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Study the economic viability of biodiesel production of cooking oil in Manaus[1]

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Resumo

O biodiesel no Brasil é realidade a partir da soja, sebo bovino e em pequena quantidade, óleo de fritura, matéria-prima que não compete com os alimentos. Todavia, em Manaus-AM não há registro da produção de biodiesel em escala industrial, justificado pelo isolamento da região, que acarreta em elevado custo dos insumos da indústria de biodiesel. Este estudo indicou que Manaus possui uma oferta potencial de 296.100 litros mensais de óleo residual nas residências, sendo oportuna a implantação de uma usina de 10.659 L/dia de biodiesel. Os custos, bem como investimento da produção também foram analisados.

Palavras-chave: óleo de fritura; biodiesel; Manaus

Study the economic viability of biodiesel production of cooking oil in Manaus. Biodiesel in Brazil comes from soy, beef tallow, and, in smaller quantities, cooking oil. Waste cooking oil is an interesting raw material, because it does not compete with food. However, in Manaus-AM there is no production of biodiesel at industrial scale, because the city is located at a geographically isolated region, surrounded by the Amazon rainforest and hydrographic basin, plus the high cost of inputs for the biodiesel industry. The present study indicates that Manaus has a potential to offer, monthly, 296,100 liters of waste oil from residences, which means that it's possible to implement a biodiesel plant to produce 10,659 liters per day. The costs of production as well as the investment in manufacturing were also analyzed in the present work.
Keywords: economic viability, cooking oil, biodiesel, Amazon

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1. Introduction

Biofuels date back to the 1940s, when researchers first attempted to use energy from vegetable oils and fats in internal combustion engines. In the 1970s, the Pro-Alcohol program, which introduced ethanol in the energy plan, led to strong momentum for biofuels in Brazil (SUAREZ & MENEGHETTI, 2007). Nowadays, although Brazil ranks fourth in world production of biofuels, behind the US, France and Germany, the country has been assembling the structural conditions to become a strong candidate for leading the production of fuels from biomass (VICHI & MANSOR, 2009). This has motivated the emergence of several initiatives for this type of fuel production in various regions of the country. Technical studies have recommended palm oil, *Jatropha* and waste frying as sources for conversion into fuels (PHAN & PHAN, 2008; NETO et al. 2000).

According to the National Agency of Petroleum, Natural Gas and Biofuels (ANP), the predominant raw materials in biodiesel production are vegetable oil (80.95%, mainly soybean oil), bovine fat (13.88%) and other fatty materials (5.17%) (ANP, 2011). Refined vegetable oils represent between 70% and 95% of the cost of production (ZHANG et al. 2003; WANG et al. 2007; MENGYU et al. 2009), and this cost leads to a relatively higher price of biodiesel in comparison to diesel (DABDOUB et al., 2009).

Although Brazil is a major world producer of soybean (CECI et al. 2008), waste frying oil represents only 0.22% of the raw materials used to produce biodiesel. Fortunately, recycle of waste oils is increasingly gaining ground, not only because the waste materials have low commercial value but also because the effects of environmental degradation resulting from incorrect disposal of this waste by industries, bars, restaurants and residences are reaching increasingly alarming levels (PINTO et al. 2005; BERTI et al. 2009). Moreover, there is great pressure on the world for new biofuel production technologies, including those that are not using raw materials that compete with food production or generate deforestation. The use of frying oils, waste animal fat, grease trap filtered and microbial oils is totally compatible with this position are (LAM et al. 2010).

In Amazonas state, the research related to raw material for biodiesel production has been directed at vegetable oils of native plants, such as tucuman (*Astrocaryum aculeatum* Meyer), uricuri (*Attalea phallerata* Mart.) murumuru (*Astrocaryum murumuru* Mart.) babassu (*Orbignya phalerata*), andiroba (*Carapa guianensis* Aubl), and palm (*Elaies guianeensis*). The main incentive has been for the cultivation of oil palm, that has a productivity of more than 4000 kg of oil per hectare/year (MAPA, 2011). However, the capacity for producing those raw materials at Amazonas state is still much slower than the market demand, which discourages any initiative for investment in biodiesel production in the region. Neverthless, native oil seeds disseminated in the region already meet the demand for pharmaceutical and fine chemical industries, and it is possible to produce those native oil seeds also for biodiesel production. In other words, despite the most common uses for these oils, it is also possible to produce biodiesel in the region, given that its production should occur from raw material that provides steady flow of production.

