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Economic Analysis of Biodiesel Production from Waste Vegetable Oil in Mexicali, Baja California

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Abstract: Mexicali, capital of Baja California, Mexico, has a motor vehicle fleet of diesel estimated at 14,000 units and cargo transport. The transport cargo sector with 11,861 units, consumes about 169 million liters of diesel. The diesel used in Baja California comes from southern Mexico and is one of the causes of CO_2 emissions that affect air quality in Mexicali, it is therefore important to explore options for replacing it with biodiesel, which produces less CO_2 and can be obtained from waste material. Thus, in the analysis, was considered the use of waste vegetable oil from the Mexicali restaurant industry as a raw material for the production of 4.78 million liters of biodiesel energy equivalent to 4.45 million liters of diesel. The environmental benefit involving the replacement of such a volume of diesel with biodiesel is to reduce emissions by about 9,700 tons of CO_2, 22 tons of SO_x and 11 tons of PM_{10}. To determine the economic feasibility of producing biodiesel, were applied the methodologies of net present value and internal rate of return. The results indicate that the production of biodiesel is profitable. However, the recovery time of investment, coupled with the uncertainty presented by the biofuels market, make necessary a policy that implements local tax resources to support the promotion, production and use of biodiesel for the transport sector. Therefore, under the circumstances considered in this analysis, the production of biodiesel is feasible if it is developed a synergy among the productive sectors, education and government.

Key words: Biodiesel; Economic analysis; Waste vegetable oil; Transport cargo sector

Mexicali, capital of Baja California, is located in the northwest region of Mexico on the border with the United States of America and has a population of one million inhabitants (CONAPO, 2009). It has a motor vehicle fleet of diesel estimated at 14,000 units of cargo and transport, which is responsible for 50% of air pollution by emission of greenhouse gases, causing negative impacts on human health.

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Diesel fuel is the main energy supply source for transport sector, is also one of the causes of CO2 emissions that affect air quality in Mexicali. The production of biodiesel is an opportunity to decrease the diesel use. The city ranks first in CO and PM10 emissions exceeding the permissible limits for environmental regulations and sixth in per capita Ozone nationwide. It then presents a favorable position to process biodiesel considering its ecological contribution on conventional fuel. With this background, has been developed an economic analysis of the process of obtaining biodiesel from waste vegetable oil (WVO). The results presented in this document reflect the profitability of the process. These results show an analysis of biodiesel production from an economic approach geared to meet the fuel demand for transportation cargo sector (TCS).

As a case study was taken the Mexicali city TCS which comprise approximately 11,861 units, that represents 14% of Baja California transportation sector and consume about 169 million liters annually. In the case of Mexicali, it was estimated an annual production feasible of 4.78 million liters of biodiesel from WVO, from restaurant industry, energy equivalent to 4.45 million liters of diesel (Coronado, 2010). The environmental benefit involving the replacement of 4.45 million liters of diesel by biodiesel is to reduce emissions by about 9,700 tons of CO_2, 22 tons of SO_x and 11 tons of PM_{10}.

Another advantage of incorporating biodiesel into the transportation sector from the energy point of view is that biodiesel is a renewable energy source. Likewise, the use of biodiesel can extend the life of diesel engines because it is more lubricating than diesel. Biodiesel is the only alternative fuel that runs in any conventional diesel engine without requiring major modifications. The most common blend is 20% biodiesel with 80% diesel, known as B20.

To replace a fraction of diesel that is currently consumed in Mexicali with biodiesel, it was necessary to assess the cost to produce it and identify key indicators that determine the level of investment. Therefore, the objective of this study was to estimate and analyze the financial indicators that determine the level of the project profitability to produce biodiesel in Mexicali.

1. MATERIAL AND METHODS FOR BIODIESEL PRODUCTION

Alkaline Catalysis. By this process sodium hydroxide or potassium hydroxide can be used with alcohol, and with any type of vegetable oil. It is recommended to produce the alkoxide in order to improve the overall efficiency of the reaction. The types of alcohol most used in this method are methanol and ethanol. The reaction was carried out at temperatures between 55 and 60ºC, but depends on the type of catalyst (Meher, 2006).

Acid Catalysis. In this method the raw material composed of fatty acids and triglycerides, reacts with methanol and sulfuric or sulfonic acid as catalyst. In acid and alkaline catalysis excess alcohol produces a better conversion of triglycerides, but the recovery of glycerol is more difficult and the optimum ratio of alcohol and other material should be determined experimentally, considering that each process is a new problem. The reaction temperature is typically above 100 ºC and requires more than 3 hours to complete the conversion (Meher, 2006).

