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Reuse of cupuaçu shells for producing energy by processing them in briquettes

Reaproveitamento de cascas de cupuaçu para a produção de energia através da sua transformação em briquetes

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ABSTRACT
Due to the problems that fossil origin energy brings, the global trend is to substitute this type of source for alternatives that generate a lower impact on the environment, among them, the use of biomass residues generated by the agro-industry, through the briquetting process. At the same time, the preservation of the Amazon has been violated, among other factors, for the production of firewood. Thus, the objective of this work is to conduct a preliminary study of a briquetting plant as a sustainable destination for the residues generated in the cupuaçu processing industry, whose production occurs on a large scale in the state of Amazonas. The research on the market and production was done through Google, the plant design, costs and economic analysis were based on the Manual Plant Design and Economics for Engineers. The Brazilian briquette market presents great potential. For the project a total of 5,000 t/year of wet raw material produced was considered. The total initial investment capital resulted in the value of R$ 1.590.525,56. The suggested price to be practiced is R$455.00/ton and, considering the production of 3,217.77 tons per year, the annual revenue is R$1,488,655.35. The annual gross profit resulted in R$ 677,257.64 and the net profit resulted in R$ 654,966.96 per year, disregarding depreciation. The working capital resulted in R$587,943.96 per year. The number of years to pay off the investment was 2.7 years. The preliminary analysis of the project shows economic viability, however for the technical analysis more tests are needed.

Keywords: Cupuaçu shell, Briquettes, Biomass, Solid waste utilization.

1 INTRODUCTION

The supply of energy, as it is known today, has provided great technological and economic advances, and access to it directly influences people's quality of life.

It is estimated that by 2040 the demand for energy will increase by one percent per year, planetwide (STEVENS, P. 2019).

However, due to the problems that fossil energy brings, the global trend is to substitute this type of source for alternatives that generate a lower impact on the environment. Among these alternatives is biomass, which is expressly rich in most regions of Brazil. Expanding its transformation has been the target of interest, since this also translates into new sources of income.

It is also in this context that the issue of the Amazon, one of the most important biomes on the planet and that, as a consequence of land exploitation, its preservation has been violated. Valuing and preserving the Amazon biome, allied with the balanced development of consumer goods that provide human health and well-being, generating fair jobs for the members of the region's communities, has been the goal of both private enterprise and the relevant public entities, promoting a series of debates, research, and initiatives in this regard. It is by these guidelines that the present work will be guided.

Among the various forms of biomass found in the Amazon region, the cupuaçu shell has been studied as a way to obtain thermal energy, especially in some riverside communities, whose source of income for the vast majority comes from the cultivation of this species.

Allied to the use of peels or other residues generated from the agro-industry, are the utilization methodologies such as briquetting. The briquetting process promotes the energy densification of biomass, making it more efficient for burning. At first, the residues would not have any added value, but their transformation into a compact product would allow their use as a substitute for firewood, even having a better performance than this input. Thus, briquetting plants represent a sustainable solution not only for the final destination of residues, whose inadequate disposal could cause damage to the environment, but they would also promote the reduction of deforestation, as well as the reduction of gas emissions to the atmosphere.

1.1 THE PROBLEMS RELATED TO THE USE OF FOSSIL FUELS

Fossil fuels are the predominant energy source, providing about 80 percent of the world's energy distributed in electricity, heat, and transportation, and are also constituents of many products, such as steel or plastics. These fuels include coal, oil and natural gas which, when burned, release carbon dioxide (CO_2) and other greenhouse gases, which in turn create a gaseous layer in the atmosphere that does not allow heat to escape, contributing to global warming and hence to climate change and its effects

Still, the enormous technological advances cannot be denied, indirectly made possible by the supply of energy through these types of fuels, which have greatly benefited communities, including the poorest. However, today, governments and private entities in each country are committed to the replacement of this energy matrix by other renewable and less polluting sources, as well as in the investment to achieve greater energy efficiency and reduce the costs of atmospheric carbon recovery technologies, among others. At the international level, the emissions reduction targets stand out as one of the goals of Agenda 2030 (AGENDA 2030; NUNEZ, C. 2019).

Another important point to note about fossil fuels is to political instability involving the countries with the largest oil reserves. International conflicts have been an incentive to the search for new energy alternatives. For example, the price of a barrel of oil has undergone several variations, causing market instability for many countries (GENTIL, L. V. B., 2008).

In this scenario, as mentioned, renewable energy sources are introduced. After the Second World War, studies on renewable energy sources such as biomass, wind, hydraulic, solar, atomic and hydrogen, among others, advanced (GENTIL, L. V. B., 2008). From that moment on, biomass became a possible alternative to fossil fuels, due to its characteristics, such as being renewable, low cost, low pollutant emission and abundant. The most promising types of biomass are lignocellulosic, originating from native or planted trees (Goldemberg, J. 1998).

There is, therefore, a worldwide trend towards the decarbonization of the economy and towards electric cogeneration with biomass where it is abundant, of good quality and at a low price (GOLDEMBERG, J. 1998).

1.2 THE AMAZON

The Amazon is known as the largest preserved forest in the world. It is the largest biome in Brazil with 4,196,943 km^2 and is home to one-third of the species that live on Earth. It is home to 2,500 species of trees, a third of all tropical wood in the world (MINISTRY OF THE ENVIRONMENT - MMA).

When talking about the Amazon forest, the concept of the Legal Amazon emerges, which was instituted by the Brazilian Government to promote the social and economic development of the States of the Amazon Region, namely, Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima, and Tocantins and part of the State of Maranhão, comprising an area of

5,217,423 km², which corresponds to 61% of the Brazilian territory. Despite its extensive size, it has the lowest demographic density in the country, with 12.4% of the total national population, but with 55.9% of the Brazilian indigenous population, around 250 thousand people, in the territory. Furthermore, it is also home to the Cerrado biome and the Mato Grosso Pantanal (OECO, 2014).

1.2.1 The problem of electrification in isolated Amazonian communities

Today, despite all the development, many rural areas still lack light, due to the lack of electricity and fuel supply (RENDEIRO, G., 2011). Consequently, this influences human development, whose rate in these places is lower. Thus, the communities there are limited, not having the means for production and self-sustainability (SANTOS, S. M. A., 2006).

In the isolated regions of the Amazon, diesel-powered generator sets are the most commonly used technology, but their economic sustainability is difficult due to the cost of transportation, which can be doubled due to the great distances. Usually these generators are only used for a short period of time (between 6 pm and 10 pm at night). This fact becomes even more aggravating because the generation of electricity by fossil fuel, in most cases, is not linked to any productive activity, thus becoming another cost in the restricted budget of the residents of these isolated communities. Because of this, it is essential to analyze the availability of energy resources and their technical feasibility in determining appropriate and efficient options to solve this problem (ANDRADE, C. S., 2010; RENDEIRO, G., 2011; SANTOS, S. M. A., 2006).

Although the Amazon region has several sources of renewable energy, especially an abundant biomass production, their use is rare, except for some small hydroelectric plants and community photovoltaic systems arising mainly from research projects (ANDRADE, C. S., 2010; RENDEIRO, G., 2011; SANTOS, S. M. A., 2006). This happens not only because of the higher cost of deployment of these ecological energies (when compared to diesel or gasoline engines), but mainly because the technology is more complex and generally unknown in the region (RENDEIRO, G., 2011).

Even so, in the case of locally available biomass, its use in small electricity generation units can be a good choice, despite the high initial cost. This is because besides being a renewable energy source, is an alternative capable of activating the local economy by generating jobs, due to the use of energy products native and/or cultivated (RENDEIRO, G., 2011).

