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ECONOMIC AND FINANCIAL VIABILITY OF DIGESTER USE IN CATTLE CONFINEMENT FOR BEEF

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ABSTRACT: This research analyzes the economic and financial feasibility of implementing a biodigester for confinement of beef cattle on a farm located in the State of São Paulo, through the approach of discounted cash flow. The anaerobic digestion technology arouses interest, due to its advantages with the generation of electricity and the pollution reduction of water resources, soil and air, from the biogas and bio-fertilizer production, high value-added products to cattle raising. It was verified that the treatment system of cattle manure with biodigesters generate biogas and fertilizer as revenue, with free cash flows that enable a return on investment in 3.8 years and return an IRR 26.40% and an MIRR of 10.69%; all above than the minimum rate of attractiveness which confirmed the economic and financial viability of the investment.

KEY WORDS: biogas, biofertilizer, cattle, discounted cash flow.

INTRODUCTION

Brazil is the second largest meat producer in the world and the world's largest exporter of beef, which is consumed in more than 180 countries (SILVA et al., 2013; CONAB, 2016).The world population growth makes Brazil one of the world's leading suppliers of grains and meats (MELZ et al., 2014).

The expectation of demand growth for Brazilian beef brings concern for the sustainability of production systems due to the extensive need for land and the environmental impact resulting from the emission of greenhouse gases (GHG) and the incorrect handling of the waste generated daily in large amount and directly on the property soil (LANSING et al., 2008; BARBOSA e LANGER, 2011; NOGUEIRA et al., 2012; BUDDE et al., 2016).

In this context, anaerobic biodigestion of organic residues is a technique capable of recycling the cattle organic matter, disintegrating it into simpler compounds, obtaining as final products the biogas, practically composed by CO_2 and CH_4 and the biofertilizer reused in the agricultural chain or even in the self-sufficiency of rural property (KUNZ, MIELE and STEINMETZ, 2009; BERGIER and ALMEIDA, 2010; NOGUEIRA et al, 2012; ORRICO Jr. et al., 2012; DUAN et al. 2014).

In addition to environmental sustainability for rural properties, the generation of electricity through biodigesters can be highlighted in the Brazilian energy matrix due to the size of the cattle herd in Brazil of 215.2 million in 2015 (CONAB, 2016; ORRICO et al., 2012).

In addition to the practical, economic eminent importance, and even public policy for the sector, the theoretical discussion of the economic feasibility for biodigesters dedicated to the bovine confinement is necessary to extend the empirical studies on the subject that concentrate on the activities of swine farming (CHERUBINI et al., 2015; FERNANDES, MAIA and GOMES, 2015).

In this way, the aim of this study is to analyze the incremental cash flow of the investment project to implement an anaerobic biodigestion system in confinement systems and to discuss the economic viability of this investment.

Nevertheless, this study presents a more complete economic evaluation of biodigesters in bovine confinement compared to other studies that point strictly to gains: operational efficiency

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(ORRICO Jr. et al, 2012), cost saving with bioelectricity (NOGUEIRA et al., 2012), recovery period of the investments (BUDDE et al., 2016), viability only with biogas revenue (BONFANTE, 2010) and use of the Profitability Index (CERVI et al 2010).

MATERIAL AND METHODS

The study was carried out in a farm located in the region of Presidente Prudente - SP during 2014. The identification of the property was omitted due to the request of the members. The main activity of the property is the breeding of beef cattle to slaughter. The property has a confinement with static capacity for 5,000 oxen and 4 cycles per year. The facilities are divided into 34 pickets with $8m^2$ per animal and 150 oxen per picket. The cleaning plan corresponds to the washing of 6 pickets per day, so the employee washes the same picket every 5 days.

The animals remain confined for 90 days and are subsequently slaughtered. These animals enter the confinement on average with 19 months, weighing approximately 350 kg and they end at 22 months, weighing about 510 kg, so they gain on average 1.8 kg of weight per day, obeying a diet of 40% of roughage and 60 % of concentrate, and the source of roughage was brachiaria grass hay and the concentrate formulated with corn and soybean meal. Besides the confinement, several agricultural activities are carried out to produce seeds of brachiarias, panicuns, leguminous trees and other varieties.

