Article

Analysis of competitiveness and profitability of biodiesel production from moringa grains in Chiapas and Yucatán, Mexico

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Abstract

The production of biofuels worldwide has grown exponentially in recent years, its development has been linked to the increase in the price of oil and the growing social awareness developed around the care of the environment. The world is currently betting on biodiesel as a partial alternative to fossil fuels given that it comes from renewable sources and significantly reduces carbon dioxide emissions into the atmosphere. Technological advances broaden the range of raw materials for biofuels, some of which; how fast-growing grasses and trees can grow in less fertile and drought-prone regions and compete less with crops for the production of human and animal food such as corn, sugar cane, soybeans and rapeseed, such this is the case of *Moringa oleifera*, which is currently cultivated in practically all the tropical, subtropical and semi-arid regions of the world, since it can grow under conditions of water scarcity. The objective of this research was to economically evaluate the integral production of biodiesel with moringa grains considering two agroecological zones of raw material production, the Soconusco, Chiapas and Uxmal, Yucatan and their transformation to biodiesel through the process of industrial transesterification in a pilot plant. For the agricultural and industrial phases, profitability indicators were generated such as the internal rate of return (TIR), net present value (VAN) and equilibrium point (PE). The results indicated that the agricultural production is highly profitable due to the additional use of the leaves as co-product with TIR of 109 and 130% for the Soconusco, Chiapas and Uxmal, Yucatán, respectively, while the industrial phase, considering zero subsidies to the production of biodiesel was profitable with TIR of 53% in Uxmal, Yucatan and 37% in Soconusco, Chiapas.

Keywords: *Moringa oleifera*, biodiesel, competitiveness, profitability of biofuels.

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Introduction

Climate change whose main characteristic is the increase in the temperature of the earth, is one of the current problems facing humanity, because its effects affect the economic, social and environmental, putting at risk the very survival of the humanity; this change in temperature patterns is mainly caused by the excessive emission of carbon dioxide and its accumulation in the atmosphere (Pardo, 2007; Gómez, 2007), which causes other meteorological phenomena such as droughts, melting of the poles and flooding between others; these phenomena affect the daily lives of people, family and national economies as well as agricultural and forestry production and productivity. It was estimated that in 2005 the economic losses from global warming exceeded 200 billion dollars (Zamarripa *et al.*, 2009).

Faced with this problem, several countries are promoting the use of more efficient and cleaner renewable energies such as biofuels to reduce the effects of global warming and contribute to the conservation of the environment. In addition, in the particular case of Mexico, the depletion of proven oil reserves, estimated to last for 8 years, highly justify the exploration of new renewable energy sources such as bioethanol and biodiesel from agricultural species (Rico *et al*., 2011).

At present, there are advances in several countries where the production of biofuels translates into benefits for farmers, since on the one hand it becomes a sustainable source of energy and on the other it is seen as a new source of income and work for farmers and rural communities around the world (Muñoz, 2013). Contrary to oil and coal, which are unevenly distributed across countries, all nations could generate a certain amount of bioenergy from some type of internally produced biomass and, thereby, help reduce their dependence on fossil fuels imported (Hazell and Pachauri, 2006).

In Mexico from the legal point of view, bioenergy was not a matter of regulation until the beginning of 2008 when the Law of Promotion and Development of Bioenergetics was published in the Official Gazette of the Federation, issuing the guidelines for the granting of permits for the production, storage, transportation and commercialization of bioenergetics of the anhydrous ethanol and biodiesel type (Sepúlveda, 2012), taking an essential step to promote its introduction as a complement to the supply of vehicular fuels, where it is perceived that they offer environmental benefits the lower emission of pollutants and at the same time it is expected that the ejidatarios, comuneros and the workers of the field in general, improve their economy by being able to participate with private investors for the cultivation of species that provide raw material for the production of biodiesel and bioethanol (Gamboa, 2009).

Despite the obvious possibilities that bioenergy presents for economic and social development, there are still important questions about what this implies for rural communities, the environment and international trade, indeed, because most of the benefits and environmental and social costs of bioenergy are not subject to a sufficiently developed market, it is necessary to define public policies in order to maximize these potentialities (Islas and Martínez, 2009). The public sector has an important role to play in ensuring positive outcomes, such as the development and implementation of appropriate policies, the development of appropriate technologies and the creation of favorable investment environments that are needed to ensure that bioenergy is developed efficiently, whose results are compatible with the reduction of poverty and global warming (Hazell and Pachauri, 2006).