It is undeniable that societies supplied with essential goods live a better quality of life and have more tools for economic growth. The absence of electric supply systems foments precariousness, a difficult barrier to overcome. The urgency for electric energy in the small isolated communities of the Amazon is evident. This essential good avoids rural exodus, making possible basic actions for a good quality of life, such as the extraction of underground water and its purification, irrigation, post-harvest processing, and the generation of goods with greater added value. In addition, it provides access to information, communication, and nobler activities such as education and recreation. It improves health conditions, giving way to the conservation of medicines and food (SANTOS, S. M. A., 2006).

1.3 PLANT BIOMASS AND BRIQUETTING

1.3.1 lignocellulosic biomass and the technologies for its use

Plant-based lignocellulosic biomass stands out as the most common energy source used among other types of biomass. It includes agricultural forestry and urban organic waste (CREMONEZ, P. A. *et al*. 2013). In terms of agricultural waste, Brazil stands out due to the high production of inputs that generate large amounts of tailings. For example, in 2019, 49.31 million bags of coffee were harvested , with 60% of the gross seed weight corresponding to hulls (CAVATON, T.; FERREIRA, L., 2019 ; CREMONEZ, P. A. *et al.* 2013). Several lignocellulosic wastes from bagasse, bark and straw are generated by agribusiness. Thus, these types of waste present themselves as potential producers of bioenergy (CREMONEZ, P. A. *et al*. 2013).

Biomasses can be treated in different ways to produce fuels through a conversion process. These methods are divided into biological and thermal. The main biological conversion processes are fermentation and anaerobic digestion, and among the thermal conversion processes are combustion, gasification, liquefaction and pyrolysis (BARRETO, E. J. F. 2008.

1.3.1.1 Physical and energy properties

Vegetable biomass has several properties that influence directly or indirectly on the energy performance of biomass. This topic will address the most relevant properties for the characterization of biomass, in view of its briquetting and combustion or gasification. According to Barreto, E. J. F. (2008), the structure and composition of biomass will determine the stoichiometry, mass balance and efficiency of the surrounding combustion reactions. The type of products generated, such as volatiles, ash and tar, then need to be known. Furthermore, the immediate analysis tests performed by Barreto, E. J. F. (2008), follow the NBR 16586 (ABNT, 2017) for mineral coal, and the ASTM D2000 standard for wood, since a standard standard for biomass analysis has not yet been developed (BARRETO, E. J. F. 2008) .

1.3.2 Briquetting

Briquetting is the process of compacting fine or crushed plant biomass by applying high pressure, through holes between rotating cylinders or other similar artifices, in order to form compact blocks of defined shape, thus resulting in the energy densification of biomass (ZANELLA, K. 2018). The pressure exerted causes a temperature rise that results in the plasticization of lignin, which in turn acts as a binder of the particles during compaction, together with proteins, starches, fats and soluble carbohydrates, which are also biomass adhesives (FIGUEIRA, F. V.; MARTINAZZO, A. P.; TEODORO, C. E. S. 2015; QUIRINO, W. F. 1991). This occurs naturally for lignocellulosic base residues (BARRETO, E. J. F. 2008). In the absence of these binders, briquetting is done with the prior mixing of biomass with binders, in order to allow the correct compaction (ZANELLA, K. 2018).

From the briquetting you get a product with granulometric homogeneity, with higher energy density per unit volume, easy to handle, low humidity, with high storage capacity and resistance to the generation of fines. In addition, briquettes have high calorific value and generate lower ash content. Thus, the briquetting enables the reuse of energy waste generated for further burning and energy production. Due to the compaction, the briquettes have greater potential for energy generation than the biomass waste from which they were generated, being the best technological choice for their use. The densification process then produces a product of higher commercial value that can be used as a solid fuel for energy generation (ZANELLA, K. 2018).

A variety of wastes can be used, such as waste from the wood processing, cotton, corn, elephant grass, rice husk, coffee, peanut and sunflower, sugarcane bagasse, coconut, among other agroforestry residues (BARRETO, E. J. F. 2008; BIOMAX; FIGUEIRA, F. V.; MARTINAZZO, A. P.; TEODORO, C. E. S. Es. 2015; GENTIL, L. V. B. 2008; ZANELLA, K. 2018).

1.3.2.1 Briquette

The briquette is a product made from biomass, used as fuel for both heat and power generation. The briquette emerges as an alternative to the disposal of agroforestry residues and as a solution to increase the energy density of these residues.

In parallel, it also contributes to minimize the consumption of wood for firewood or charcoal since, due to its uniformity of combustion and calorific density, it is able to replace these products and can even have a better combustion performance (CAVALCANTI, M. A., CORREA, A. Z., SANTOS, N. S. S. 2010; GENTIL, L. V. B. 2008; VARELA, M.; LECHÓN, Y.; SAÉZ, R.1999).

Furthermore, the use of lignocellulosic waste in the form of briquette is more advantageous from the economic point of view and in terms of the reduction of environmental impacts related to the production, transportation, and use of fossil fuels (VARELA, M.; LECHÓN, Y.; SAÉZ, R.1999).

The briquette is used in furnaces, ovens and boilers in industries. They serve a variety of commercial segments such as slaughterhouses, ceramics, cereal producers, breweries, distilleries, starch mills, hospitals, hotels/motels, the candy industry, the soybean oil industry, the paper industry, the soft drink industry, dairies, laundries, metallurgies, restaurants, bakeries, pizzerias, retreaders, dyeing plants, and homes for home heating (BIOMAX; FIGUEIRA, F. V.; MARTINAZZO, A. P.; TEODORO, C. E. S. 2015; GENTIL, L. V. B. 2008; VARELA, M.; LECHÓN, Y.; SAÉZ, R. 1999; ZANELLA, K. 2018).

In Brazil there is no methodology or specific standards for the manufacture and marketing of briquettes. In general terms, the sequence of the briquetting process, according to a majority of authors (BARRETO, E. J. F. 2008; FIGUEIRA, F. V.; MARTINAZZO, A. P.; TEODORO, C. E. S. 2015; GENTIL, L. V. B. 2008; ZANELLA, K. 2018), consists of: Receipt of waste (storage in silos); Standardization of dimensions (comminution); Screening; Drying; Machine feeding; Briquetting; Cooling; Packaging and Commercialization.

According to Oliveira, R. R. L (2013), for the briquette formation process to be efficient and give rise to a good quality product, the characteristics of the biomass used must be known. Obviously**,** the energetic characterization of the biomass, is equally valid for the briquette. Characteristics such as the ash content, particle size and moisture content of the material compromise the quality of the briquette. The ash aggregates all the elements that are not relevant in the combustion reactions, such as potassium, phosphorus and calcium, among others, reducing the energy utilization of the briquette. Thus, the smaller the amount of ash, the better the quality of the briquette. Furthermore, the higher the humidity of the briquette, the lower its burning performance, since part of the energy will be used to heat and vaporize this humidity. In turn, the granulometry of the residues also influences the quality of the briquette. The smaller the particle size, the better the compaction process and the higher the mechanical resistance. Due to the biomass being of diverse origin, the conditions and characteristics of the briquetting process and of the briquette will vary. Even so, it is observed the existence of a standard range of variation, to which the biomass fits.

According to Gentil, L. V. B (2008) the temperatures reached in the briquetting chamber range from 170 °C to 270 °C, for sawdust briquettes. The humidity content on wet basis of the briquette will vary from 5 % to 15 % and its density is between 1000 kg/m^3 to 1500 kg/m^3. Furthermore, the briquette should be presented in cylindrical or hexagonal pieces with a diameter of about 70 mm to 100 mm and a length of 10 cm to 40 cm.