To date, there is no biodiesel production unit in the state of Amazonas on an industrial scale (ANP, 2011). There are only two small plants. One produces biodiesel from seeds uricuri and is located in the community of Extractive Reserve Roque, the Middle Juruá Carauari municipality, 728 km from Manaus. Its production capacity is about 15 kg of oil per hour. The other is a palm biodiesel plant, located at the Experimental Field of Embrapa Western Amazon, a company under the Ministry of Agriculture, Livestock and Food Supply in the city of Rio Preto da Eva. It is designed to produce 1000 liters per eight hours and has the

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ability to produce up to 3000 liters of oil/day with 24 hours of operation (GONZALEZ et al. 2008). Both plants are still experimental and were established by the Federal Government through the Ministry of Mines and Energy (MME).

The Amazonian cuisine is based on regional fried fish and a type of banana called Pacovan (*Musa* sp), which is often fried, resembling to potato chips (MATSUURA et al. 2002). The frying residues could be used as raw material to supply the production of biofuel in small units of energy production at isolated communities in the region. In those isolated areas, most of the electricity and fuel intended for river transport utilizes diesel oil. The cost of transporting diesel to remote areas in the region is extremely high, up to three times its own value (ANDRADE & MICCOLIS, 2010). On the other hand, the Amazonas state capital, Manaus, is virtually an island, where the cargo and passengers transport occur by air or by river. This regional isolation contributes to the rising cost of inputs for energy production, and once more, biodiesel production can be an excellent alternative.

Other policies to encourage the collection of waste cooking oil have been discussed in two projects of the Act (No. 166/2007 and No. 152/2009) laying down rules for the disposal, collection and reuse of waste oil or fat used in frying of food, focusing the pollution of rivers. The country's largest river basin, which surrounds the Amazon, represents one-fifth of the world's fresh water. Amid this complex hydrography, there are several creeks that weave the neighborhoods, resulting in a differentiated urban network. This river network represents major transport routes in the region. Unfortunately, these streams become turning points of disposal for municipal and industrial waste; houses on its banks receive great most of the waste produced in the area, which also leads to serious environmental impacts. The Educandos stream, in Manaus, remains a site for the disposal of municipal waste, requiring the intervention of government agencies to implement measures aimed at revitalizing the area.[18] The presence of oil on the surface of water coming from discharges of domestic and industrial sewage might contaminate the water bodies due to the formation of oil films on the surface. This provokes depletion of oxygen concentrations on the water, leading to anaerobiosis, affecting aquatic life (MELO *et al*., 2005).

The present work examines the technical and economic feasibility of producing biodiesel from cooking oil in the city of Manaus, considering the estimate of the consumed and rejected amount of oil, besides the parameters of costs, revenues and profits of the biofuel obtainment process via alkaline transesterification.

2. Material and methods

2.1 Obtaining primary data

The analytical framework is based on a set of economic indicators. First, a questionnaire was administered to measure the consumption of oils and fats by households, commerce, public service units and industrial companies located in the city of Manaus from 2009 to 2011. The field research was conducted with a representative sample. The minimum sample size was determined to estimate the consumption of vegetable oils and fats as well as the proportion of people in each sampling unit (home, bar, cafe or restaurant, industrial, utility plant).

In a pilot sample, 15 of 21 participants responded "yes" to a question about their knowledge about the contamination of rivers by inadequate discard of waste frying oil (WFO). This research resulted in an initial estimate the value of $p = 0.714286$ and a 95% confidence interval ($n = 872$). Based on observations of the pilot sample, the questionnaires were adjusted. The sample size was set at $n = 1000$ and divided proportionally among households and businesses (bars, cafes and restaurants). According to the proportion of sampling units, 40% of the questionnaires were applied in businesses and 60% in households. The population size was

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stratified by geographical area, proportionally to the size of each zone.