JUNQUEIRA (2011), COSTA et al (2016) and SANTOS & NOGUEIRA (2012) studies were used as bases to obtain data on the characterization of bovine manure. These data allowed the calculation of the biodigester dimensions and the biogas potentials and biofertilizer production and quality, as shown in Table 01.

TABLE 1. Dimensioning of biodigesters, biogas potential and biofertilizer production and quality.

Dimension of Biodigester	Daily load of 466,550L after dilution (1: 6)	Useful biodigester volume of 13,996.500L after HRT= 30	4 Biodigesters	3,500 m^3
Biogas Potential	TS in daily load 2.93%	0.274m^3/kg TSad	3.741.9m^3 of biogas/day	7,519.45Kwh/day
Biofertilizer Potential	1.87% of DM in biofertilizer	2.81% of N	1.46% of P	2.68% of K
		245.15kg of N/day	127.37kg of P /day	233.81kg of K /day

Source: Created by the authors.

In order to carry out the technical analysis, the technical coefficient data for biogas production, electric energy and biofertilizer generation were calculated. The data shown in Table 01 allowed the calculation of the expenses associated with the implementation of the system, operating costs and revenues obtained with the use of biogas and biofertilizer.

The amount of waste per animal is greater than that identified in the study of NOGUEIRA et al. (2012) (10 kg/animal), which may be associated with differences in the diet of the animals, considering that this information was not highlighted in the authors' study. As the diet of this study has higher concentration in concentrate (60%), it is expected that methane production will also be more efficient, as evidenced by ORRICO Jr. et al. (2012) and ORRICO Jr. et al. (2010).

a) Biodigester Dimensions

The biodigester that has been defined for this study is the continuous tubular flow biodigester (Canadian model) with solid separator, which receives a continuous feed of load daily. The hydraulic retention time (HRT), which is the length of stay of the organic matter inside the biodigester, it was determined in 30 days (sufficient time for the microorganisms to degrade the organic matter). The method for estimating the useful volume of the biodigesters was calculated by the product of the daily load and the retention time, according to Formula 01:

$$UVB = VL \times HRT \quad (1)$$

That,

UVB - Useful volume of the biodigester (m^3);

VL - Volume of daily load (manure + water) (m^3 day^{-1}), and

HRT - Hydraulic retention time (days).

To determine the volume of the daily load, the average mass of the waste produced by the herd was calculated, observing the ratio of manure/water of 1:6, according to the data described by JUNQUEIRA (2011). Therefore, considering the reality of the property studied and the structure of its herd, it is possible to estimate, through the Formulas 02 and 03, the average amount of waste produced per day and the daily load volume.

$$ADMPO = AWO \times PM/100 \quad (2)$$

That,

ADMPO - Average daily manure production per ox (kg * ox^{-1} * day^{-1});

AWO - Average weight of the live ox (kg), and

PM - Percentage of manure production by ox weight (3.1%).

$$DLV = (ADMPO \times N \times DR) + (ADMPO \times N) \quad (3)$$

That,

DLV - Daily load volume (L);

ADMPO - Average daily manure production per ox (kg * ox^{-1} * day^{-1});

N - Total number of animals (heads), and

DR - Dilution ratio (L).

b) Biogas

In order to determine the biogas production, 20.49% of the dry matter in the waste was used, as shown in the results of Junqueira's (2011) and the amount of biogas potential of 0.274m^3 kg^{-1} of manure found in the results of COSTA et al. (2016). Once established the amount of daily load, the percentage of dry matter (DM) and the biogas production potential of the bovine waste, the daily biogas production was calculated from the following formula:

$$DPB = LV \times DM\% \times BPP \quad (4)$$

That,

DPB: Daily production of biogas (m^3 * day^{-1});

LV: Daily load volume (waste + water) (m^3 * day^{-1});

DM%: Dry matter percentage in the daily load (kg), and

BPP: Biogas production potential from cattle waste (m^3 * kg^{-1}).