In Table 1, typical values of the thermophysical characteristics of briquettes are described.

Table 1 - Average thermophysical characteristics of briquettes

Product	PCS (MJ/Kg)	Humidity (%)	Carbon Fixed (%)	Volatile (%)	Ash (%)	Density (Kg/m)
Briquette	19,2	12	14	84	2	1200

Source: (BARRETO, E. J. F. 2008).

1.3.2.2 The advantages of briquette over firewood

According to Gentil, L. V. B. (2008), in comparison with domestic firewood, the bulk density of sawdust briquette is 700 kg/m^3, while domestic firewood is 380 kg/m^3. It has a moisture content between 5 % and 15 %, compared to domestic or planted firewood, which is in the range of 25 %. Thus, briquette has a higher Useful Calorific Value (UCC).

According to Figueira, F. V.; Martinazzo, A. P.; Teodoro, C. E. S. (2015), one ton of briquettes based on corn, soybean and wheat residues are equivalent, in terms of calorific density, to 5 m^3 of firewood, which correspond to a little over two tons in weight. That is, briquettes of this type of biomass also have a higher calorific value than firewood. In addition, the briquette occupies less space, since 1 ton of the product fills about 2 m^3 of space.

Barreto, E. J. F. (2008), states that from the compaction of lignocellulosic based residues briquettes are obtained with superior quality to any kind of firewood, containing from 2 to 5 times more energy density.

Among the advantages of using briquettes cited by the author, compared to firewood, the following stand out for briquettes: they are produced in standard sizes (in the shape of cylinders or cookies); they are contained in standardized packages; they are a hygienic product without the drawbacks of firewood; they occupy less storage space; their combustion provides thermal regularity in the furnace.

In addition to the advantages described above, the briquette generates less smoke, is odorless, non-toxic, avoids deforestation and is exempt from inspection by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) or the Secretary of Environment (SEMA) (FIGUEIRA, F. V.; MARTINAZZO, A. P.; TEODORO, C. E. S. 2015).

1.3.2.2.1 THE BRIQUETTE MARKET IN AMAZONAS

The production of briquettes in Amazonas began in the year 2012, made from sugar cane waste. The name of the company that started the project is unknown and possibly it sells its products in Marketplace MFRURAL, a commercial page for agribusiness products (A CRÍTICA, 2013). Besides this company, it was found that there are only two others that supply briquettes to Manaus, and only one of them has a plant in the city. They are, namely, Madebriq (briquettes from wood waste) and Florida Clean Power, located in Roraima. The company[1] produces 15,000 tons/year, of which 75% are sold in Manaus at R$ 550.00/ton. It is concluded, then, that there is an unsatisfied demand in the city of Manaus.

The increasingly strict enforcement of environmental agencies counteracts the illegal extractivism, which generates a lower availability of firewood. Thus, the market is increasingly smaller and more expensive. This indicates that the briquette can replace this demand. Each ton of briquette prevents ten trees from being cut down. In addition, one can take into account the shorter boiling time in relation to charcoal, and the product's accommodation, which is more practical. These advantages are added to the others already mentioned and indicate the market's predisposition to substitute firewood for briquette.

Furthermore, there are research projects supported by FAPEAM (Fundação of Amparo à Pesquisa do Estado do Amazonas) and the Amazonas State Government, which encourage the use of briquettes to replace charcoal, oil, and firewood by companies in the food industry, domestic market, and industries. Some restaurants and collectors' cooperatives have already joined the idea and become partners of these initiatives. Thus, although the briquette market in the Amazon is small, there are indications that it is growing and has the favorable opinion before research institutions, the government and private entities (CAVALCANTI, M. A., CORREA, A. Z., SANTOS, N. S. S. 2010; A CRÍTICA, 2013).

Another positive aspect for enterprises of this type is the Free Trade Zone of Manaus. The installation of plants there is advantageous, since the current tax policy is differentiated, being granted tax benefits, which represents a decrease in the cost of processing briquettes. Moreover, the industrial park of Manaus has at its disposal several lands with water collection and treatment infrastructure, urbanized road system, water supply network, telecommunications network, sanitary sewage network, and rainwater drainage. Moreover, it has a variety of warehouses available, fully structured, suitable for the immediate installation of a plant (SUFRAMA).

1.4 CUPUAÇU AND ITS RESIDUES

Cupuaçu, *Theobroma grandiflorum* is a native fruit of the Amazon and one of the most important species of the genus *Theobroma*, standing out as one of the most appreciated fruits by the inhabitants of the region (NAZARÉ, R. F. R. *et al.* 1990; PARENTE, V.; JÚNIOR, A.; COSTA, A. 2003; SOUZA, A. G. C. *et al.* 1999). Its cultivation has significant economic and social value for the populated regions of the Amazon, not being limited only to extractivism, but with a high rate of cultivation growth and industrial potential (PARENTE, V.; JÚNIOR, A.; COSTA, A. 2003; SOUZA, A. G. C. *et al.* 1999).

Rich in nutrients and with a characteristic aroma, its pulp is prepared for preparing juices, ice cream, creams, jellies and sweets, liqueurs, cookies, among others, involving more than 60 types of consumption as food (EMBRAPA, 1997; MÜLLER, C. H. *et al.* 1995; NAZARÉ, R. F. R. *et al*. 1990; PARENTE, V.; JÚNIOR, A.; COSTA, A. 2003; VASCONCELOS, M. N. *et al.* 1975; VENTURIERI, G. A. 1993).

Until the mid-seventies, cupuaçu was unknown in most of Brazil. Its consumption was concentrated in the region. This came to change as the delicacies produced with the pulp became more widespread, causing the gradual growth of the cultivation system, the emergence of small and medium-sized agro-industries, and the development of research to cure the difficulties arising from cultivation, such as pests, management, etc. (PARENTE, V. *et al.* 2003; SOUZA, A. G. C *et al.* 1998; SOUZA, A. G. C *et al.* 1999; VENTURIERI, G. A. 1998).

Its *sui generis* characteristics highlighted and promoted enthusiasm in its production and research. It was then aimed at a greater promotion of the products generated not only in the main urban centers of the country but also in the international market, with the exportation of cupuaçu, since sustainable natural products were gaining prominence abroad (PARENTE, V.; JÚNIOR, A.; COSTA, A. 2003; SOUZA, A. G. C. *et al.* 1998;).

The cupuaçu has a long, ovate, elliptical or round shape. The outer part of the pericarp is differentiated in a green, dry, rigid shell, whose thickness varies from 0.6 cm to 1.0 cm. It is covered by a rusty powdery layer that flakes off when handled. The endocarp is fleshy, yellowish-white, with a very active aroma and well adhered to the seeds by means of fibers (PARENTE, V.; JÚNIOR, A.; COSTA, A. 2003; SOUZA, A. G. C. *et al*. 1999; VENTURIERI, G. A. 1993).

The trees can reach up to 20 meters in height, the length of the fruit reaches up to 40 cm and its diameter up to 15 cm. The weight of cupuaçu varies from 2.5 to 5.0 kg, with 1.5 kg being the average weight considered. The seeds, surrounded by the pulp, are arranged in five rows, have ovoid or ellipsoid shapes, 2 cm to 3 cm long, 2 cm to 2.5 cm wide, 1 cm to 1.8 cm thick, and weigh approximately 7 g. (PARENTE, V.; JÚNIOR, A.; COSTA, A. 2003; SOUZA, A. G. C. *et al*. 1999; VENTURIERI, G. A. 1993;).