2.2 Indicators of Economic Viability

The field survey data were tabulated and organized into tables, to express information convergent with the research objectives. The tab was estimated from the volume of vegetable oils consumed by households and business units for each urban area, and then the amount of discarded frying oils after cooking was estimated.

By the knowledge of the amount of vegetable oil consumed and discarded by their families led to an estimate of the potential supply of basic raw material for biodiesel production. However, the existence of supply alone is not sufficient for an economic feasibility analysis, so it was necessary to use other economic indicators as well. The revenue of the enterprise and its operational costs, including fixed (expenditure incurred that is independent of production) and variable costs (costs that are directly associated with production) were important to scale the production level and to guarantee a minimum return of the enterprise. In other words, it was set a *Break-even* point, which is a technique that studies the relation between fixed costs, variable costs and return. The Equation 1 (Equation of Grade Point, GP), below, corresponds to the point where the return is equal to the costs:

$$GP = Q = F/(p - v) \qquad \text{Eq. 1}$$

For this period, return on investment, internal rate of return (IRR) and Net Present Value (NPV) were also estimated. The net present value, in turn, was obtained from the project's cash flow when using the discount rate, which represents the weighted average cost of capital of the enterprise. From a formal perspective, these concepts can be translated as follows:

i) Payback (Equation 2):

$$T = R/I \qquad \text{Eq. 2}$$

ii) Net Present Value (Equation 3):

$$NPV = \sum_{j=0}^{n} R_j (1+i)^{-j} - \sum_{j=0}^{n} C_j (1+i)^{-j} \qquad \text{Eq. 3}$$

iii) Internal Rate of Return (Equation 4):

$$IRR = \sum_{j=0}^{n} A_j (1+i)^{-j} = 0$$

$$\sum_{j=0}^{n} R_j (1+i)^{-j} - \sum_{j=0}^{n} C_j (1+i)^{-j} = 0 \qquad \text{Eq. 4}$$

2.3. Sensitivity Analysis

In the sensitivity analysis, we used only the net present value (NPV) to verify the project's economic viability of the production unit. Thus, we performed a sensitivity analysis of NPV to a variation of 10% and 15% on the price of the raw material (methanol and catalyst).

2.4. Experiments to produce biodiesel

2.4.1.Collection of samples and physicochemical characterization

Samples of oil for frying fish and pastry and for frying oil in general were collected from the northern city of Manaus for the purpose of guiding the technical feasibility to process the frying oil into biodiesel. Refined soybean oil, which is commonly used in local cuisine, was used as a parameter in the analysis.

The oils collected were filtered to remove food waste, packaged in amber bottle and stored in a freezer. The quality of the samples was determined by Acid Value (mg KOH / g oil), saponification (mg KOH.g^{-1} oil), peroxide (meq O_2. Kg^{-1} oil), iodine (I_2.100g^{-1}) and free fatty acid (% oleic acid) according to the methodology of the Instituto Adolfo Lutz (LUTZ, 2008). The characterization of physics to density (hydrometer Dendi-series) and viscosity (Ostwald viscometer) was also determined. Analysis were performed in the Research Laboratory and Testing of Fuel - LAPEC/UFAM.

2.4.2. Transesterification reaction

The transesterification reaction via basic catalysis was conducted on a bench scale with only the oil samples that had less than 1.0% free fatty acid content (LEUNG

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& GUO, 2006). The reactor comprised a round-bottomed flask attached to a condenser. The system was kept under reflux and magnetic stirring under the following reaction conditions: molar ratio of oil/methanol = 1:6 and 1% NaOH catalyst in relation to the mass of oil and temperature of 65°C (ENCINAR et al. 2007). The product was separated from glycerin and washed with distilled water at 80°C to remove the catalyst, alcohol and remaining glycerin. Then, it was dried in an oven at 110°C for 1 h.

The reaction was performed in a Parr 5500 reactor containing a 600 mL capacity reaction vessel equipped with temperature control and mechanical agitation (1200 rpm) under the same conditions as the bench scale, maintaining a temperature of 70°C in order to approach the industry scale. The conversion of oil samples in methyl esters was measured using Nuclear Magnetic Resonance of Hydrogen, ^{1}H NMR (MEHER et al. 2006).

