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# STUDY OF THE TECHNICAL AND ECONOMIC FEASIBILITY ON THE REPLACEMENT OF THE CURRENT ENERGY SOURCE FOR CASSAVA FLOUR PRODUCTION BY RESIDUAL BIOMASS

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***Abstract.*** *Along with the increasing environmental concerns, arises the need of searching new alternatives for energy production. In this scenario, the residual biomass from agriculture presents itself as an option for power generation by combustion in equipment such as boilers and furnaces. This study aims to analyze, in two stages, the use of residual biomass from different cultures, quantifying and evaluating the technical and economic feasibility of waste processing for power generation in ovens from five cassava flour houses In technical analysis, the wild region of the biomass in Alagoas (Brazil), privileged by its high agricultural production were identified and quantified from the data presented in recent surveys in the region. It was determined the average firewood consumption of flour houses, used as fuel in furnaces, and made up the comparison in relation to the energy potential of biomass waste, verifying that the replacement of this fuel would be possible, the wood, the agricultural waste. The economic aspects analyzed also showed that agricultural waste could be used in the furnaces of the home meal in question, without processing or densification, replacing the fuel currently used without significant drop in the income of Cassava Flour houses.*

***Keywords:*** *Energy; Agricultural Waste; Economy*

## 1. INTRODUCTION

The development of efficient alternatives for production and distribution of energy is an essential element for humans. Given this dependence on energy resources, emerges the need to diversify the use of energetics sources available.

The current scenario indicates that renewable energy sources should take increasing role in the global energy matrix with the prospect of reducing fossil fuel reserves and, even more, for environmental reasons. In this context the use of alternative energy sources in particular biomass, shows up as an opportunity and energy supply.

The biomass' energy consists mainly of organic origin substances, thus, for being a source of clean and renewable energy, its use is considered to be strategic for the future.

The issues involving power generation and distribution, in a country of immense land mass, such as Brazil, always represented a great challenge and should be treated with great serenity and critical spirit. Energy's demand is booming along with environmental, social and economic problems. Brazil is a country with great biodiversity, therefore, it has a wide range of types of biomass in its territory, but only a few may be used for power generation, due to the availability and viability of existing raw material in a particular region. Biomass can be obtained from non-woody and woody plants, as is the case of matter and their residues. Other types are organic waste such as agricultural, municipal and industrial waste and biofluids such as vegetable oils. The great challenge is to develop new sources of energy from alternative sources of low cost, making them economically competitive. Thus, several research agencies in the country, have struggled to develop new alternatives and among the various possibilities, it is highlighted the use of biomass residues for power generation through it's burning.

The Alagoas's State (Brazil), due to large agricultural production has great potential for power generation from alternative sources such as the different types of residual biomass discussed in this work.

There are numerous forms of biomass utilization; one of them is the manufacture of briquettes for waste compression. Potential customers in Alagoas's State (Brazil), for the use of thickened biomass are flour mills, bakeries, pizzerias and industries that use boilers or furnaces. There have been various restrictions in order to use undocumented fuels. Cassava flour production in Alagoas's State (Brazil) is responsible for the livelihood of more than 25,000 families whose domestic economy is linked to the production chain in its more than 600 flour mills located in the region and more than 20 thousand hectares of planting root. Harvesting, crushing, crumbling and toasting cassava are themes for songs in the arid zone of Alagoas (Brazil). It is the very picture of the local culture and the true story of men, women and children in the region (SEBRAE, 2006). Hence there is a need to search for new energy sources for the improvement of cassava processing.

## 2. METHODOLOGY

The method of study was divided into two steps:

### 2.1 Technical Analysis

It was held the identification of agricultural cultures present in the wild region of Alagoas (Brazil) and, from the collected data and literature, it was possible to estimate the waste percentage from each crop taking into account the differences in residual percentage.

In Table 1 are represented this information, obtained from literature for corn, cotton, cassava and coconut, bean and peanut, "Ferreira-Leitão et al., 2010, "Souza et al., 2011" and "CENBIO, 2008".