According to Venturieri, G. A. (1998), the centesimal composition of cupuaçu comprises the values of 46.47 % for peel, 36.79 % for pulp and 16.74 % for seeds. According to the research of Souza, A. G. *et al*. (1999), the pulp represents 40% of the fruit utilization. The remaining 60 % is made up of the fruit skin (40 %) and the seeds (20 %). Parente, V.; Júnior, A.; Costa, A. (2003) reported that, on average, the percentage is distributed as follows: rind 43%, pulp 38.5%, seeds 16% and placenta 2.5%.

The species *T. grandiflorum* occurs spontaneously in the southern and eastern part of Pará, covering the areas of medium Tapajós (microregion Itaituba), rivers Xingu (microregion Altamira), Anapu (microregion Portel), Guamá (microregions Guamá and Bragantina) and Tocantins (microregion Tucuruí). It is also found in northeastern Maranhão, with a strong presence in the Turiaçu and Pindaré rivers (MÜLLER, C. H. *et al.* 1995; VASCONCELOS, M. N. *et al.* 1975;).

Currently it is distributed throughout the Amazon basin, with the highest concentration of production and consumption in the states of Pará, Amazonas, Rondônia and Acre (SOUZA, A. G. *et al*. 1998; SOUZA, A. G. *et al*. 1999).

Being a perennial species, its harvest takes place between the months of December and March. It is produced in warm climates, with average monthly temperatures ranging between 24.2 °C and 28.2 °C and humid, with high relative humidity (minimum limit of 77 % and maximum of 88 %, being 64 % in the driest month and 93 % in the wettest month) (MÜLLER, C. H. *et al.* 1995).

The productivity of Cupuaçu varies depending on the genetic quality of the seedlings, the climatic and soil conditions, the harvest period, as well as the cultural and phytosanitary treatments, results in each harvest (LÓPEZ, P. A. B. 2015; SOUZA, A. G. C. *et al.* 1999; VENTURIERI, G. A. 1993). The cultivation of this species produces lower yield scale in the first years (between 4 to 7 fruits/plant/year), increasing and stabilizing after the fifth year (LÓPEZ, P. A. B. 2015). According to Venturieri, G. A. (1993), under good conditions, 5-year plantations generate around 20 to 30 fruits/plant and can reach 4.7 to 7 tons/ha/year of fruits. In 7 year old plantations, the productivity is 60 to 70 fruits/plant, with 14 to 15.4 tons/hectare per year of fruits, in a 7m x 7m arrangement (triangular spacing) with 234 plants/ha. These numbers reveal that, already from the fifth year on, the amount of bark produced can reach 3.02 ton/ha/year (referring to 7 ton/ha/year of fruits, with a percentage of the average fruit house at 43.16 %).

Although the improvements are significant, the harvest is never constant. The quantity and quality of the fruit depends mainly on the climatic conditions to which the plantations have been subjected and, secondly, on pest management and care. Regarding the latter, the main bottlenecks affecting production are the witch's broom, a disease caused by a fungus, and the fruit borer pest, contributed by the lack of management knowledge by the producer (IDAAM, 2015).

When it comes to production at the state level, the state of Pará is the main producer, followed by the states of Amazonas, Rondônia, and Acre (LÓPEZ, P. A. B. 2015). In the State of Amazonas, in 2013, according to IDAAM (2015), cupuaçu production was over nine million fruits (reducing 1 million compared to the 2011 harvest). The municipalities that stood out were Novo Remanso (2,096,000 fruits), Manacapuru (1,137,400 fruits), Itacoatiara (1,120,000 fruits), Autazes (1,100,000 fruits) Presidente Figueiredo (800,000 fruits). In 2016, Itacoatiara (176 kilometers east of Manaus) stood out, reaching R$ 296 million with the agricultural production of fruits and becoming the fifth municipality with the highest production value in the country. Pineapple and cupuaçu are its two main crops, according to Gomes, B. (2014).

1.4.1 Initiatives for cupuaçu shell utilization

The cupuaçu shell is a residue that has no relevant interest from producers and processing industries. The most significant use is as organic fertilizer, performed by the producers themselves on their cultivars, but the shells are mostly discarded. Some communities still use the peel for handicraft, but this utility, compared with the production, is minimal (LOPEZ, P. A. B. 2015).

In turn, the disposal of this waste generates an accumulation of garbage, which promoted reuse initiatives, especially in the energy sector, serving as biomass for energy production. Santos, S. M. A (2006) described the use of the cupuaçu shell for the generation of energy, from its charcoal, applying gasification technology to replace diesel, in a riverside community in the Amazon. The quality of the charcoal generated from the gasification of the cupuaçu shell is similar to charcoal from eucalyptus chips, eucalyptus waste pellets, and babassu endocarp. Table 7 below shows the main thermophysical characteristics of the cupuaçu shell found by the research of Santos, S.M.A (2006). Furthermore, we highlight the project developed by Santos, E. C. S *et al.* (2004) which aimed to research the production of briquettes from cupuaçu bark.

LÓPEZ, P. A. B. (2015) cites the use of cupuaçu bark as a biosorbent for dyes in aqueous solution in the textile industry, but no further studies on the subject were found.

Table 2 - Thermo-physical characteristics of the cupuaçu shell

Waste	Humidity b.u.s. (%)	PCS (MJ/Kg) b. s	Fixed carbon b.s. (%)	Volatile content (%)	Ash content b.s. (%)
Cupuaçu peel	11,6	19, 2	16, 2	79	4, 8

Source: (SANTOS, S. M. A. 2006)

2 MATERIALS AND METHODS

In the following, the entire methodology followed for the elaboration of the plant.

2.1 MARKET SURVEY AND PLANT LOCATION

The market study was conducted following the research methodology proposed by VVillar, A. M.; NNóbrega, J. C. L. (2013) in the manual Industrial Facility Planning. Through the Google search tool, information was obtained about the market situation at a national and regional level, the quantity produced in the region chosen for the plant, the type of demand and consumer profile, the product's average price, market trends, and the enterprise's potential. A survey was also conducted to identify what would be the product's differential in relation to the established market.

The region of the plant was chosen based on cupuaçu production. The city was chosen based on the shortest possible distance to the places with the greatest supply of raw material, easy outlets, and where there are economic incentives for the enterprise, thus minimizing the costs with transportation and possible taxes.

2.2 ESTIMATION OF THE AMOUNT OF RAW MATERIAL AVAILABLE AND FACTORY OPERATION

The IDAAM Portal (IDAAM, 2015) was consulted to find the production data of cupuaçu in Amazonas. Although news on local webpages report that more recently the amount of cupuaçu harvested is higher, the last record of IDAAM dates to the year 2013 and, thus, it was from this data that we estimated a hypothetical value of the amount of residual bark (43% of the total tons of cupuaçu, according to Parente, V.; Júnior, A.; Costa, A. (2003)).

For the operation, an eight-hour workday was stipulated, during weekdays and with five days a year reserved for maintenance.2.3 PROCESS FLOWCHART

The steps of the briquetting process were based on those described by Barreto, E. J. F. *et al*. (2008), Figueira, F. V.; Martinazzo, A. P.; Teodoro, C. E. S. (2015), Gentil, L. V. B. (2008) and Zanella, K. (2018). The process flowchart was prepared using *SmartDraw software* (SMARTDRAW, 2017).