3. Results

3.1. Location of research areas

The city of Manaus features strong industrial activity characterized by the Manaus Industrial Pole. Its urban area is located between the coordinates 03 º 08 'south latitude and 60 º 07' west longitude on the left bank of the Negro river at its confluence with Solimões river to form the Amazon River. Its land area is 11,401.077 km^2 and is subdivided into six urban areas (South, South Central, East, West, Central West and North). The research was performed in the six areas of the town (Figure 1).

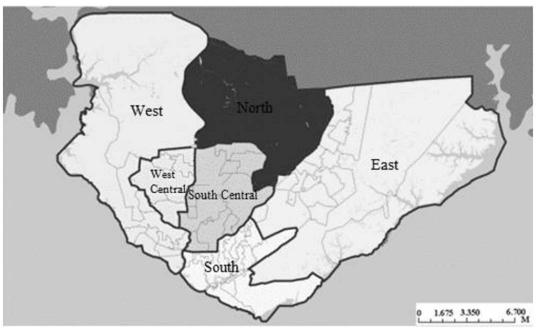

Figure 1. Map of urban areas in the city of Manaus.

3.2. Consumption of vegetable oil in urban areas of Manaus

The first field researched was the consumption of vegetable oils and fats by households, bars, restaurants, cafeterias, and large companies located in the six urban areas of Manaus. It was found that the average consumption of vegetable oil is 2.82 liters per month for households and 48.88 liters per month for businesses. The average consumption estimated for private enterprise likely underestimates the actual consumption, since these companies sampled for convenience during the field research.

A higher consumption of vegetable oil was identified for households at East area (Figure 2), followed by the West area. The average consumption of other areas is not distant from the consumption found for East and West areas, as confirmed by the coefficient of variation. From the business perspective, the South Central and South areas show more consumption than other areas (Figure 3).

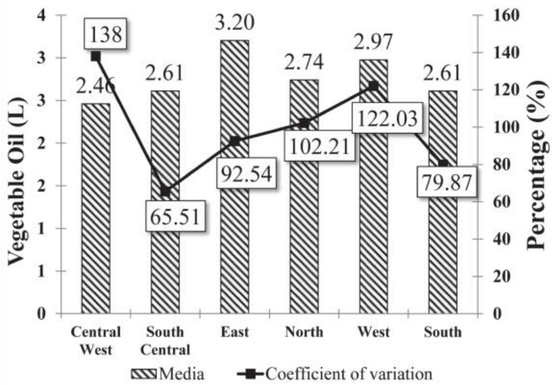

Figure 2. Average monthly consumption of vegetable oil by families.

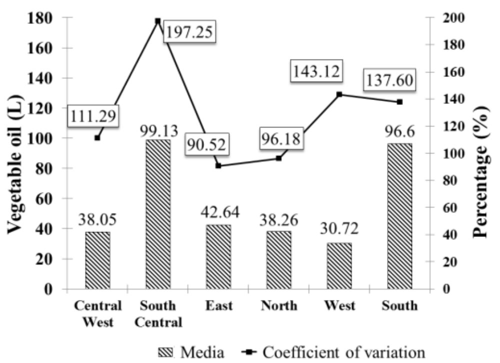

Figure 3. Average monthly consumption of vegetable oil by companies.

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By the other hand, the high values for standard deviation and coefficient of variation can be explained by the irregular demand of oil in the three urban areas that shows the highest consumption (South Central, South and West) .Another explanation is that the market is quite seasonal in the region. Bars, cafes and restaurants are most prone to the nuances of the market; when the local economy experiences periods of prosperity, there are opportunities to maximize profits in the short-term. However, in phases of low growth, many small companies go out of business. These economic changes affecting small businesses result in consumption of raw materials, including vegetable oil.

In the case of families, unstable oil consumption was observed around the Central-West, North and West areas; the coefficients of variation were relatively high (Figure 2). Probably, this heterogeneity can be associated by their inconstant earning and alimentary habits.

Considering this fact, we estimate the supply capacity of waste frying oil (WFO) by households, excluding consumption of businesses and industrial kitchens. Based on the survey, each household consumes an average of 2.82 L per month of oil. A product of 2.82 L per 350,000 existing homes in Manaus, results in 987000 L/month of oil consumed by households. Of this consumption, it is estimated that 60% is used for frying, which equates to 592200 liters. But it appears that only half of this value becomes waste (a total of 296100 liters). This translates the potential amount for waste frying oil generated in the city of Manaus (Figure 4).