Various raw materials such as sugar cane, soybeans and corn have been used for the production of biofuels, however, there is disagreement in their cultivation for that purpose, since they compete for their use in the production of human and animal food and this has caused that the sowing surface destined to the production of oleaginous and grain is insufficient (Collymore *et al*., 2008; Huerta, 2010; Ramos, 2010). For this reason, technologies have been developed that not only help bioenergy compete better with fossil fuels in terms of price, but also the range of raw material options, such as fast-growing grasses and trees, has been expanded. they can thrive in regions that are not very fertile and prone to drought (Hazell and Pachauri, 2006). Such is the case of *Moringa oleifera*, which represents a technical, socioeconomic and environmentally favorable opportunity for its use in the production of biodiesel and other beneficial coproducts for society.

Moringa is a tree native to India, where its fruits, seeds and roots are mainly used for human consumption, while its stems are used for animal feed; in addition, the oil extracted from its seeds is used as a lubricant and in the cosmetic industry for the manufacture of creams and soaps (Martín *et al*., 2013). It is a perennial species tolerant to high temperatures and drought, its optimal temperature range is between 15 to 35 degrees Celcius (Pérez, 2010). In general, it thrives best with annual rainfall of 500 to 1 500 mm (Pérez, 2010), it grows very little when it is cultivated at altitudes higher than 1 500 meters above sea level, so its cultivation is recommended below 500 meters above sea level (Olson and Fahey, 2011). Its intense cultivation, with irrigation and fertilization, increases the biomass yields up to 100 tons per hectare (Martín *et al*., 2013).

For the foregoing and in order to generate knowledge and production technologies in a cost-effective and competitive way both raw material for biodiesel and co-products such as leaves used for human consumption and moringa cake, which can be used for animal feed since it contains 60% protein (García, 2013), INIFAP, in coordination with other research institutions, carried out the project: “Research and development of moringa production to obtain biodiesel in Mexico”. Within the framework of this project, the objective of this work was to evaluate the profitability and competitiveness of the production of biodiesel with moringa grains from the integral perspective of the value chain in Chiapas and Oaxaca, Mexico, considering and evaluating the co-products that can derive as much from the agricultural phase as the industrial one, quantifying the levels of costs and profits of the agricultural and industrial sectors and contributing with elements for the formulation of policies aimed at their use.

Material and methods

The present investigation was developed during the period from 2014 to 2016, in two agroecological zones with potential for moringa plantations, in which there is a background of experimentation on agronomic aspects of the species such as evaluation of collections, planting arrangements, fertilization, pruning systems, among others, that is, have the technical support necessary to make inferences about production and marketing. The study sites were: Uxmal located in the municipality of Muna, Yucatan and the Soconusco Region, located in the state of Chiapas (Figure 1).

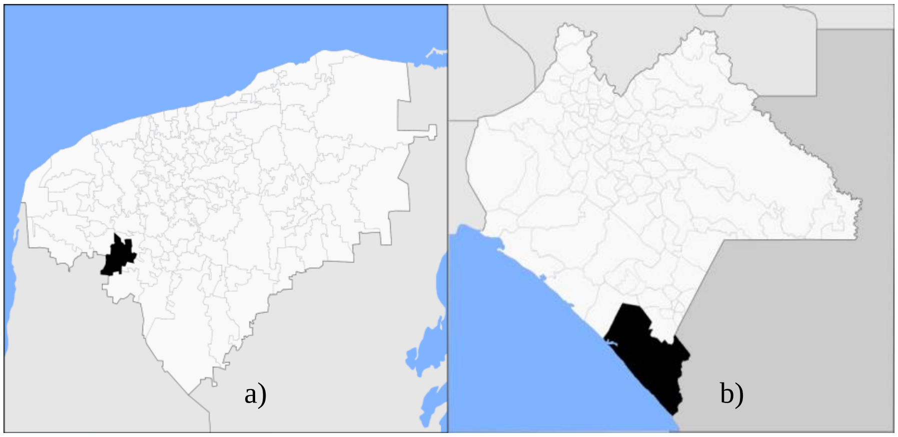

Figure 1. Location of the municipality of Muna in the state of Yucatán (a) and the region of Soconusco in the state of Chiapas (b).

The municipality of Muna is located in the south west region of the state of Yucatán (Figure 1a), it borders on the south with the Sierrita and borders the following municipalities: on the north with Abala, on the south with Santa Elena, on the east with Ticul and Sacalum, to the east with Halacho, Opichen and Kopoma and to the west with the state of Campeche. Its geographical coordinates are: 20° 29' 05" latitude north and 89° 42' 47" west longitude and it has an area of 270.81 km^2. Its population to the year 2010 was of 12 366 inhabitants.