2.4 CALCULATION OF ENERGY CONSUMPTION AND BRIQUETTES IN THE KILN AND DRYER

In the kiln of the dryer, part of the briquettes produced by the plant will be burned. For this purpose, the amount of air required for drying, briquettes produced and the amount of them for burning were calculated. First, certain values were assumed for the parameters involved in the operations. The Calorific Value of the cupuaçu peel was the one corresponding to the PCS of 19200 kJ/Kg on a dry basis (11.6 % humidity), according to Santos, S. M. A. (2006). We assumed an initial moisture of the raw material of 35%, as described for agricultural residues, according to Silva, S. J. (2008). Since it was not found in the literature, but in order to enable the continuation of the preliminary analysis, it was adopted for the bark apparent specific gravity the value of 250 kg/m^3 , based on the analyses performed by Barreto, e. j. f. (2008) (see point 3.3.2.3.2, page 30).

The unit operations calculated concern the reactions that occur in the furnace and the dryer. At the furnace inlet, the conditions of 27 ºC temperature and 60% relative humidity of the ambient air were stipulated, based on the average found through the Climate-Data Portal (CLIMATE-DATA). The inlet air temperature and outlet air relative humidity were chosen randomly, but considering reasonable values, namely 80 ºC and 90%, respectively. From the amount of bark stipulated for the project, the flow of the same entering the dryer was obtained. The humidity of the raw material at the exit of the dryer was established in 10%, based on the theoretical reference of the briquetting stages, mentioned above.

From the temperature and relative humidity (RH%) of the air entering the furnace, the enthalpy (H) and the absolute humidity (U_{abs}) of the air (which also corresponds to the absolute humidity of the air entering the dryer) was calculated using the CATT3 *software* (JOHN WILEY & SONS, INC., 1996). With the same program and from the absolute humidity and temperature of the input air, the enthalpy (H) was obtained. In turn, with H and the RH% of the air at the exit of the dryer, the U_{abs} was obtained at the exit of the dryer. With the input flow of shells in the dryer on a wet basis, the amount of water of the shells that would need to be dried to reach the desired percentage of final moisture was found, using the formula:

$$m_{água} = vazão\ (bu) \times (1 - U) \quad (1)$$

Where flow bu is the raw material flow rate on a wet basis and U is the corresponding moisture content.

Based on the amount of water to be dried from the raw material, it was determined the mass flow rate of air (v_{ar}) required for drying from the formula:

$$v_{ar} = \frac{v_{água}}{\Delta U_{abs}} \text{where } \Delta Uabs = Uabs,s - Uabs,e \quad (2)$$

Where $v_{água}$ is the water mass flow rate and $\Delta Uabs$ is the difference of the absolute humidity at the outlet ($U_{abs,s}$) and inlet ($U_{abs,e}$).

From the psychometric chart (INCROPERA, F. P.; DEWITT, D. P. 1999)we obtained The specific volume (V_{esp}) of air at 27 ºC and 60% RH was calculated. With the V_{esp} , the volumetric flow (V_{vol}) of air needed for drying was ascertained. To calculate the amount of heat (Q) needed to heat the air the formula was used:

$$Q = v_{ar} \times \Delta H \text{where } \Delta H = Hs - He \qquad (3)$$

Where v_{ar} is the mass flow rate of air needed for drying the raw material and ΔH is the difference of enthalpy at the exit (H_s) and entry (H_e) of the furnace. An additional 10 % heat required for heating the raw material to be burned was assumed and a 30 % heat loss in the furnace was also considered. With these data, the necessary amount of raw material for burning in the furnace was calculated using the formula

$$m_{casca} = \frac{Q}{PCS\ casca} \qquad (4)$$

Where Q is the heat required for drying and PCS shell is the Upper Calorific Value of the cupuaçu shell. In this case, it was ignored that the PCS obtained for shell was 11.6% humidity (slightly above the established humidity for the present work).

The dry bark mass flow rate was calculated by the formula:

$$vazão\ bu,s = vazão\ bs,e + (vazão\ bs,e \times X_2) \text{where } X_2 = \frac{U_f}{1-U_f}, \quad (5)$$

Where flow rate bs,e is the raw material input flow rate on a dry basis (i.e. without 35 % moisture) and X_2 is the final moisture fraction.

2.5 EQUIPMENT AND ITS COSTS

The search for the company supplying the equipment was made through the Google search platform, and the conditions established for the choice were: a national company or one that produced the equipment in Brazil; supplied the majority of the equipment.

The final choice would be based on the lowest total cost. Two companies were selected and the budget for the equipment was requested, and from them the type of material to be briquetted and the production volume were requested. Neither company works with cupuacu shells, however, to continue the study, the equipment was determined (by the companies) as for coconut shells. The selected company provided a list of almost all the equipment needed, their respective values for the month in which the budget was given, the minimum area needed for the industrial plant, number of operators and supervisors needed, value and duration of the installation. The only equipment not costed by the company was the chipper, whose type, size and value were stipulated from the manual Plant Design and Economics for Engineers (PETERS, M. S.; TIMMERHAUS, K. D.; WEST, R. E. 2002002).

2.6 COST ESTIMATION AND ECONOMIC FEASIBILITY ANALYSIS

For the analysis of costs and economic feasibility, we used the methodology proposed in the manual Plant Design and Economics for Engineers (PETERS, M. S.; TIMMERHAUS, K. D.; WEST, R. E. 2002002). The Total Capital Investment (TCI) is subdivided into Fixed Investment Capital (CIF), required to pay for the installation of the plant, and the initial Production Cost (PC), necessary for the operation of the machining plant in the first three months. For the latter, the annual CO was calculated, without considering interest rates, and this value was multiplied by one quarter (the equivalent of three months of operation).

The CIF is subdivided into Direct Costs (DC) and Indirect Costs (IC). The CO is subdivided into Total Manufacturing Costs (TCM) and General Manufacturing Expenses (DGM). The estimate of the Capital Investment was based on Method C, in which the CIF is calculated based on the Cost of Equipment Delivered (CEE). For each item, the value is given considering a percentage of the EEC. This type of method is common in preliminary studies and its expected accuracy is in the range of 70 % to 80 %, possibly reaching 90 %. Since all but one item of equipment has been costed with value accuracy, it is expected that a capital investment value close to reality will be achieved.

Adding up the value of all the plant's equipment, a 15 % surcharge was made for their delivery. Based on this final value (the CEE), the CD and CI were then calculated.

Among the DCs, the installation was calculated in days worked by operators BIOMAX operators and locals, totaling two operators at the supplier company and four from the region. Twenty-two days of installation, thirty days of accommodation and travel expenses for the BIOMAX operators were accounted for. The prices and days of installation were informed by the company itself, as well as the number of workers that should work in a plant of the proposed size.

The lease of the factory space was evaluated at R$10,000.00 according to the Real Estate Portal Viva Real, and includes the external part, piping, electrical system, and complete service facilities. Thus, all these items were not accounted for. For the ICs, engineering services, legal expenses, and contingency were accounted for at 1.5 %, 3 %, and 2 % of the EWC, respectively.

For PC, TCM is divided into Direct Production Costs (DPC) and Fixed Production Expenses (FPD). Among the CDP, operational and supervisory work was accounted for based on the average salary given by the Salary Portal (SALARY). Taxes and charges were determined according to Fernandes, D. P. (2018). Utilities (water and energy) were accounted for based on data obtained through the Amazonas Energia S/A (AMAZONAS ENERGIA) and Águas de Manaus (ÁGUAS DE MANAUS) portals. Maintenance and repair was calculated at 5% of the CIF and operational supplies were estimated at R$ 500.00/month. For the present project, costs with *royalties* and raw material were not identified, once it was assumed that the raw material is a discarded residue and its capture would be a solution for the processing industries. The DF were evaluated in taxes (0.08 % of CIF), insurance (0.05 % of CIF) and depreciation, based on the value of the equipment delivered and installation, increased by 20 % because of the speculated inflation and considering 20 years the duration of the equipment. This section also includes the financing interest rate, 10 % of the TCI. The last that makes up the CP are the general expenses that include administrative costs, based on the Salary Portal (SALARY), and marketing, whose spending target was set at R$ 500.00 per month in order to reduce impacts on the cost, in addition to product transportation (5 % of TCM), raw material collection (transportation during the harvest) and contingency (5 % of TCM).