Table 1. Percentage of waste from each crop

| | Peanut | Cotton | Coconut | Beans | Cassava | Corn |
|---|---|---|---|---|---|---|
| *% R* | *30.0* | *20.7* | *60.0* | *70.0* | *10.0* | *22.0* |

The residue quantitative calculation was made by means the Equation (1) described below:

$$R = P \cdot \%R \tag{1}$$

R– Amount of waste generated; P - Production with residue; % R - Waste percentage generated for each biomass.

After the identification and quantification of waste, were analyzed their energy potential of waste biomass, which was estimated by multiplying the value of the Lower Heating Value (LHV) of the crop, by the value of the quantity of waste generated. The average power consumption of the cassava flour mills analyzed was estimated using annual data production with use of fuel wood. The procedure used to calculate the energy potential of waste biomass is the same for calculating the energy potential of wood that is currently being used in flour houses.

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### 2.2 Economic Analysis

At this stage, the fair values assigned to the agricultural waste in the region were quantified. Transportation costs (freight) were analyzed by prices fixed by farmers. It was held a survey of machinery costs necessary for the drying , briquetting and storage steps, highlighting low-cost alternatives that might be used along with such investments. Scaled up a briquettes manufacturing mini plant with production capacity of 1 ton / h. Finally, it was designed a diagnostic of financial viability for use of residual biomass obtained in wild country as a source of energy in furnaces of Arapiraca municipality of flour mills in Alagoas's State (Brazil)..

## 3. RESULTS AND DISCUSSION:

### 3.1 Technical Analysis

From the identification of the municipalities comprising Alagoas (Brazil) rugged region, it was performed the quantification of their agricultural products, through literature surveys based on permanent and temporary crop data provided by the "IBGE, 2012" and the Alagoas Bioenergy Atlas (Salomon et al., 2014). It has been quantified for each municipality in the rugged region, the production of the following biomasses: peanuts, cotton, coconut, beans, cassava and corn.

With the production values of each culture, the calculation was made for each type of waste. It is important to mention that the average weight of each fruit of coconut was around 500 g and this value was determined experimentally by weighting several samples. The biomasses with greater residue generation, among the analyzed, is the cassava; the data can be seen in Tab.2.

The potential energy of the residual biomass was been estimated multiplying the value of LHV, (Souza et al., 2011) crop value over the amount of waste generated. The obtained value was given in MJ / month; the data can be seen in Tab.3.

Table 2. Agricultural Production of the Municipalities in the rugged Alagoas's State (Brazil).

| | Peanut | Cotton | Coconut[1] | Beans | Cassava | Corn |
|---|---|---|---|---|---|---|
| Total Production (ton/year) | 52.00 | 674.00 | 3,478,000.00 | 7,232.00 | 248,475.00 | 15,011.00 |
| Total Production (ton/month) | 4.33 | 56.16 | 289,833.33 | 602.67 | 20,706.25 | 1,250.92 |

[1] Fruits

Table 3. Energy Potential of Waste.

| Agricultural Culture | Total Production (kg/month) | % of residues | Quantity of Residues (kg/month) | LHV (MJ/kg) | Energy (MJ/month) |
|---|---|---|---|---|---|
| Peanut | 4,330 | *30.0* | 1,300 | 20.00 | 26,000.00 |
| Cotton | 56,160 | *20.7* | 11,626 | 16.27 | 189,155.02 |
| Coconut | 144,916 | *60.0* | 86,950 | 9.13 | 793,853.50 |
| Bean | 602,670 | *70.0* | 421,869 | 15.04 | 6,344,909.76 |
| Cassava | 20,706,250 | *10.0* | 2,070,625 | 11.96 | 24,764,675.00 |
| Corn | 1,250,920 | *22.0* | 275,202 | 15.28 | 4,205,086.56 |
| | | | Total Production of (MJ/month) | | 36,326,679.84 |

The same procedure previously used is given to the fuel energy calculation currently used in flour mills (A, B, C, D, E).