Although this oil supply may potentially be turned into biodiesel, feasibility depends in part on selective collection programs, while the city is still beginning a social program for recycling WFO. Figure 5 illustrates the destination of frying oil in the city of Manaus: 5.84% of fried oil is being re-profited; 2.67% are recycled, while 3.17% are sent to another destination. By the other hand, in Manaus, more than 90% of waste frying oil is discarded into drains and sinks using the landfills.

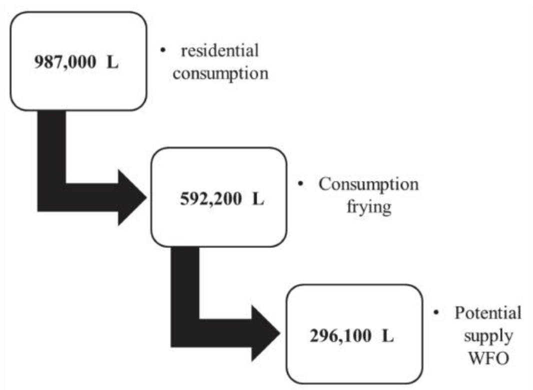

Figure 4. Monthly estimate of the potential cooking oil waste supply (L/month) from households in the city of Manaus.

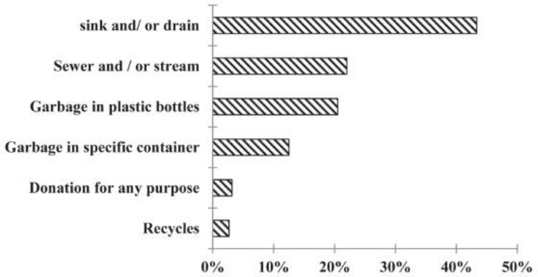

Figure 5. Destination of frying oil waste in the city of Manaus.

3.3. Experiments to produce biodiesel

Table 1, below, summarizes the values obtained in the physicochemical characterization of samples of oil for frying fish, pastries and fried foods in various residences. Their physical and chemical features remain high compared to refined soybean oil. This trend can be explained by oxidative and thermoxidative hydrolytic reactions from the frying process. On the other hand, the presence of free fatty acids was less than 1%, although the frying process lasted about seven hours in the case of samples obtained from the university cafeteria and remained in use for four days in pastries, indicating the possibility of conversion of oil by transesterification via alkaline catalysis (ENCINAR et al. 2007).

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Table 1. Physicochemical characterization of samples of cooking oil and refined soybean oil.

Physico-chemical	Sample of oil			
	Refined soybean	Frying fish	Fried foods in general	Pastel frying
FFA (% oleic acid)	0.13	0.63	0.72	0.78
Iodine Value g I_2.100g^{-1}	108.08	97.56	98.66	102.83
Saponification number, mgKOH.g^{-1} oil	173.9	177.8	177.1	170.13
Peroxide value, meq O_2.g^{-1}	2.79	8.05	17.91	13.41
Density at 20 ºC, g.cm^{-3}	0.9185	0.9212	0.9192	0.9307
Viscosity at 40 ºC, mm^2.s^{-1}	32.48	35.05	37.99	71.99

With regard to viscosity (Table 1) for restaurant and home samples, values were very close to the refined soybean oil; pastry samples showed nearly twice the viscosity. This increase is likely due to the polymerization process of the oil caused by the intensive use (4 days), which also contributed to the darkening. The density follows the same trend and registered a slight increase in the density of oil that came from pastry production (very common at street fairs) compared the home and restaurant samples. Note that density and viscosity are important parameters in the atomization of fuel, preventing the direct use of vegetable oils in the engine (MEHER et al. 2006). In turn, the yield of methyl esters obtained in the reactor for samples of frying oil biodiesel was similar to that obtained from soybean oil, an average of 87%, confirming that the technique is suitable for processing waste frying oils into biodiesel with low values of acidity.