Most percentage values were based on the percentages described in the Handbook *Plant Design and Economics for* Engineers (PETERS, m. s.; TIMMERHAUS, k. d.; WEST, r. e. 2002002) and assumed annual values. The values that are not estimated as per the manual, were based on reasonable values in order to reduce the cost impact. Thus, the TCI was calculated by adding the CIF plus three months of CP.

Finally, a sales value was suggested for the product, based on the values practiced in the market for briquette, to obtain the Annual Revenue (AR). The Gross Profit (BE) was calculated by subtracting the CP from the AR. The Net Profit (LL) was obtained by subtracting 12 % in taxes from the value of the LB, disregarding depreciation. The taxes were accounted for at 12 %, based on the policy practiced in the Manaus Free Trade Zone, described in the SUFRAMA (SUFRAMA) Portal. After this, the Working Capital (WC) was calculated, adding to the LL the Annual

Depreciation. The number of years to pay off the investment was calculated by dividing the TCI by the CG.

3 RESULTS AND DISCUSSIONS

3.1 MARKET STUDY AND PLANT LOCATION

Based on the market survey and the conditions favorable to the enterprise the plant will be located in the Industrial Park of Manaus, capital of the state of Amazonas, the second state with the highest level of cupuaçu production. Manaus is located relatively close to all the main producing and processing municipalities of cupuaçu, and has a good location for export, which represents a lower transportation cost. Added to this is the fact that the city also has an unsatisfied demand for briquettes, which makes it the main consumer.

3.2 QUANTITY TO BE PROCESSED

The amount of briquettes to be produced will depend on the production of cupuaçu in the chosen region. However, the history of cupuaçu production over the years has varied and it was not possible to find satisfactory data. Still, it is speculated that in the year 2011 were produced around 6,450 tons of bark and for the year 2013, 4,033.44 tons (considering 43% of bark). Thus, for the elaboration of the project a quantity of 5,000 tons of bark per year was established. The table below lists the main producing municipalities and the respective estimated amounts of bark produced (percentage of 43% in bark, according to Parente, V.; Júnior, A.; Costa, A. *(*2003)).

Table 3 - Estimated amount of cupuaçu peel in the main municipalities of the state of Amazonas in 2013

Municipalities	Bark generated (t)
New Remanso	1351,92
Manacapuru	733,623
Itacoatiara	722,4
Autazes	709,5
President Figueiredo	516

Source: Author (2020)

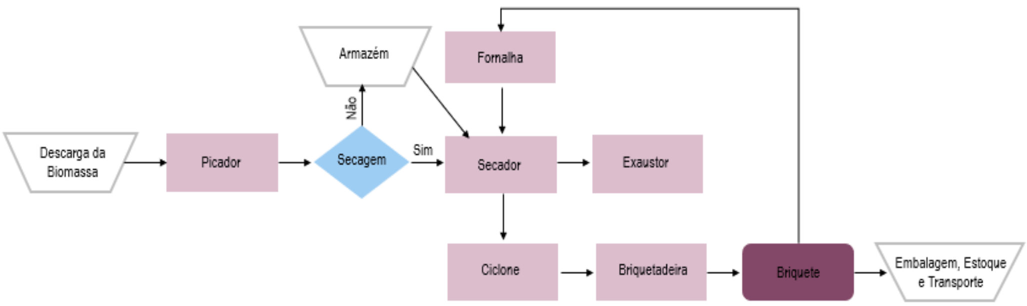
3.3 BRIQUETTE PROCESSING

In this step, the production chain is demonstrated, as well as all the aspects concerning the operation of the plant, including the calculations of unit operations.

3.3.1 Process flowchart

Once the cupuaçu shells are collected from the fruit processing industries, they are unloaded at the mill, passing directly to the chopper in order to obtain a material with dimensions suitable for the briquette. Part of the unloading will be stored while the other part will be taken to the dryer, because during the eight months of harvest there will be a large amount of raw material, which will be processed (starting with the drying process) throughout the year. All the raw material will go through the drying process in order to guarantee an adequate humidity for the briquetting process. At the exit of the dryer, the dried residues will precipitate in the exhaustion cyclone, being discharged into a rotating gravity exhaustion valve. From the valve, the residues will be taken by a mechanical transport system to the underground silo of the briquetting plant and then go through the briquetting process. In addition, some other residues and hot gases from the furnace will be sucked by the exhaust, crossing the entire dryer. After briquetting, a small part of the briquettes will be used in the furnace to heat the dryer, while the majority will be packed, stored, and then transported to customers. The flowchart presented here details all the stages through which the raw material will pass until the moment of obtaining the briquette and its final disposal.

Figure 2 - Flowchart of the proposed briquetting process of cupuaçu shells, performed from *Smartdraw software* (SMARTDRAW, 2017)



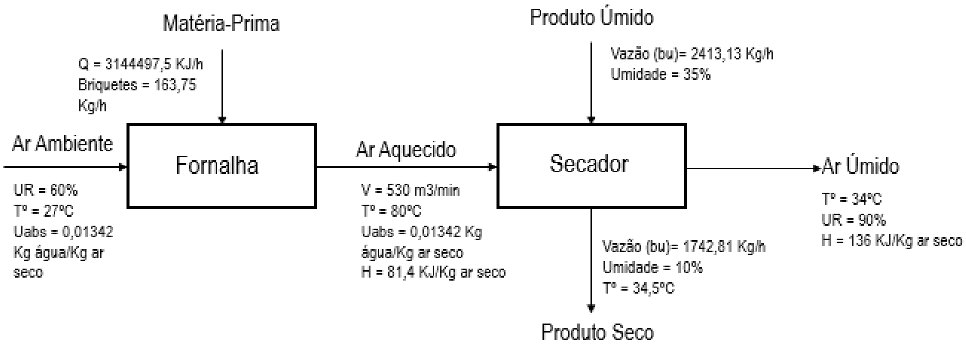
Source: Author (2020)

3.3.2 Production and calculation of energy consumption of briquettes in the furnace and dryer

The plant's operation results in 259 days per year of operation. The unit operations were calculated from the processing of 5,000 tons of wet raw material per year. Unit operations were calculated from processing wet raw material of 5,000 tons per year of bark.

The Figure below, shows the diagram of the unit operations in both stages of heating the air in the furnace and drying the shells in the dryer, describing the data found for each of the stages, which will be presented below.

Figure 3 - Flowchart of unit operations of the briquetting plant



Source: Author (2020)

3.3.2.1 Furnace

For a temperature of 27ºC and RH of 60% of ambient air, the U_{abs} of the ambient air at the entrance and exit of the furnace resulted in 0.01342 Kg water/kg dry air.