The generator set necessary to meet the biogas demand produced by the biodigester is the 330 kVA biogas motor-generator set. The number of operating hours of the motor can be calculated according to the formula:

$$EW = BDP / HBC \quad (5)$$

That,

EW: Number of engine working hours (h);

BDP: Biogas daily production (m^3 * dia^{-1}), and

HBC: Hourly biogas consumption (m^3 * h^{-1}).

The benefits with the generation of electric energy generated in the motor-generator set were interpreted as the portion of the income that is no longer transferred to the electric power provider. Thus, the benefit was interpreted according to the electric power consumption in function of the engine operating time and the electricity tariff paid by the owner, as follows in [eq.(6)]:

$$RE = (NDO \times EEP \times EW)\ ET \quad (6)$$

That,

RE - Revenue from electricity (R$);

NDO - Number of days of engine operation;

EEP - Effective engine power (kWh);

EW - Engine working time (hours),

ET - Electricity tariff (R$ * kW^{-1} * h^{-1}).

The benefits were calculated through the energy tariff paid by the owner, which is classified as a consumer of “B2 Group/ Rural Conventional”. The average electricity supply tariff of Energisa Plant located in the region of Presidente Prudente - SP, in the rural category presented by the National Electric Energy Agency – ANEEL was used in July 2014, that is, the value of R$ 250.67 per MWh, with taxes (ANNEL, 2014).

c) Biofertilizer

The biofertilizer produced in the biodigester contains several nutrients, which in its composition contains N, P, K, Ca, Mg, Na, Zn, Cu, Fe and Mn. In order to determine the biofertilizer revenue value, only N, P and K nutrients were used, which are commonly found in the market as mineral fertilizer for general fertilization. The daily availability of the macronutrients (N, P, K) from the N, P and K percentages present in the effluent from the biodigesters analyzed by Junqueira (2011) was estimated for the calculation of the benefits generated by the biofertilizer production. The daily availability of each nutrient was calculated according to eqs (7), (8) and (9).

$$NQ = DLV \times DM\% \times N \quad (7)$$

That,

NQ - Nitrogen quantity present in the biofertilizer (kg * day^{-1});

DLV - Daily load volume (L);

DM% - Percentage of dry matter remaining in the biofertilizer (kg), and

N - Nitrogen present in the biodigester effluent (2.81%).

$$PQ = DLV \times DM\% \times P \quad (8)$$

That,

PQ - Phosphorus quantity present in the biofertilizer (kg * day^{-1});

DLV - Daily load volume (L);

DM% - Percentage of dry matter remaining in the biofertilizer (kg), and

P - Phosphorus present in the biodigester effluent (1.46%).

$$KQ = DLV \; x \; DM\% \; x \; k \quad (9)$$

That,

KQ - Potassium quantity present in the biofertilizer (kg * day^{-1});

DLV - Daily load volume (L);

DM% - Percentage of dry matter remaining in the biofertilizer (kg), and

K - Potassium present in the biodigester effluent (2.68%).

The benefits with biofertilizer production were computed according to the quantity of N, P and K nutrients in function of the average prices of commercial fertilizers practiced in the market. In order to determine the annual biofertilizer revenue, [eq. (10)] was used.

$$RBP = QN \; x \; E \; x \; Y \; x \; PFM \quad (10)$$

That,

RBP - Annual revenue from biofertilizer production (R$ * year^{-1});

QN - Daily quantity of the macronutrients present in the biofertilizer (t);

E - Equivalence to the commercial fertilizers (SA, SS, Kcl) (%);

Y - Number of days in the year (days), and

PFM - Price of commercial fertilizers in the market (R$ * kg^{-1}).

In the analysis of expenses, the initial investment and the total costs of the plant were determined.

a) Initial investment

The initial investment was classified as the necessary expense for the installation of the facilities and acquisition of materials and equipment. The costs of concrete of the confinement floor, biodigester, motor-generator set and shelter, and the electric power transmission network were considered. The values of these investments were taken with the construction companies in the region and suppliers of electric motors.

b) Annual cost of the system

For the calculation of the annual costs of the system the following was considered: costs of depreciation, maintenance and operation. For the calculation of the depreciation of the physical installations of the biodigester, the concrete of the confinement, the equipment and the electrical installations, a period of 10 years of useful life was considered. For the determination of the depreciation and exchange of the plastic blanket of the biodigester, a period of 5 years of life was considered, according to the manufacturers' information.