3.4. Analysis of the economic viability of biodiesel production from waste frying oil

3.4.1. Basics

The calculations of the economic viability of biodiesel were determined based on a production unit that operates eight hours per day in a month. In addition, by prioritizing the methylic route, an analysis of production costs must be made taking into account the reaction of alcohol consumption of approximately 56% as well as recovery due to the distillation of excess alcohol in the range of 37%, which is also recorded in the variable costs of operations.

Besides the definition of the production process, the economic viability of the investment project must be submitted to the adherence of indicators of economic evaluation, obtaining information about the capacity to collect monthly waste frying oil at selected points. According to data from this research, the city of Manaus has the potential to collect about 296,100 liters per month of frying oil in homes, without regard to trade, factories, hospitals, schools and barracks. Certainly, these units produce much larger quantities of frying waste than families.

The potential oil supply from household (80% to 90%) can be converted into biodiesel (FELIZARDO *et al.*, 2006), which is consistent with the experiments in this study. A single plant would have to produce a maximum of 90% (266,490 liters per month) of biodiesel from WFO. Thus, in Manaus, it would be appropriate to establish a plant with production capacity of up to 10,659 liters per day of biodiesel. However, the collection of WFO at residences requires a great commitment to the actions of awareness to the entire population, which takes time. Short-term difficulties to acquire a regular supply can be solved by other consumer units. The most promising oil could be collected from commercial establishments, schools, hospitals, barracks and companies in the industrial area. A bigger offer of raw material means security and regularity to the production of biodiesel.

Traditionally, the economic viability of an enterprise requires estimating returns on investment, costs, revenues and profits as well as considering the interest rate in the market. In this line, fixed and variable costs, the social price of the product and net income are needed in order

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to estimate the amount of return on investment, the internal rate of return (IRR) and net present value (NPV).

Setting the technological route of transesterification, both fixed cost and variable production costs can be estimated. Fixed costs occur regardless of actual production. Certainly, fixed costs vary periodically, whether due to adjustments in staffing or administrative rationalization. Variable costs depend on production. To the extent that production increases, spending on labor, direct labor, raw materials, transportation, energy, water, etc. also tends to grow. Finally, the sum of fixed costs (FC) and variable costs (VC) results in the total cost (TC) of the enterprise.

i) Fixed Costs

Table 2 presents the estimated fixed costs of a plant with production capacity of 10,659 liters per day of biodiesel, based on other successful biodiesel plants in Brazil (PAGLIARDI et al. 2006).This amount of fuel requires a medium-sized plant and an initial investment of $986,245.87 U.S. dollars. Of this amount, US$639,727.05 is used to purchase of the plant, while US$346,518.82 is used to acquire and construct an area of 500 m^2. However, these costs can be recovered more effective production time. The cost analysis of the raw materials account for an average of US$1919.18/month. Over time, the plant and the buildings will suffer wear, or in other words, loss of market value of production resulting from heavy use, action of nature or obsolescence. This was accounted for as asset depreciation, estimated in this study as 10% for plant facilities and 4% for buildings. Because any business incurs (sometimes unpredictable) administrative overhead, this item was estimated as 2% of other cost items.

Table 2. Other administrative expenses (2% of fixed costs).

Fixed Cost	US$ 1.00
Total	1,294,815.01
Biodiesel plant	639,727.05
Buildings of the biodiesel plant	346,518.82
Salaries, payroll taxes and social benefits (*)	152,894.76
Maintenance (amount up to 1% on the investment of the plant)	9,862.46
Fire insurance (2% of investment)	19,724.92
Cost analysis of the raw material (US$ 1.919,18.00 x12)	23,030.17
Depreciation	77,833.46
Other administrative expenses (2% of fixed costs)	25, 223.37

(*) Benefits: personnel carriers-4 x 4 valleys (US$ 1,20) x 25 days / month x 12 months. Food stamps-4 employees x US$ 5,33 x 25 days x 12 months. Salaries: Manager (US$ 1.865,87 /month), Secretary (US$799,66 /month), Security (US$799,66 each/months). Quotation of the U.S. dollar exchange Central Bank of Brazil in 30/12/2011.

ii) Variable Costs

The variable costs (Table 3) amounting to US$2,480,825.80 were estimated taking into account eight sources of costs, beyond the size of the production plant designed. It is therefore considered a reactor with a capacity of 11,844 liters of oil/day flow at a ratio of 1:6 of alcohol and 1.0% catalyst, which will result in 10,659 liters of biodiesel/day. Finally, the plant operation will process 3,197.700 liters of biodiesel per year.