To determine the power consumption, the five flour mills were visited, then it was observed that the average firewood consumption ranged from 25 to 40 m³ / week, equivalent to a monthly consumption between 100-160 cubic meters of firewood. Thus, it was calculated the energy required to maintain a flour mill during one year in operation. It was acknowledged the value of the lower heating value for firewood 8.133 MJ/kg (Souza et al., 2011) and 1m³ of firewood equivalent to 400 kg according to BIOMAX, national company focused on the development of solutions in the use of industrial waste. The results are presented in Tab. 4.

Table 4. Firewood Consumption by Flour Mills.

| Flour Mill | Monthly Consumption (m³) | Consumption Firewood (kg/month) | LHV (MJ/kg) | Energy (MJ/month) |
|---|---|---|---|---|
| A | 160.00 | 64,000.00 | 8.133 | 520,512.00 |
| B | 140.00 | 56,000.00 | | 455,448.00 |
| C | 120.00 | 48,000.00 | | 390,384.00 |
| D | 110.00 | 44,000.00 | | 357,852.00 |
| E | 100.00 | 40,000.00 | | 325,320.00 |
| | Total Energy Potential of Firewood (MJ)/month | | | 2,049,516.00 |

The value found for energy that can been generated from agricultural residues available in the rugged region per month is 36,326,679.84 MJ in Tab.3. The monthly energy demand of the five flour mills totaled 2,049,516.00 MJ in Tab.4.

Each year, this consumption with wood is 24,594,192.00 MJ. Analyzing the potential of the rugged region and the monthly energy consumption of flour mills, it could be realized that the energy demand of the five flour mills is well below that the energy generated by agricultural waste. So, if the firewood was replaced by briquettes from residual biomass, then it would be needed just 5.64% of the monthly energy production of agricultural waste.

### 3.2 Economic Analysis

Obtaining positive results in technical analysis of residues, further then, began the analysis of the economic viability thereby determining whether if it will be financially profitable or not to replace the of firewood with residual biomass from the field.

It was first made a geographical survey counting the distances between where the agricultural waste is generated and the city of Arapiraca in Alagoas's State (Brazil), so as to measure how much will be spent on the transport of biomass as the transport logistics is one of the crucial points of this analysis. Agricultural waste without processing on the field and those resulting from a beneficiation in the agricultural industry have a low density, making it difficult and a burden on transportation costs. An alternative for the transport of waste from the collection site to the place of burning would be the consolidation of the volume still in the field, however due to the seasonal nature of agricultural production investments in infrastructure in the field for the peripheral consolidation of this waste would throttle a project of biomass reuse. Besides transportation, proper storage of waste is also an item to be considered. The same should be adequate to ensure the constant supply of waste avoiding changes in the fundamental characteristics, allowing moisture loss naturally and avoiding the incorporation of organic matter.

It was took into consideration the amounts currently charged by carriers in the rugged region and the average cost per kilometer for cargo transportation in the region is estimated as R$ 1.50 / km carrying 21.5 tonnes of waste per trip. Attention should be paid to the fact that only coconut and cassava residues are sold at the price of R$ 25.00 and R$ 30.00 per ton (in natura) respectively, the others are discarded or used in the maintenance of agricultural crop. In Tab. 5 are represented the results.

Every month, the five flour mills consume about 630 m³ of wood / month, totaling around R $ 50,400.00 per month, taking the amount of R$ 80.00 per m³ of wood, the average cost of fuel currently on the market. Calculating the monthly waste consumption of the five flour houses, therefore, 1 ton of briquettes is equivalent to 5 cubic meters of firewood and 1 ton of briquettes is equivalent to 1.27 tons of waste, yielding the following results in Tab. 6.

It was considered in this preliminary analysis only municipalities of the rugged region, which owned production at or above the required by the five flour mills. The waste used for the production of briquettes would be provided by one of these six municipalities (Arapiraca, Girau do Ponciano, São Sebastian, Taquarana, Igaci, Palmeira dos Indios). Only for the municipality of Palmeira dos Indios would not be economically viable, to replace the wood by agricultural waste, as its cost of transportation and purchase of biomass exceed the amount spent for the corresponding quantity of firewood.