The maintenance cost of biogas generators was determined by the product manufacturer (5% of the value) and is associated with lubricants, oil changes, oil and air filter changes, belt and bearing changes and a complete overhaul in the 5th Year (grinding). The cost of maintaining the biodigester is estimated at 5% per year on the biodigester value, according to the specifications provided by the manufacturer. The operation of the generator set is daily and requires the presence of a person responsible for engine ignition, cleaning and maintenance of the facilities. The cost of labor to keep the biodigester in operation is relatively low due to the simplicity of the system.

Only a cleaning is necessary for the removal of the precipitated sludge in the biodigester and the crust that forms on the surface. Thus, the direct costs with payment and IPE (Individual Protection Equipment) for two rural workers in the state of São Paulo were taken into account for the calculation of Expenses on labor required to maintenance and operation of the equipment.

The total gross revenue of the investigated property was within the limits of the presumed profit criterion, thus, the taxation is simplified from corporate income tax (CIT) and social contribution on net income (SCNI) and in this case showed better taxable income than the option for Real Profit. The tax rates determined for this tax system are 15% (fifteen percent) of the presumed profit and the percentage of the presumption profit is 8% (SANTOS and JURCA, 2013).

The depreciation costs of the motor generators, biodigesters and containment facilities did not enter into the free cash flow of the project, since with the option for Presumed Profit there is no calculation of costs for CIT and SCNI deduction.

Establishing the collection of revenues and Expenses of the system the free cash flow of the project was determined through the indicators: Net Present Value (NPV), Profitability Index (PI), Internal Rate of Return (IRR) and Period of capital recovery – With the Payback discounted, the economic viability analysis were carried out (GRAHAM & HARVEY, 2001).

To calculate the net present value, it was necessary to calculate the discount rate (risk) of the project. For this, the value of the main revenue of the project was used, the biofertilizer.

c) Discount rate

The risk rate is considered as the rate of return of the investor by the waiting cost, that is, the rate that compensates the risks of the investment made (ANDRIKOPOULOS, 2013). Damodaran (2007) clarifies that for the methodology in which the cash flow of the shareholders is adopted, the discount rate adopted would be the model of the asset pricing known as Capital Asset Pricing Modeling (CAPM), while for the methodology in which it applies the net cash flow at the appropriate discount rate would be defined by the Weighted Average Cost of Capital (WACC).

In order to determine the value of the project in question, in which the free and discounted cash flow was used, the method for calculating the discount rate is obtained by the Weighted Average Cost of Capital (WACC). According to DAMODARAN (2007) this rate is calculated by the following formula:

$$WACC = \left\{\left[Ke \times \frac{EQ}{EQ+TC}\right] + \left[Kd \times \frac{TC}{EQ+TC}\right]\right\} \quad (11)$$

That,

WACC - weighted average cost of capital;

EQ - Total value of equity;

TC - Total value of third-party capital;

Ke - Cost of equity, defined by CAPM, and

Kd - Cost of third-party capital (debt).

The cost of equity is obtained by adopting the asset pricing model - CAPM, as follows:

$$Ke = Rf + \beta \times (Mr - Rf) \quad (12)$$

That,

Rf - Risk free rate;

(ß) - Beta coefficient is the measure of the systematic (non-diversifiable) risk of the asset,

Mr - Market return.

To obtain the weighted average cost of capital, we calculated the beta that determines the non-diversified project risk in the amount of 0.66. This risk refers to this project to the capital returns in the mineral fertilizer market (NPK) correlated with historical data referring to capital returns of the main Brazilian market index (IBOVESPA) in the period from 2007 to 2014. For the calculation of the risk-free rate, the Selic value was used for the month of October/2014 at 10.90% per year. In addition, the historical premium of the Brazilian capital market was taken at 6% per year. (SANTOS & JURCA, 2013).