1.1 Procedure for Biodiesel Production

Given the characteristics of the mixtures of the WVO collected, it is necessary to make the process of biodiesel production in two stages. Previous studies (Meher, 2006; Canacki, 2005, Felizardo, 2005; Canacki, 2003) demonstrated that high acidity in oils inhibits the transesterification reaction via alkaline, leading to a saponification process. It is therefore a need for a pretreatment consisting in the reaction of oils with an alcohol in the presence of an acid catalyst, to convert free fatty acids in their corresponding esters. It is recommended that the amount of free fatty acids present in the WVO be less than 1% after pretreatment to achieve better conversion rates. Another variable to be controlled is the amount of water present in the WVO because reduces the yield of reaction.

Fig. 1 exhibits the simplified process that was conducted in the laboratory for the production of biodiesel from WVO, using methanol and sodium hydroxide. This process formed the basis for the development of the economic analysis.

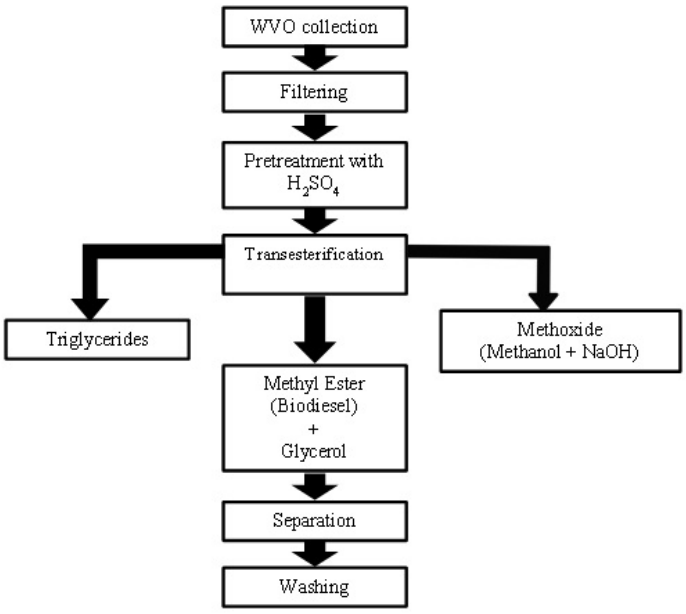

Fig. 1: Scheme of biodiesel production from WVO

The process involves the main stages of biodiesel production from WVO: 1) collection of WVO in restaurants, 2) WVO filtering to remove solid waste, 3) pretreatment of WVO with sulfuric acid, 4) preparation of sodium methoxide, 5) transesterification reaction, 6) separation of biodiesel and glycerin and 7) washing.

1.2 Transesterification Reaction

The reaction of transesterification consists replacing the glycerol by a short chain alcohol such as methanol or ethanol, so as to produce methyl or ethyl esters of fatty acids. The reaction can be represented in a simplified manner (Zhang, 2003).

$$RCOOR_1 + R_2OH \longleftrightarrow RCOOR_2 + R_1OH$$

Triglyceride + Methanol ◄⟷► Methyl Ester + Glycerol

where:

R = Fatty acids chain

R_1 = Triglyceride chain

R_2 = Methyl group

1.3 Yield Analysis

Tab. 1 illustrates the results of 5 representative cases of experimentation in biodiesel production from WVO collected in Mexicali.

As it is evidenced, samples with lower pH present a decrease in the yield of the reaction. It is therefore necessary pretreatment with acid to convert free fatty acids to achieve better conversion to esters. Excess of free fatty acids promotes the saponification reaction with NaOH, resulting in the formation of soap.

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Tab. 1: Biodiesel and glycerol production

SAMPLE	1	2	3	4	5
Biodiesel %	86.4	87.5	88.5	91	91.4
Glycerol %	6.4	5.5	6.5	7	8.55
Impurities %	7.2	7	6.8	2.0	0.05
pH	5.0	5.0	5.0	6.0	6.0

1.4 Diesel Supply Estimation

It is important to note that the TCS accounts for 54% of diesel consumption in Mexicali, with annual average demand of 169 million liters of diesel. In terms of the potential technological conversion was estimated in 11,861 engines. However, in the first phase is planned to cover 3% of demand for TCS with B100, represents the production of 4.78 million liters of biodiesel in a period of five years, considering a B5 blend would be possible to turn 57% of cargo vehicles to biodiesel use.