Figure 4 - Data obtained in the *CATT3* program

#	Temp.	Wet bulb temperature	Enthalpy	Absolute Humidity	Relative Humidity	Temp. Dew	Excess water
	°C	°C	kJ/kg (dry air)	kg water/kg dry	%	°C	kg water/kg dry
1	27	21,2	81,4	0,01342	60	18,58	0
2	80	33,37	136	0,01342	4,516	18,58	0
3	34,46	32,93	136	0,03171	90	32,58	0

Source: Author (2020)

3.3.2.2 Dryer

Considering a total of 5,000 t/year of wet raw material, for the production in 259 days with eight-hour shifts, a flow of 2,413.13 Kg/h of wet bark was obtained. On a dry basis 1,568.53 Kg/h of raw material was obtained. The amount of water needed to evaporate the bark resulted in 670.31 Kg/h and the U_{abs} of the air at the dryer exit resulted in 0.03171 Kg water/kg dry air, as shown in Figure 13. Considering a minimum humidity of 10%, the flow of raw material that will be briquetted resulted in 1,742.81 Kg/h. Considering the U_{abs} at the dryer entrance (0.01342 Kg water/kg dry air), the total U_{abs} in the dryer air resulted in 0.01829 Kg water/kg air. The air mass flow rate resulted in 3,6649.16 Kg/h and the volumetric flow rate resulted in 530.80 m^3 /min. It was preferred to obtain the amount of air needed for drying in m^3 /min to better understand the volume that will be occupied by air in the dryer and how much air will circulate per minute. For further studies, the time required for drying can be calculated.

The input (H_e) and output (H_s) enthalpies resulted in 81.4 kJ/Kg air and 136 kJ/Kg air, respectively, as shown in Figure 13. Thus, the process enthalpy resulted in 54.6 kJ/Kg air. With the mass flow of air and the total enthalpy of the process, the heat required to heat the air was 2,001,043.9 kJ/h, but 10% more was added to the value to account for the heat required to heat the raw material that will be burned before in the furnace. Furthermore, a heat loss of 30% through the furnace walls was considered. Thus, the amount of final heat required to heat the air resulted in 3,144,497.549 kJ/h.

The amount of raw material needed for the furnace was calculated from the heat for heating the air and the calorific value of the cupuaçu bark (19200kJ/Kg) and resulted in 163.78 Kg/h of bark. Thus, subtracting this value from the production of 1,742.81 kg/h of briquette, we have that for sale 1,579.038 kg/h of briquette are produced. Considering the days and hours of production, a total of 3,271.77 tons of briquette is produced annually.

3.4 EQUIPMENT

The budget was prepared by the company BIOMAX and, knowing the level of production, they carried out an inventory of all the necessary equipment, their dimensions and models, as well as their values. The list of necessary equipment is described in point 5.6.1, and they already come with motor, pipes, sensors, control panel, etc., according to each type of machine.

3.5 ECONOMIC FEASIBILITY ANALYSIS

3.5.1 Equipment Cost and Delivery

As mentioned before, the budget for the equipment was given by BIOMAX (Table 10) and, in the case of the chipper, the cost was based on the manual *Plant Design and Economics for Chemical Engineers* by Peters, M. S.; Timmerhaus, K. D.; West, R. E. (2002).

Table 4 - Cost of all equipment budgeted by BIOMAX

Biomax Equipment	Quantity	Amounts (R$)
Underground silo/doser	2	56.000,00
Chupim of the dryer	1	35.000,00

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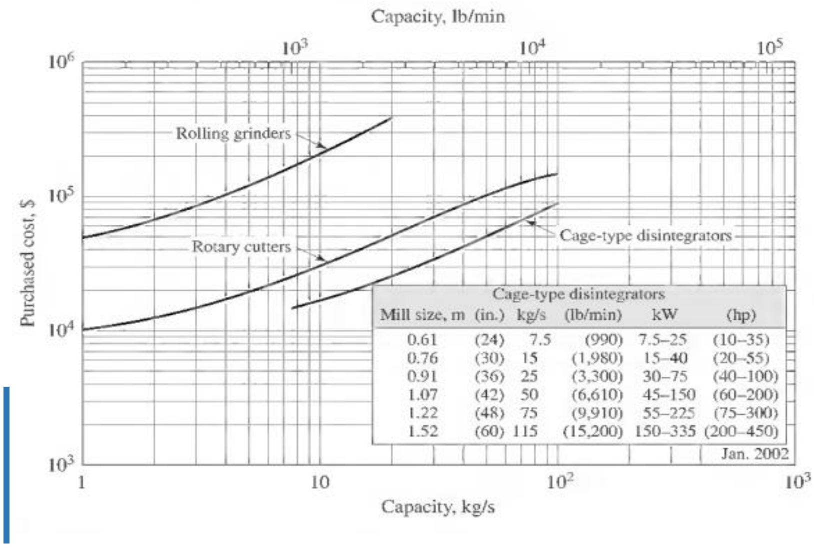
Drum dryer B 18000.	1	416.000,00
Mechanical conveyor system	2	46.000,00
Chupim of the Briquetting Machine	1	20.000,00
Briquetting Machine B 95/210R	1	316.000,00
Total		866.000,00

Source: Author (2020)

The value of the chopper was based on the chart below. A knife mill was chosen because the size reduction achieved by this tool is up to 50 times. The chipper will process the 5,000 tons received during the 8 months of harvest (approximately 248 days). Thus, the chipper should have a capacity to process 20.16 tons per day or 0.23 Kg/s. For this capacity, the value of the chipper is approximately US$10,000.00, converted to R$57,000.00 (conversion obtained in July 2020), to enable the analysis of economic feasibility in Brazilian currency. The value includes motor and accessories. Companies manufacturing this type of chipper were found, but it was not possible to obtain the budget. However, considering the other equipment, it is assumed that the stipulated value is reasonable.

Figure 4 - Graph of the cost of a chipper. Blue line points to the capacity closest to that needed for the chipper and the corresponding value



Source: (PETERS, M. S.; TIMMERHAUS, K. D.; WEST, R. E., 2003) Adapted

The total value of the equipment is around R$ 923,000.00 and the total installed power is approximately 140 kW. The freight of the equipment will be calculated at 15% over the value of the equipment delivered (CEE), resulting in a total of R$ 138,450.00. Peters *et al* (2013) mention that the value of the transport is about 10% of the value of the equipment, but it was decided to add 5% due to the distance and the difficult access via road to the city of Manaus.

3.5.2 Investment Capital

3.5.2.1 Fixed Investment Capital (CIF)

Within the CIF are the DCs that include installation of all machinery and piping, installation of services and site. According to the information given by BIOMAX, the installation will take 22 days and will require two operators coming from the company and whose value is R$650/day/operator, resulting in a total of R$28,600.00. Added to this value are the air tickets (R$2,000.00 per passenger), accommodation and meals (R$300.00/person/day), resulting in R$13,000.00. In addition, 4 operators will be needed for the production, who will be hired and in the first month of work will assist with the installation. The cost per operator is R$ 3,500.00, considering all charges. The total with the installation results in R$ 55,600.00. Based on the minimum size suggested by BIOMAX, given according to the size of the project, it was estimated a total area between 800 m^2 to 1,000 m^2 and, because it is an industrial area with several sheds to allocate or to buy already fully structured, all costs involved in the construction are neglected, as well as the assembly of the electrical system and service and office areas. The amount stipulated for the rental of a structure that meets the needs of the plant is R$10,000.00. The service facility will have kitchen, cleaning, storage room, storeroom, and office equipment. The value corresponds to 15% of the EWC, resulting in R$ 159,217.50.

Besides the DCs, the CIF is also composed of the ICs, which correspond to the legal expenses and contingency. With the legal expenses it was calculated to spend 3 % of the EEC, resulting in R$ 31,843.50, and the contingency in 20 % of the EEC, totaling R$ 212,290.00. As a result, the total CIF was calculated at R$ 1,530,401.00.