The estimated cost of debt was defined as 5.5% per year, based on the Low Carbon Agriculture (LCA) financing line of the National Bank of Economic and Social Development (BNDES), available for implementation, maintenance and improvement of waste treatment systems and waste from animal production for energy generation. Thus, it is possible to finance up to 100% of the investment and to have a 5-year grace period. The deduction of the CTI/SCNI in the cost of the debt was not made, because in the presumed profit, the financial expenses are not deductible.

RESULTS AND DISCUSSION

From the calculations made, the biogas production was 3,741.90 m^3/day and an estimate of 1,365,795.07 m^3 of biogas/year. The biogas produced was used directly in the electric power conversion system, which operates for 17.81 hours day^{-1}. Thus, a period of 312 days of operation per year can be estimated, which resulted in 5,589.84 operating hours per year.

The generator set used in this system operates on average of 20 hours daily, discounting the hours with the preventive and corrective stops. The biogas consumption by the motor-generator set was 210 m^3 h^{-1}, being necessary, to meet the daily production of this plant, two groups of generators of 330KVA in steady state with constant load. The evaluated system was designed to consume 100% of the volume of biogas produced by the plant.

The gain of the producer with the reduction in the consumption of electric power was R$ 686,149.43/year (Table 02), value in function of the amount of energy generated and the price of R$ 0.25 KW h^{-1}, value practiced by Energisa energy distributor that serves the region of Presidente Prudente.

TABLE 2**.** Revenues from the generation of electricity.

Production of biogas ($m^3.day^{-1}$)	Hours of Operation (h)	Power of 2 generators ($kW.h^{-1}$)	Production of energy (kW. $Year^{-1}$)	Revenue from electricity (R$$Year^{-1}$)
3,741.90	17.82	422	2,744,800.00	686,149.43

Source: Created by the authors.

The results of Table 2 confirm the study by CALZA et al. (2015), which compared the performance of swine, goat and cattle manure for biogas generation, where it was found that cattle manure is the one with the highest performance in the annual production of electricity from biogas.

Biofertilizer Production

We considered a use of 100% of the biofertilizer produced by the plant; therefore, 466,550.00L of biofertilizer/day are produced. According to the data obtained by JUNQUEIRA (2011) in its analyses, the concentrations of macronutrients were: Nitrogen (2.81g $100g^{-1}$), Phosphorus (1.46g $100g^{-1}$) and Potassium (2.68g $100g^{-1}$). Thus, the revenue from biofertilizer production was estimated according to the Table 03, being the price of market value consulted with suppliers for the State of São Paulo in 2014.

TABLE 3**.** Revenues from the production and application of biofertilizers.

	Nutrients (kg. $Year^{-1}$)	Fertilizer (kg. $Year^{-1}$)	Fertilizer Price (R$. Kg^{-1})	Total
Ammonium sulfate (21% N)	89,482.68	447,413.40	0.75	335,560.05
Super Simple Phosphate (20% P2O5)	106,468.47	591,491.49	0.83	490,937.93
Potassium chloride (60% K2O)	102,411.49	170,685.82	1.24	211,650.42
Total				1,038,148.41

Source: Created by the authors.

Initial investment

It was necessary to measure the price of 4 biodigesters of 3,500m^3, 2 biogas generators of 330KVA, the costs with installation and civil engineering of these equipment and the costs for concreting the confinement (Tables 04, 05 and 06) to attend the amount of waste generated by the 5,000 animals. The total initial investment for this project was estimated at R$ 4,362,506.75. GOMES & PIACENTI (2016) estimated an investment of R$ 6,772,257.09, in the installation of an anaerobic biodigestion system, for the treatment of 285,484 animals among swine, cattle and poultry for electricity generation. CERVI et al (2010) and LIMA & MIRANDA (2014) in their study with swine estimated investments of R$ 51,537.17 and 75,000.00 respectively.

TABLE 4. Expenses made in the purchasing and installation of generator set.