1.5 Economic Analysis

Depending on the yield obtained by the method of alkaline catalysis, it was designed an interactive model to establish the annual production level that achieves a volume of 4.78 million liters of biodiesel in the horizon of five years. On this basis, was calculated the cash flows to present value in order to explore the best cost option to produce biodiesel for the Mexicali TCS. The financial indicators used to perform the modeling are described above:

Net Present Value (NPV). It is one of the methodologies used to evaluate projects and is updated by an interest rate, all cash flows or project future cash in order to know its present value or real value and determine the value of money in time. The NPV itself means nothing, however, to know the true desirability of a project, you must compare different alternatives and the highest NPV is often used as a selection criterion. To determine the NPV using the following equation:

$$NPV = -I + \sum_{n=1}^{N} \frac{Q_n}{(1+r)^n} \tag{1}$$

Where:

Q_n = Cash flow

I = Initial investment

N = Number of periods

r = Interest rate

Internal Rate of Return (IRR). It is an indicator to quantify the efficiency of an investment. Unlike the NPV that delivers results in magnitude, the IRR gives a percentage that indicates the profitability of a project. The IRR is calculated from the change in the discount rate or interest, to equal the sum of adjusted flow or NPV to zero, then the interest rate obtained is defined as IRR.

$$\sum_{i=1}^{N} NPVi = \sum_{i=1}^{N} NPVe \tag{2}$$

Benefit/Cost (B/C). It is determined from the ratio of income NPV/ expenditure NPV in accordance with cash flow.

$$\frac{B}{C} = \frac{\sum_{i=1}^{N} NPVi}{\sum_{i=1}^{N} NPVe} \tag{3}$$

Profitability Index (PI). It is calculated dividing NPV by the Investment to determine the profitability will be obtained for each dollar invested.

$$PI = \frac{NPV}{INVESTMENT} \tag{4}$$

2. RESULTS

After conducting a series of tests on samples taken from the same food preparation establishment was determined at the laboratory that for every liter of processed WVO was obtained on average 82.3% of reusable raw materials, because the remaining material had a high content of solid waste food and water. Subsequently underwent transesterification producing 91.4% biodiesel and 8.6% glycerol.

2.1 Profitability Analysis

Based on experimentation results, it was developed a cost-benefit analysis considering a production model to meet a volume of 4.78 million liters of biodiesel in a period of five years. This volume represents a fraction of the potential demand detected in TCS estimated at 169 million liters of diesel. The production target is achieved with an average annual growth of 9%. The production scheduling is done on a monthly basis with the intention of observing the flow behavior in more detail and determines the moment of payback as an indicator to consider in evaluating the financial feasibility of the project. As a result of the production model were obtained the following results:

a) The production costs of biodiesel were located for the period referred to in the range of 0.55 to 0.49 USD per liter, with an average cost of 0.51 USD which remains within the range of costs reported by SENER (Mexican Secretary of Energy) in 2006, ranging from 0.42 to 0.98 USD per liter.

Tab. 2: Cash flow of investment and cost per liter estimation (in USD)

ANNUAL PERIOD	INCOME	EXPENDITURE	CASH FLOW	CASH FLOW TO NPV	CASHFLOW ACCUMULATED	PRODUCTION (LITER)	COSTPER LITER
0	0	1,729,273	-1,729,273	-1,729,273	-1,729,273	0	0
1	1,928,368	1,729,273	199,095	417,764	-1,311,509	0	0
2	2,325,888	1,805,652	520,236	402,764	-909,245	0	0
3	2,614,149	2,107,826	506,324	524,652	-384,593	0	0
4	15,819,199	13,068,229	2,750,970	808,340	423,747	0	0
5	0	0	0	0	423,747	0	0
TOTAL	22,687,604.09	20,440,252.42	2,247,351.67	423,747.01		0	0.51

b) Net Present Value. The result of the NPV is important for the valuation of fixed assets investment by showing a flow of 423,747 USD, as seen in the Tab. 2. The NPV greater than zero means that the project is deemed profitable. The best approach is to test the acceptance of cash flow under the analysis of other potential scenarios, which would be the largest NPV which defines the acceptance or rejection of the project.

Fig. 2 displays the behavior of monthly cash flow and time-adjusted return on investment.

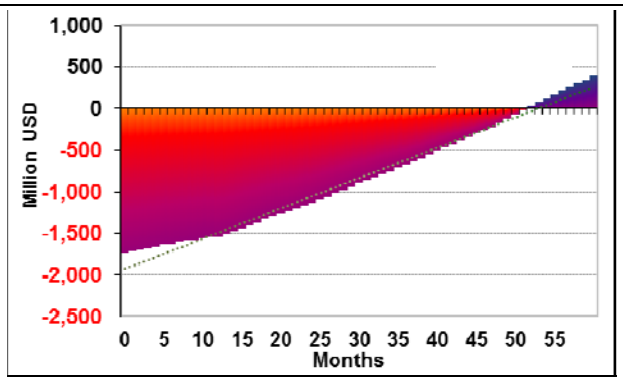

Fig. 2: Behavior of monthly adjusted cash flow

c) Internal Rate of Return. The IRR indicates that for every unit of investment is recovered the unit and 23.5% extra. Considering that the discount rate was set at 17% per year and the risk of such a project of technological innovation, represent favorable characteristics to support financially, with a margin of 7% above the discount rate. This coupled with the estimated time of return on investment of 52 months of a 60, generates an unfavorable scenario for the project. Although the IRR is a reliable indicator for assessing a project, must be used in conjunction with the VAN to make a good decision and not reject a project that can deliver higher profits in other circumstances.