The demand for electricity to operate a plant that provides a monthly production of 266,490 liters of biodiesel, equivalent to 213,192 kg, is about 266,000 kWh. That is, every 1000 kg of biodiesel yields a fuel consumption of 28 kWh. The cost per kWh in the range of industrial use corresponds to US$90.09 (ANEEL, 2011). This creates an annual cost of

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US$287,582.90 a year. On the other hand, the cost of reverse logistics, i.e., the collection of oil stations to the plant, is US $0.16 for liter. In general, the storage of collected oil is done in 1000 liter containers at a cost of about US$735.69. For a daily collection of 11,844 liters, 24 containers are allocated for the collection point and 12 for replacement at the same point.

Table 3. Costs (monthly period of 25 days).

Variable Cost	US$ 1.00
Total	2,480,825.80
electric power	287,582.90
Catalyst (US$ 11,73 kg)	375,057.90
Methanol (US$ 1,89 liter)	1,121,415.75
Transport of collected oil	511,442.58
Container to accommodate the oil collection	17,656.47
Water for cleaning	1,383.28
Salaries of direct labor, social charges *	159,931.76
Other operating expenses	6,355.16

(*)Transport benefits: employees 4 x 4 valleys (US$ 1,20) x 25 days/month x 12 months. Food stamps: 4 officers x US$ 5,33 x 25 days x 12 months. Supervisor salaries (US$ 1.599,32/month), Secretary (US$ 959,59/month), Security (US$ 959,59 each /month). Quotation of the U.S. dollar exchange Central Bank of Brazil in 30/12/2011.

Washing water, a production input, is estimated at 10% (MÉNDEZ et al. 2008). For the production of 266,490 liters per month, which equals 266,49 m^3, consumption is 26,649 m^3 plus 10 m^3 for general cleaning. With regard to the value paid by the company supplying water in the state of Amazonas, Amazonas SA Water, the cubic meter of water equals US$4.50. It an expense of US$115.27 per month or US$1,383.28 per year.

Three workers and one supervisor are required for the production of biodiesel on the scale proposed. The monthly costs for the supervisor (US$19,191.81) and the three workers (US$959.59) total US$53,737.07 per year. The project demands social costs of US$94,039.88 as well as benefits of $12,154.81 U.S. dollars. Other operating expenses amounted to $6,355.16 U.S. dollars, resulting from maintenance and purchase of spare parts, among others.

iii) Revenue estimated

Revenue (Table 4) is derived from sale of the product on the market. The last auction of the ANP had a liter of biodiesel cost of US$1.09 in the domestic market.

Table 4. Revenue, Total Cost and Net Annual Income assumed for a plant operating with an efficiency of 99%.

Discrimination	Value US$ 1.00
Sales revenue	3,494,857.66
Total Cost	2,789,394.94
• Total Variable Cost	2,480,825.80
• Total Fixed Cost	1,294,815.01
Net income (surplus)	705,462.72

Quotation of the U.S. dollar exchange Central Bank of Brazil in 30/12/2011.

Judging by the data generated, the implementation of a biodiesel plant with production capacity of 10,659 liters/day in Manaus is economically viable, since the

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cost of initial capital required is around \$986,245.87 U.S. dollars. The book value may be recovered from the second year of operation, since a net income of US\$705,462.72 is expected in the first year. Maintaining regular revenue from the second year in operation will allow the enterprise to recover the initial investment and operating costs.

Table 5 shows streams of income, investments of \$986,245.87 U.S. dollars, a discount rate of 12.5% per year, and an NPV of \$198,234.75 U.S. dollars. This is the net return current generated in the second year of the project. This means that the capital invested can be recovered, according to the payback, in 1.43 years. Finally, the Internal Rate Return, which makes the NPV zero, is 27.6%.