So far, the analysis was based on the existence of a briquetting mini-plant in the rugged region, since according to "Souza et al., 2011"; comparing the calorific value of waste biomass before and after compression (briquetting) they present a considerable increase. One goal of this work is to verify the feasibility of installing this mini-plant in the city of Arapiraca, since the costs of waste would be smaller those spent on firewood and the investment would been taken back over the years with the profit generate by the replacement. The investment initially made to this mini-plant would be around R$ 744,400.00, according to the budget provided by the company "LIPPEL, 2013", specialized in waste processing. The financial quotation has been held for a briquetting mini-plant with production capacity of 1 ton / h due to seasonality of agricultural production in Alagoas rugged region.

In addition, the waste recycling project through the implementation of a briquetting mini-plant fits in the group of technological projects, that may have funding from FINEP (Financier of Studies and Projects), that acts in encouraging the research projects focused on innovation technology. The interest rate adopted in funding for implementation of the briquetting mini-plant would be 5% (Jun / 2014) per year, over 10 years. According to data provided by one of the five flour mills, the gross monthly income of a flour mill is R$ 50,000.00 and the monthly net income is R$ 10,000.00. Although consumption firewood of the five flour mills vary between 100 and 160 m³, it was admitted up, with a small margin of error, that the gross monthly income of the five flour mills is R$ 250,000.00 and a net monthly in-come is R$ 50,000.00.

Table 5. Costs Waste + Shipping.

| City | Total Generated Waste (ton/month) | Shipping (R$) |
|---|---|---|
| Arapiraca | 842.82 | 0 |
| Campo Grande | 8.37 | 110.40 |
| Coité do Nóia | 49.20 | 46.20 |
| Craíbas | 55.70 | 57.00 |
| Feira Grande | 100.91 | 48.90 |
| Girau do Ponciano | 298.83 | 68.70 |
| Lagoa da Canoa | 65.92 | 36.60 |
| Limoeiro de Anadia | 20.05 | 51.90 |
| São Sebastião | 265.10 | 71.10 |
| Taquarana | 455.86 | 48.90 |
| Belém | 22.91 | 80.10 |
| Cacimbinhas | 37.79 | 191.70 |
| Estrela de Alagoas | 50.15 | 126.60 |
| Igaci | 265.58 | 68.70 |
| Maribondo | 1.62 | 147.90 |
| Mar Vermelho | 0.98 | 157.50 |
| Minador do Negrão | 8.82 | 220.50 |
| Palmeira dos Índios | 173.69 | 112.50 |
| Paulo Jacinto | 3.24 | 207.90 |
| Quebrangulo | 2.29 | 188.70 |
| Tanque d'Arca | 8.40 | 103.20 |
| Olho d'Água Grande | 19.41 | 113.40 |
| São Brás | 6.05 | 190.20 |
| Traipu | 103.89 | 169.50 |

Source Alves,2013

Table 6. Waste Consumption by flour mills.

| Flour mill | Monthly consumption ($m^3$) | Waste consumption by flour mills (ton/month) |
|---|---|---|
| A | 160.00 | 40.64 |
| B | 140.00 | 35.56 |
| C | 120.00 | 30.48 |
| D | 110.00 | 27.94 |
| E | 100.00 | 25.40 |
| | Total (ton/month) | 160.02 |

To supply the need of waste required for operation of the five flour mills, a monthly production of 126 tons of briquettes will be needed, and as the mini plant has the capacity to produce 1 ton / h if it operated 6 h / day, only 21 days would suffice to fill the monthly briquettes demand of those flour mills, generating savings since the plant was not operating on all days of the month and could also produce briquettes for storage, quite positive point due to seasonality of agricultural production, or sell which would generate extra profit. It is also considerable in this analysis the costs with operation, maintenance and depreciation (where 10% in each year of useful life is depreciation) of equipment of the briquetting mini plant. The results are shown in Tab. 7 and Tab. 8.