d) Benefit / Cost Ratio. This financial ratio is regularly used by public projects; however, in order to take into account is to complement the analysis of NPV and IRR. The criterion of acceptance of the B/C is greater than or equal to unity. In this case, the result is 1.05, therefore, is slightly positive for the project.

e) Profitability Index. The PI value reflects the ratio of investment performance. The estimate for this project indicated a lower rate to unity; this means that real income is less than the investment to be made. Taking into account the flow set and the amount of investment at present value, profitability index is 0.227, an amount that provides reliability to the project.

3. DISCUSSION

The current state of fiscal supports given to diesel leaves the commercialization of biodiesel in disadvantage. The economic analysis proved that the WVO process for biodiesel production has a moderate competitive cost, however, considering the price of diesel is the reference to enter the market and its trend continues to rise, generate a vision for biodiesel which promises to be favorable in the medium term, as long as they take advantage of tax breaks intended for the production and use of biofuels that plan to provide the Mexican federal government, thereby increasing the competitive conditions of the biodiesel.

Currently there is no biodiesel production in Mexicali on commercial scale, however, under certain terms is possible to establish a successful biodiesel plant in Mexicali, being key to this, taking the main sources of WVO, such as food industry process and restaurant industry, which on one hand, would provide a low cost feedstock and on the other, would give the opportunity to work on new methods to reduce the processing cost of WVO, therefore, the conditions of scale and quality will improve in function of lowering production cost and by the increasing of biodiesel demand in the local market.

On the environmental side, the production and use of biodiesel offers significant benefits, by replacing diesel with biodiesel can reduce CO_2 emissions into the atmosphere, greatly improving the ecological balance necessary for the sustainability of economic development in the city.

It is essential that the biodiesel production be made with local technology. The selection of technology will depend on the security of getting the volume and quality needed to maintain a production level that achieves the goals set in the annual production program.

The economic support of Mexican government is key to structuring a technological upgrading program for TCS, which necessarily require financial resources for infrastructure development in the production and distribution of biodiesel, because the market for biofuels in the town is immature, therefore, the project's viability will depend on the implementation of a local policy to support such investments.

4. CONCLUSIONS

The profitability indicators are set at the discretion of the financial analysis methodology, the final report of economical evaluation of this project is supported with the following results:

a. The net present value (NPV) with a bank interest rate of 17%, meets the acceptance criteria to generate 423,747 USD, however, the magnitude of the indicator does not provide the certainty to accept conditions of project implementation.

b. The internal rate of return (IRR) is calculated based on cash flow net present value, resulting in the profitability of 23.5%, therefore the project is considered financially viable, however, an acceptance criterion is to get 10 points above the discount rate.

c. The Benefit/Cost Ratio result is 1.05, therefore, is slightly positive, meets the criteria of acceptance, but does not provide the necessary clearance to run the project within the evaluation period.

d. The Profitability Index (PI) of the project is 0.227, which does not meet the acceptance criteria for the project.

Based on the evidence derived from cost-benefit analysis may conclude that carrying out the project to produce biodiesel from WVO in Mexicali is profitable. However, the return time of investment and the uncertainty presented by the biofuels market, make necessary a policy that implements local tax resources to support the promotion, production and use of biodiesel for the transport sector. Therefore, under the circumstances considered in the analysis, we recommend running the project as long as it will be achieve the synergy among the productive, education and government sectors.

REFERENCES

[1] Canacki, M. (2006). The potential of restaurant waste lipids as biodiesel feedstocks. *Bioresource Technology*, *98*, 183-190.

[2] Canacki ,M., Van, Gerpen J. (2003). A pilot plant to produce biodiesel from high fatty acid feedstocks. *Transactions of the ASAE, 46*, 945-954.

[3] CONAPO (2009). *Population projections for the municipality of Mexicali.* Mexico.

[4] Coronado, M. (2010). Feasibility study of energy production from waste vegetable oil in restaurant industry. Master's Thesis. Autonomous University of Baja California.

[5] Felizardo, P., Neiva, C. J., Raposo, I., Mendes, J., Bermeier, R., Bordado, J. (2005). Production of biodiesel from waste frying oils. *Waste Management*, *26*, 487-494.

[6] Meher, L.C., Sagar, Vidya, Naik, S.N. (2006). Technical aspects of biodiesel production by transesterification a review. *Renewable & sustainable energy reviews, 10*, 248-268.

[7] Zhang, Y,, Dubé, M.A., McLean, D.D., Kates, M. (2003). Biodiesel production from waste cooking oil: 1. process design and technological assessment. *Bioresource Technology*, *89*, 1-16.