BRL 10,823.60, a 10.73% IRR p.a, and Payback of 9.96 years are obtained, while with an increase of 9%, the NPV becomes negative (BRL -29,956.02).

In scenario 7, changes in starch content are suggested. The levels were changed by 5%, 10%, 15%, 20%, 25% and 50%, and the NPV for a 417 L day^{-1} production was positive with a 450 g kg^{-1} starch content (wet basis) (NPV is BRL 831,992.14, IRR 19.89% p.a., and Payback of 7.53 years), that is, 50% more than that used for the other simulations. Therefore, with a 450 g kg^{-1} starch content, the number of farmers producing and delivering sweet potatoes to the microdistillery would be reduced from 29 to 20, with a 417 L day^{-1} production. The amount produced is approximately 4% higher than those presented in the other scenarios. However, according to the microdistillery manufacturer, there is a safety margin of up to 10% of the production capacity in the industry.

Scenario 8 is elaborated from the parameters suggested in scenario 7, but with a larger industry, reaching a 811 L day^{-1} production. With a 15% variation in the starch content, that is, 350 g kg^{-1} starch, an NPV value of BRL 2,222,675.06, 28.89% p.a. IRR, and Payback of 5.77 years are achieved. In this case, the number of farmers would be reduced from 58 to 50. The break-even point is between 300 g kg^{-1} and 290 g kg^{-1}. With a 290 g kg^{-1} starch content, the NPV becomes negative, reaching BRL -110,082.48.

Taxes are responsible for approximately 30% of the costs of the microdistillery (BRL 138,432.32 for the 403 L day^{-1} production, and BRL 276,864.63 for the 807 L day^{-1} production). In this sense, the Law Project n. 9625 of 2018 provides for stimulating the production of ethanol on a small scale, with the production of up to 10,000 L day^{-1}, and also direct sales to the consumer and tax exemption, such as PIS / PASEP and Cofins (Brasil, 2018). Scenario 9 suggests changes and exemption from taxes, varying -5%, -10%, -15%, -20, -50% of the total taxes, including PIS / PASEP and Cofins, according to the Law Project. In the 403 L day^{-1} production, even with the elimination of taxes, the project would not be viable.

In scenario 10 (807 L day^{-1} capacity), when reducing taxes by 20% (BRL 221,491.71), the NPV reaches BRL 762,562.99, with a 19.16% p. a. IRR, and Payback in 7.71years. Even if increasing taxes by 15%, the NPV is still positive, with a value of BRL 17,933.77, a 10.82% p.a. IRR, and return on investment in 9.94 years. When simulating the increase in taxes by 16%, the NPV becomes negative (BRL -3,341.35).

Scenarios 11 (403 L day^{-1}) and 12 (807 L day^{-1}) are also analyzed according to the Law Project in force, regarding the exemption from PIS / PASEP and Cofins taxes, and considering the sale price directly to the final consumer (BRL 2.92 L^{-1} – an average of the amount charged in 2019). As a result, scenario 11 shows the NPV value of BRL 386,780.65, 15.44% per annum IRR, and Payback of 8.62 years. In scenario 12, the NPV reaches BRL 4,053,178.70, with a 39% p.a. IRR, and Payback of 4.43 years, being the most promising scenario among those analyzed.

6 DISCUSSION

Some variables were more relevant to the viability of investing in a sweet potato ethanol microdistillery. One of the best examples is the processing capacity, which influences the initial investment, costs and revenues. Regarding the initial cost, the value per unit produced of ethanol has no linear correlation with the capacity to be installed, the greater the capacity to be installed, the lower the initial cost per liter of ethanol to be produced. In this sense, the most economically attractive scenarios were those with micro distilleries with a 807 L day^{-1} production capacity.

The sale price is another extremely important factor in the feasibility of the project, as demonstrated in the proposed scenarios. With the 403 L day^{-1} industry, both the sale price to the distributor and the direct sale did not result in the viability of the enterprise. However, for the microdistillery with 807 L day^{-1} capacity, there was an increase in NPV from BRL 337,060.58 to BRL 2,672,050.23 when the direct sale was simulated. It should be noted that in the case of direct selling, there would be other structural and legal needs.

When thinking about the structure of this microdistillery, a collective of people is expected to work for local development. The implementation of associations and cooperatives becomes an alternative for the families in this process, that could lead to the promotion of another marketing channel, the addition of value to the product, and teamwork encouragement. Besides, the process tends to stimulate the professional qualification of those involved, being especially important as an incentive for the rural youth to remain in the countryside if we consider the problem of rural exodus in Brazil. The number of farmers involved in these organizations, which could vary from 20 to 58, would be one of the most important factors to take into account since this number could hinder the suggested process, as more people would be working together. In addition to the social challenge, the economic challenge of the distances between raw material and microdistillery could lead to the non-fulfillment of these deliveries or their delay.

Another aspect involved would be the incentive to energy sovereignty. Recently, in the 2018 truckers' strike in Brazil, we could notice the great existing dependence not only on fossil fuels but also on the big biofuel producers. The ethanol production based on different raw materials and in small distilleries may open possibilities to the producers involved in this process to purchase the biofuel, as well as local companies, and agencies such as city halls and state departments.