Table 7. Operating Costs and Maintenance of the Mini Plant.

| | |
|---|---|
| Cost of Labor (R$ / ton) | 27.47 |
| Maintenance cost (R$ / ton) | 10.82 |
| Depreciation cost of Equip. (R$ / ton) | 12.01 |

Source: Adapted (BIOMAX, 2013)

Table 8. Economic Analysis.

| | |
|---|---|
| *Arapiraca* | |
| Total cost transport / Payroll / Maintenance (R$/month) | 8,648.44 |
| Rate of Return (years) | 1.60 |
| Present Value (R$) | 2,764,841.34 |
| Internal Rate of Return | 47% |
| *Girau do Ponciano* | |
| Total cost transport / Payroll / Maintenance (R$/month) | 16,159.16 |
| Rate of Return (years) | 1.97 |
| Present Value (R$) | 1,904,405.65 |
| Internal Rate of Return | 34% |
| *São Sebastião* | |
| Total cost transport / Payroll / Maintenance (R$/month) | 17,550.57 |
| Rate of Return (years) | 2.06 |
| Present Value (R$) | 5,192,463.58 |
| Internal Rate of Return | 90% |
| *Taquarana* | |
| Total cost transport / Payroll / Maintenance (R$/month) | 12,285.57 |
| Rate of Return (years) | 1.76 |
| Present Value (R$) | 2,427,821.85 |
| Internal Rate of Return | 41% |
| *Igaci* | |
| Total cost transport / Payroll / Maintenance (R$/month) | 17,509.29 |
| Rate of Return (years) | 2.06 |
| Present Value (R$) | 1,943,787.82 |
| Internal Rate of Return | 32% |

It is observed that the return rate in years, relation between "earned money", as a result of an investment, and the amount of money invested, for the municipalities considered was around two years, a good rate since the investment would be split along 10 years. Arapiraca was the city that had the lowest return rate (1.60 years), which was already expected because in this municipality there no considerable money spent on residual biomass transport to the location of processing the briquettes. Concerning total cost, which takes into account costs of biomass, transportation, operation, maintenance and depreciation of equipment, Arapiraca city also presented the lowest value (R $ 8,648.44 / month), due to the absence of significant costs with biomass transport to the briquetting mini plant. For the Internal Rate of Return (IRR), defined as a discount rate of an investment that makes your net present value zero, ie, that causes the design to pay the initial investment when considering the value of money over time. All analyzed municipalities had a higher IRR than the Minimum Acceptable Rate of Return (MARR), in this case considered by 5% per year, an amount relating to maximum margin that the investor would accept pay for funding, meaning that the investment is economically attractive.

The Net Present Value (NPV) second “Souza, 2003, p.74” is the difference between the present value of net cash inflows associated with the project and the initial investment required. It brings the flows of inputs and outputs to the zero point. The NPV values obtained for the five municipalities were considered positive, and then the value obtained in the project will pay the initial investment, which makes it feasible. The value is returned to the investor within the first year getting the growing balance over the years.

## 4. CONCLUSION

Technically analyzing the use of biomass residues as substitute of wood, usually used in the furnaces of the flour mills, is satisfactory because the amount of biomass generated throughout Agreste region would serve very well the energy demand required for the functioning of the five flour houses simultaneously. And as there is a production so rich and diversified of biomass in the region there is no obstacles for using these wastes. The study also proposed the construction of a mini briquetting plant as a way to optimize the energy potential of agricultural waste in the region as a way to improve the production process. An economic study for the implementation of mini briquetting plant was made and proved feasible, with good results. The replacement of wood by residual biomass briquettes would be made, with a good margin of error, and could still be held the trade of these briquettes would generate a new source of income for flour mills since the briquettes are a good source of energy and would not present the same problems of illegality and high prices of firewood. The economy of the replacement would be quite significant, since the purchase of firewood currently commits around 10% of gross monthly income of a flour mill. The reuse project of agricultural waste by processing in a mini briquetting plant turned out to be technically and economically viable for small and medium-sized enterprises located in prime areas with agricultural waste.

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## 6. RESPONSIBILITY NOTICE

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