Another important indicator in this analysis is the point of leveling that shows from what level of production revenues equal the costs; thus, it is the starting point to generate economic benefits for the enterprise. Estimates show that production is the point of leveling, at 4,082,040.33 liters of biodiesel per year. From this level of production, the enterprise can make a profit.

Table 5. Initial Investment, Revenue and Cost - US\$ 1.00.

		investments	net returns	NPV	return on investment
Annual Period	0	-986,245.87	-986,245.87	-	
	1	-	627,077.97	-359,167.90	
	2	-	557,402.64	198,234.75	1.43 years
	amount	-	-	198,234.75	-

Quotation of the U.S. dollar exchange Central Bank of Brazil in 30/12/2011.

3.4.2. Sensitivity Analysis

Tables 4 and 5 present the initial investment, expected revenue, total cost, and cash flow (net return). From these data, taking into account an interest rate of 12.5% per year, the Selic (Special Clearance and Escrow System, the Brazilian Central Bank's system for performing open market operations in execution of monetary policy), the Central Bank can yield a NPV of US\$198,234.75 in the second year of operation, after deducting the investments.

Among the variable costs, methanol (45.20%), transportation of oil collection (20.62%) and catalyst (15.12%) are the most significant operating costs. The sensitivity of NPV to a price change in the catalyst and/or methanol was simulated by a shock of 10% and 15% in the price of each component, with constant revenue and interest rate.

Figure 6 shows that the price change in the catalyst increased the total cost from \$2,826,900.73 to \$2,845,653.63 U.S. dollars. This resulted in a decrease in the NPV of \$135,262.06 and \$103,775.72 U.S. dollars, respectively. In turn, the total cost of methanol increased to \$2,901,536.52 and \$2,957,607.30 U.S. dollars, resulting in NPV of \$9,947.65 and \$39,893.04 U.S. dollars. That is, raising the price of methanol by 15% generated a negative NPV. Thus, the NPV is more sensitive to variations in the price of methanol, since the input is the most onerous operating cost in the production process.

4. Conclusions

The present study shows that using vegetable oil as fuel can become a reality in the city of Manaus, with benefits in economy, pollution and environment.
From the statistics generated, the Manaus market demands a considerable amount of vegetable oil, with an average consumption of 51.70 liters between residential and business segments. The change in volume of oil consumption is associated with population growth and income, which in turn allows for consumption habits to

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change. Frying oil waste tends to grow exponentially.

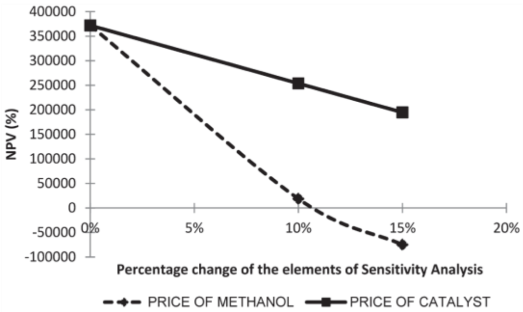

Figure 6. Sensitivity analysis of Net Present Value.

The field research points to a potential supply of 296,100 liters per month. This means that the city can hold at least one plant with capacity of 10,000 liters per day from the collection of waste frying oil at home. However, the feasibility of installing a plant of this size depends in part on selective collection programs and raising awareness. The study found that 90% of frying oil waste is dumped into the sewage system directly from sinks and garbage cans.

The economic viability of a plant with daily production of 10,659 liters of biodiesel is around $986,245.87 U.S. dollars, based on a yield of 90% of the product obtained via alkaline transesterification. Estimates of fixed and variable costs as well as net income show that the power plant can be economically viable, given that the investment return would occur within two years of operation. However, the sensitivity analysis shows that the NPV is sensitive to variation in the price of methanol and the catalyst.

Taking into account these aspects, the plant is considered an important opportunity to generate income and, more importantly, a significant contribution to cleaning up the city and therefore improving the environment.

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Divulgação

Este artigo é inédito e não está sendo considerado para qualquer outra publicação. O(s) autor(es) e revisores não relataram qualquer conflito de interesse durante a sua avaliação. Logo, a revista Scientia Amazonia detém os direitos autorais, tem a aprovação e a permissão dos autores para divulgação, deste artigo, por meio eletrônico.

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