When analyzing each point of the total CIF, the values presented are in agreement with reality. Furthermore, even though the briquette market is visibly expanding, the enterprise is innovative, especially for the region. Therefore, it is observed that the purchase of a site can be risky, besides greatly increasing the cost of the investment. Thus, renting the space presents itself as an option to make the investment more viable, besides releasing the company from the possible risks of the enterprise.

3.5.2.2 Estimated annual Production Cost (PC) and capital for operation

Within the CO there are the Total Manufacturing Costs (TMC) and the Expenses General Manufacturing (DGM). In turn, TCM is divided into:

a) Direct Production Costs (CDP)

- Operational work, as mentioned before, composed of 4 operators whose salaries and social charges are R$ 3,500.00/month/operator. Total of R$ 168,00.00 per year.
- Supervision, an engineer whose salary and social charges are R$ 6,000.00/month. Total of R$ 72.00,00 per year.
- Utility service with power and water. The plant will have approximately 140 kW installed, where it will be charged 0.75 R$/kWh. Counting eight hours a day for a total of 22 working days, the value of R$2,310.00/month for energy is obtained. Since water is not a raw material and will only be used for cleaning, toilets, and drinking, the monthly fee was set at R$800.00/month. Total of R$37,320.00 per year.
- Maintenance and Repair, calculated at 5% of the CIF, resulting in R$ 76,520.05 per year.
- Operational supplies (packaging and pallets): estimated at R$ 500.00/month, resulting in R$ 6,000.00 per year.

Thus, the CDP were valued at R$ 359,840.02 per year. However, the cost of maintenance and repair proved to be very high when observed the low quantity and complexity of the equipment and the process itself. Therefore, an expense with maintenance and repair calculated at 2.5% of the CIF would result in a value more appropriate to reality (R$ 38,260.025 per year), thus reducing the CDP to R$ 321,580.00 per year.

b) Fixed Production Expenses (FPD)

- Depreciation, which was calculated based on the value of the equipment delivered and installation, plus 20% to cover inflation over the 20-year useful life of the equipment. This resulted in a total of R$67,023.00 per year.
- Taxes: 0.8 % of CIF, since it is an industry with tax incentives. Total of R$ 12,243.208 per year.
- Insurance: 0.4% of the CIF, resulting in R$7,652.005 per year.

- Interest rate: 10 % of the TCI, which will be financed. Total of R$ 160,050.357 per year. To obtain the TCI, which encompasses the CIF and the three-month CP, the CP was previously calculated disregarding the interests (described below).

The DFP was valued at R$365,970.80 per year. Thus, the TCM of the briquette, results in R$ 687,555.08 per year. The DGMs are distributed as follows:

- Administrative costs, which include an employee with a salary and charges of R$3,500.00 per month, and expenses with telephone, internet, and administration software packages, which comprise a total of R$400.00 per month. Annually, the amount spent is R$46,800.00.
- Marketing, whose service hiring goal is R$ 500.00 per month, totaling R$ 6,000.00 per year.
- Product Transportation: 5% of TCM, resulting in R$34,377.57 per year.
- Transportation of the material, obtained through the monthly transportation value of the product multiplied by the eight months of harvest, totaling R$ 22,918.36/year.
- Contingency, valued at 2% of TCM. Total of R$ 13,751.02/year.

In summary, the cost of the DGM is R$123,846.92 per year. The total of the annual PC, which is equivalent to the sum of the DGM and the TCM, results in R$ 811,397.7 per year. Not accounting for the interest rate, the total SC results in R$ 652,345.14 per year. Thus, for the first three months of operation, the PC resulted in R$ 163,086.29.

3.5.2.3 Total Capital Investment

The TCI, equivalent to the sum of the CP for the first three months of operation and CIF, resulted in the amount of R$1,590,525.56.

3.5.3 Estimated Annual Revenue

The price charged for briquettes in Brazil varies from R$ 300.00 to R$ 450.00 per ton. In Manaus, of the two known supplying companies the values practiced are:

a) MF Rural, at 420R$/t of briquette;
b) Florida Clean Power, at 550R$/t of briquette.

Based on these data, the suggested price to be practiced is R$455,00/ton. Considering the production for sale of 3,271.77 tons of briquette per year, the annual revenue is R$ 1,488,655.35.

3.5.4 Gross Profit (LB), Net Profit (LL), Working Capital (CG) and years to pay back the investment

The annual LB resulted in R$ 677,257.64. The LL resulted in R$654,966.96 per year, not considering depreciation. The GC resulted in R$ 587,943.96 per year. The number of years to pay off the investment was calculated by dividing the TCI by the GC, resulting in 2.70 years.

3.5.5 Techno-economic feasibility analysis

Considering that this is a preliminary study, during the elaboration of the project some gaps that compromise feasibility were verified. Among these, the most important is the lack of studies on the physical-chemical characteristics of the cupuaçu shell or access to them. Although the use of the bark has been considered, and even research institutes have ongoing studies on the subject, pilot-scale tests of briquetting the bark to prove its effectiveness have not been performed. For this reason, technical feasibility is compromised. In addition, no briquetting machine adapted for cupuaçu bark has been evaluated yet. Another point of difficulty concerns the collection of the raw material. In everyday life, that is, for producers and processing industries in general, the cupuaçu shell is a discarded residue, without any relevant interest. The correct destination is a problem.

For the proposed business, this situation would be an advantage because the raw material The raw material, as stated before, would be provided free of charge and there would be plenty of it. Or rather, for regulated companies, the collection of the cupuaçu shell could be charged, generating additional revenue. However, for an efficient collection of this raw material it would be necessary the commitment of these industries and private producers to deliver the shells in an adequate manner, storing them in an appropriate place to avoid contamination or getting wet.

In addition, for the evaluation of this type of action, one must take into account that the collection of only this type of waste should not be of interest to most companies. Furthermore, depending on the commitment of companies, especially when, in most cases, the disposal in an undefined place is not inspected or punished, may compromise the efficiency of transportation. Another opposite solution would be the acquisition of the product, but this would require a more in-depth study of the possible resulting economic and social effects.

In terms of economic viability, the lease option is attractive because the investment will be paid back in less than three years, which would increase to approximately five years if the site were bought (for the price of R$ 1,000,000, already considering negotiations, according to the Portal Viva Real (VIVA REAL)). Moreover, the dimensions of the site and the equipment also allow an increase in the production of briquette, which still allows the expansion of production and consequent increase in revenue.

Despite being a preliminary study, the project is economically sound. viable, besides presenting an enormous potential, once the briquette market in Amazonas is still initial, but its demand is increasing.

4 CONCLUSIONS

The project has the potential to be implemented in the City of Manaus, once

that the preliminary analysis of technical feasibility is positive. Still, some gaps need to be considered, such as the need for more in-depth studies on the physical-chemical characteristics of the cupuaçu shell and on the logistics and possible problems. In addition, pilot-scale testing of briquetting with cupuaçu peel and subsequent evaluation of the briquette produced is fundamental to confirm the potential of the enterprise.

Another important point to emphasize is the scale of production, which can be increased with the use of other residues similar to the bark. The addition of other raw materials does not represent logistical costs, since the mentioned municipalities that produce cupuaçu also produce other varieties of cultivars. Furthermore, the site and equipment are sized for a production margin appreciably higher than necessary, making expansion possible.

It is concluded that, for an initial planning phase, the project presents a good perspective and technical-economic feasibility. However, adjustments and an analysis with more indicators are needed, so that there is more reliability in the feasibility.

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