Motor Generator Set and Installation	Unit	Quantity	Unit cost (R$)	Sub-Total
Motor Generator Set	Unit	2	350,000.00	350,000.00
Electrical Installations	-	-	19,069.00	19,069.00
Shelter of the generator set (civil engineering s)	-	-	1,970.93	1,970.93
Total				721,039.93

Source: Created by the authors.

TABLE 5. Expenses with concrete for the confinement area.

Concrete of the Containment (civil engineering) 4080 m^3	Unit	Quantity	Unit Cost (R$)	Sub-total
Concrete FCK=25 MP	m^3	4,080	312.70	1,275,816.00
Labor (5)	daily	100	180.00	135,000.00
Shipping	300 Km	80	1,500.00	120,000.00
Total				1,530,816.00

Source: Created by the authors.

TABLE 6. Expenses with equipment, installation and civil engineering of the biodigester.

Biodigester (equipment)	Unit	Quantity	Sub-Total
Biodigesters	-	4	R$ 664,623.17
Excavation, piping, labor and civil engineering	-	-	R$ 443,017.75
Total			R$ 443,017.75

Source: Created by the authors.

The variation between the results presented by CERVI et al (2010) and LIMA & MIRANDA (2014) who worked with 2,300 and 6,800 swine, respectively, and those reported in this study, are justified according to COLATTO & LANGER (2011), which highlight in their study that cattle manure is 4.5 times more bulky than swine, making it necessary to implant a plant with greater capacity and consequently greater investment. CALZA et al (2015) point out that, for 100 cattle, the capacity of the biodigester is 120 m^3, being the Canadian model the one that presents a lower implantation cost, corroborating with the data presented in this study.

Annual cost of the system

The annual costs of the system were considered as: operation, maintenance and residual cost. According to the specifications in the manual of the biogas generator set, the cost was given by the period of use of the generator set of 17.82 hours day^{-1}, that is, 6,504.3 hours year^{-1} and the average maintenance hour cost of 8.54 hour^{-1} or 0.04 kWh^{-1}.

The total annual costs with maintenance and operation of the biodigester and generator set were R $ 228,315.90, and in the 5th year the value was R$ 561,240.53, as a consequence of the exchange of the plastic vinimanta and in the 10th year the cost was R$ 925,086.23, which recorded the vinimanta exchange and the residual value of the system (uninstallation of the system). The residual value represents 10% of the investments with the civil engineering of the biodigester and the concrete of the confinement. The total costs of maintenance, operation and residual value in the

10 years of the project were R$ 3,312,853.99. These costs represented 76% of the initial investment for the implementation of the system.

TABLE 7. Costs of maintenance and operation of the project.

Annual Costs (R$)			
Maintenance		Operation	
Biodigester	R$ 83,231.16	Labor (2 employees)	R$ 32,595.84
2 Motor-Generator	R$ 111,084.67	IPEs	R$ 1,404.24
Total of Maintenance	R$ 194,315.82	Total of Operation	R$ 34,000.08

Source: Created by the authors.

Economic analysis

The free cash flow of the project was estimated considering the free cash flows of the project, the discount rate was defined as 5.7% per year, which represents the project weighted average cost of capital referring to the use of 90% of subsidized financing (5%) and 10% of equity (7.8%).

In the first year of the cash flow, we considered the use of the generated products (biogas and biofertilizer) equivalent to 8 months of the system operation, since the period for implementation of the complete system is 4 months, after the beginning to obtain the revenues. The estimated revenue for the first year of the project was R$ 1,149,531.89 representing 66% of the revenues generated in subsequent years. The cash flow of the project with the information and data required for the economic analysis are in Table 08.

TABLE 8. Demonstration of the cash flow from the waste treatment project for 5,000 cattle in 4 cycles.