In this sense, public policies to encourage family farmers to produce ethanol should be created. These could include differentiated taxation, which is supported in scenarios 11 and 12, which shows that the exemption from taxes such as PIS and Cofins impacts the NPV and turn it economically attractive. Also, the possibility of direct sales to the final consumer, seen in scenario 2, has a considerable influence on NPV, IRR, and Payback. Another aspect to consider, culturally not very often practiced in Brazil, would be the discussion of public policies that would not directly involve economic aspects, such as encouraging associations and environmental preservation.

The environmental aspect, not measured in this analysis, has indirectly great social and economic relevance. For example, when taking into account environmental and social aspects of sugar cane ethanol production, Magalhães et al. (2012) found out that even with higher NPV, production using sweet potatoes is preferable. Thus, the need for further studies, seeking to price environmental preservation and soil and water conservation is highlighted.

This study is based on the use of sweet potatoes as the only raw material to feed the industry. However, studies of the viability of flex industries, combining sweet potatoes with other crops, such as sweet sorghum, cassava, sugar cane and corn (Magalhães et al., 2012; Masiero, 2012; Taborda et al., 2015), show that the enterprise is more interesting when there is a diversity of raw materials, enabling the ethanol production planning according to the harvests of each culture, and allowing the industry always to work at its maximum capacity. In studies simulating scenarios with only one raw material in the region of Rio Grande do Sul state, with similar climate to the area of this work, it is preferable to use sweet potatoes instead of sugarcane (Masiero, 2012). This type of study could be a demand (public policy) for state research (calls for public universities, state, and federal public research agencies).

Among the revenues, values are generated with the sale of the co-product (protein must), which is normally dried and transformed into protein bran. However, the investment to purchase the drying equipment would make this process unfeasible as it can reach 80% of the price of acquisition of the ethanol industry. Therefore, by not turning the must into bran, the largest volume transported is water. In this case, the cost of transformation is avoided, however, transportation becomes more costly, as it fits in the freight type FOB, in which the responsibility of transportation is of the buyer/ farmer. The study of drying processes, via direct solar radiation, should be considered.

Sweet potato drying processes before processing into ethanol would be also interesting to increase the starch content in relation to the moist base, as highlighted in scenario 7. This process, however, demands energy, which would take time in the case of using direct solar energy and also would need post-harvest structures, or expenditure on energy and larger structure in the case of other sources. Alternative processes could be studied, for example, the possibility of reusing the thermal energy generated in the process of hydrolysis, fermentation, and distillation.

These results point to another clear demand for technological studies and scientific research regarding small industrial machines and equipment. Both for industries and use on the family farms, one of the difficulties encountered by the smallholders is finding equipment compatible with the size of the farm and/ or agro-industry. Normally the equipment is produced for a large scale, which does not match the smallholders' needs. Also, family farmers find it difficult to access capital, which creates the need for incentives and financial support so that they can increase their production, consequently their income and the quality of life in the countryside.

Another possibility that arises for ethanol producers is the market for CBIOs (Decarbonization Credits), recently legalized through the RenovaBio program. The program, aiming to reduce greenhouse gas emissions, regulates the "sale" of carbon credits. Fuel distributors will be able to prove compliance with mandatory individual reduction targets, through the purchase of CBIOs, defined as an "exchange tradable financial asset, derived from the certification of the biofuel production process based on the respective levels of efficiency achieved to its emissions" (ANP, 2017).

Future studies on the topic should include the risks of sweet potato ethanol production, considering that this study showed the economic results, but as seen, several factors can influence this viability both positively and negatively.

7 CONCLUSION AND POLICY IMPLICATIONS

To characterize microdistilleries and processes involved in ethanol production from sweet potato, a 10-year cash flow was used in an industry operating for 11 months a year with commercially available production capacity of 403 L and 807 L day^{-1}, with an interest rate of 4.6% p.a. Taxes accounted for approximately 30% of costs, while inputs and raw materials represented 55% of costs. The sale price for the distributor was BRL 2.61 L^{-1}, however, the most promising result was verified with the sale directly to the final consumer for BRL 2.92 L^{-1}.

The most promising scenarios were those with a microdistillery production capacity of 807 L day^{-1} ethanol, which would involve 58 farmers supplying 30 Mg ha^{-1} of sweet potato to the plant, with a starch content of 300 g kg^{-1}. Two scenarios simulating the direct selling price to the consumer at BRL 2.92 L^{-1} showed the best results. In scenario 2, an NPV of BRL 2,672,050.23, a (%)31.52 p. a. IRR, and a Payback period of 5.36 year were obtained. In scenario 12, which maintained the same values as scenario 2, but, in addition to direct sales, provided the exemption from PIS / PASEP and Cofins taxes, resulted in an NPV of BRL 4,053,178.70, a 39% p.a. IRR, and Payback of 4.43 years. The production of sweet potato ethanol with a 403 L day^{-1} capacity plant is not economically attractive.

When carrying out these simulations of scenarios, the need for research and studies in various fields was observed, with the possibility of generating other scenarios, using other indicators, such as ethanol production with a consortium of cultures; other marketing channels; as well as the CBIOS market; studies focusing on environmental factors, analyzing aspects in the field, as well as improvement of sweet potato yields.

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