YEAR	Total Revenue	Net Revenue	Operational costs	Net income	Free Cash Flow	Discounted Cash Flow
0					-4,362,506.75	-4,362,506.75
1	1,149,532	1,110,217.90	228,315.90	881,902.00	881,902.00	834,344.37
2	1,72,298	1,684,983.84	228,315.90	1,456,667.94	1,456,667.94	1,303,798.83
3	1,724,298	1,684,983.84	228,315.90	1,456,667.94	1,456,667.94	1,233,489.91
4	1,724,298	1,684,983.84	228,315.90	1,456,667.94	1,456,667.94	1,166,972.47
5	1,724,298	1,684,983.84	561,240.53	1,123,743.31	1,123,743.31	851,710.85
6	1,724,298	1,684,983.84	228,315.90	1,456,667.94	1,456,667.94	1,044,505.28
7	1,724,298	1,684,983.84	228,315.90	1,456,667.94	1,456,667.94	988,179.07
8	1,724,298	1,684,983.84	228,315.90	1,456,667.94	1,456,667.94	934,890.32
9	1,724,298	1,684,983.84	228,315.90	1,456,667.94	1,456,667.94	884,475.23
10	1,724,298	1,684,983.84	925.086.23	759,897.62	759,897.62	436,521.07
NPV		5,316,380.64		IRR	26.40%	

Source: Created by the authors.

All economic feasibility indicators presented favorable results, with an initial investment of R$ 4,362,506.75, "zero" year, interpreted as base year, and free cash flow of R$ 1,456,667.94, except for the 1st, 5th and 10th year, in which the amounts were R$ 881,902.00; R$ 1,123,743.31 and R$ 759,897.62, respectively. The NPV was R$ 5,316,380.64, IRR: 26.40%, PI: 121%, Discounted Payback of 3.8 years and a Simple Payback of 3.2 years, considering a 10-year project horizon. These results refer to the use of 100% of the electric power generated and the produced biofertilizer revenues.

The Payback period of this study is similar to that pointed out by BUDDE et al. (2016) in 3 years and 3 months, although in that study there is no indication of the discount rate.

The results found by GOMES & RAIHER (2013) when evaluating the implantation of biodigesters for electric power generation in a swine farm with 1,218 matrices and 2,630 finished in the state of Paraná, was economically viable, presenting a NPV of R$ 324,488.48, an IRR of 36.4%, a PI of 43% and a Payback of 3 years and 2 months, discounted at a rate of 9.1% per year.

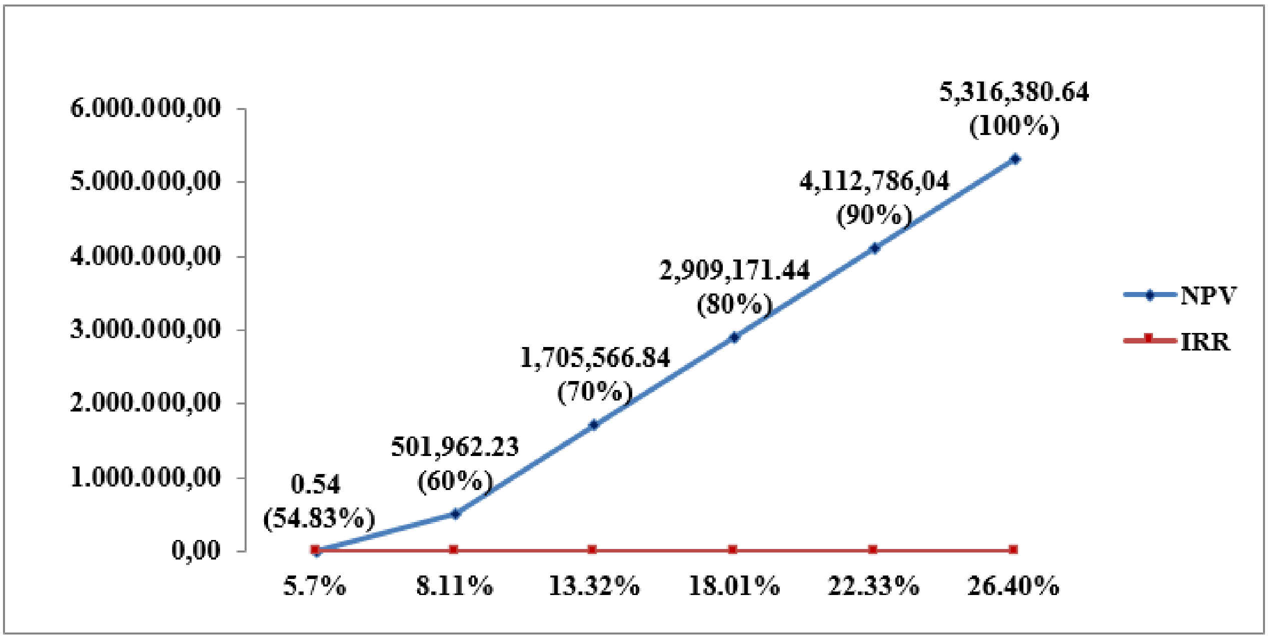
In the study of Junges et al (2009), who also analyzed investments for the treatment of swine manure for electric power generation and biofertilizer production, with and without subsidy, resulted in economically viable systems presenting NPVs of R$ 1,003,806.50 and R$ 733,592.81; the IRRs were 75.47% and 45.47%; the PIs were 398.10% and 201.00% and the Payback of 2 and 3 years respectively, corroborating with the results of this study, which also shows a very high profitability index and a short period of recovery of the invested capital.

CERVI et al. (2010), GOMES & RAIHER (2013), LIMA & MIRANDA (2014) and CALZA et al. (2015) evaluated only their electricity revenue, demonstrating from their economic results that their profitability may increase when compared to the results demonstrated in this analysis.

However, the results of 5 other scenarios compared to the current one as base were analyzed, the use by the rural producer of only a portion of the revenue generated with electric energy and biofertilizer. The scenarios were determined according to different percentages of revenue utilization: real with 100% of utilization and estimated with 90%, 80%, 70%, 60%, and 54.83% of utilization.

From the results presented in Figure 01, the invested amount of R$ 4,362,506.75 discounted at a rate of 5.7% is economically feasible in all the estimated scenarios, even if the real scenario can prove to be oversized, the estimated scenarios prove that the system brings in all cases evaluated financial returns, equal or above the expected.

The NPV refers to the real scenario is higher than the initial investment, which yields a profitability index of 121%, this high rate is translated by the IRR (26.4%) that exceeds the minimum attractiveness rate (MAR) (5.7%) at five times. Therefore, there is a highly attractive investment, based on the assumption of 100% utilization of the revenues generated. FEITOSA et al. (2015) also found a similar result when evaluating the economic viability of electric energy generation with cattle manure in the Quixabinha Irrigated Perimeter, demonstrating an IRR of 32.1% and a Payback of 3.2 years.



Source: Created by the authors.

FIGURE 1. Net Present Value with Internal Return Rate for the 5 scenarios studied.

In view of the great difference between the IRR and the MAR, there was a need to look for more concise results. The Modified Internal Return Rate (MIRR) was determined because the IRR restricts the return of the project, since it assumes that all cash inflows must be reinvested at the rate of return of the project.

The MIRR calculated in this project was 17.31%, about 10% lower than the IRR. The cash inflows were reapplied at the opportunity cost of the Brazilian market.

The profitability rates of the estimated scenarios were 11%, 39%, 66%, 94% and 121%, respectively, reaffirming the economic viability of the project, showing that for all scenarios the capital invested gives the producer quite attractive profit, only for the scenario of 54.83%, where the use of revenues is zero and NPV is null, the invested capital returns, but does not generate profits.

CONCLUSIONS

The implantation of biodigesters in cattle confinement systems can create economic value from the generation of electric power and biofertilizers (AS, SSP and CLK), due to: NPV: R$ 5,316,380.64, IRR: 26.40%, MIRR: 17.31%, PI: 121% and Discounted Payback: 3.8 years. The sensitivity function of the NPV of this project guarantees economic viability up to the limit of 54% of the use of the effective confinement capacity of 5,000 animals in 4 annual cycles.

The generation of positive cash flow in the first year of operation and the full recovery of the investment in 3.8 years guarantee to the rural producer liquidity in the financial flow of the property that use subsidized sources of financing for this purpose.

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