The Soconusco is located in the extreme southeast region of the state of Chiapas, between the Sierra Madre of Chiapas to the north and the Mexican Sea to the south, bounded on the east by Guatemala (Figure 1b), it is located at coordinates 15° 18' 56'' of latitude north and 92° 43' 55'' of west longitude, covering 5 475 km^2 (7.2% of the territory of the state of Chiapas). Its population to the year 2010 was of 710 716 inhabitants.

Technical and economic information was collected directly in plots established for experimental purposes for four years on average, where data on plantation development, yields and production costs were recorded. For the evaluation of agricultural competitiveness, the methodology called the policy analysis matrix (MAP) originally proposed by Monke and Pearson (1989) was used; Bridge (1995); Salcedo (2007); Rodríguez *et al*. (2013). With the information taken in the field, the matrix of technical coefficients was structured, consisting of a table in Excel where the quantities of inputs and labor used to grow a moringa ha are specified, with respect to yields, two components were included, the grain and the production of leaves as sources of income, this was considered because there is a market for ground moringa leaves for food purposes.

The private price matrix refers to the same coefficients, but indicating their purchase price in the local market, whose information was obtained with the technicians in charge of the plots. The private budget matrix was obtained by multiplying the two previous matrices, resulting in production costs and financial indicators such as total income, total cost, net added value and competitiveness. In Figure 2, the structuring process of the calculation matrices is shown.

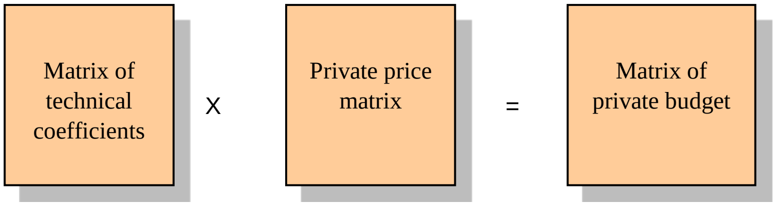

Figure 2. Process of structuring the data matrices for the agricultural phase.

The preliminary financial indicators obtained by the private budget matrix were:

Total income (IT), or value of production, was the result of multiplying the yield obtained at the parcel level (Xi) by the producer's sale price (Pi).

$$IT = PiXi$$

The total cost (CT), which was the result of the sum of the costs of inputs and internal factors, given by the price of the input (Pj) multiplied by the amount of input (Yj).

$$CT = \sum_{k=1}^{n} PjYj$$

Net profit (GN), which was the result of the arithmetic difference between total income and total cost.

$$GN = IT - CT$$

Cost benefit ratio (RBC), which was the result of the division total revenue between total cost, its interpretation is that for each peso invested in the activity how many weights are obtained, the mathematical expression is as follows:

$$RBC = IT/CT$$

The income analysis allowed to visualize the financial situation of the productive systems, and two indicators were generated: the added value (VA) as an efficiency indicator and the private cost relation (RCP) as an indicator of competitiveness. According to Morris (1990) and Padilla (1992), the VA is the difference between the price of a unit of product less the value of the marketable inputs that are required to produce said unit of product or put another way, it is the difference between the value of production and the costs of marketable inputs and is given by the following expression:

$$VA = pixi - \sum_{k=1}^{n} pkyk$$

Where: VA= added value; Xi= quantity produced in tons per hectare; Yk= quantity of marketable inputs applied per hectare; Pi= sale price of the product by the producer; Pk= price of marketable inputs purchased by the producer.

To define the RCP, it was first necessary to define the cost of internal factors (CFI), this indicator expresses the part of the costs corresponding to the payment of factors that do not have a defined external market or that cannot be exported or imported so easily. such as labor and land, among others. The CFI is given by the following expression:

$$CFI=\sum_{r=1}^{n} przr$$

Where: CFI= cost of internal factors; Zr= number of internal factors applied per hectare; Pr= price of internal factors used by the producer.

The RCP was used to measure the competitiveness of the productive system in relation to the efficient use of the resources available to the producer, whose interpretation is based on the fact that producers prefer to obtain excess profits, which can be obtained if the CFI is lower than the VA at private prices, it indicates the proportional part of the VA that is destined to cover the CFI. Therefore, what is recommended for an agricultural system to remain competitive is to try to minimize RCP, keeping down the costs of tradable inputs and internal factors and obtain the highest possible VA (Puente, 1995). The RCP is given by the following expression:

$$RCP = \frac{\sum_{r=1}^{n} przr}{pixi - \sum_{k=1}^{n} pkyk} = \frac{CFI}{VA}$$

Where: RCP= private cost ratio; CFI= cost of internal factors; VA= added value.

In order to have a comprehensive overview, the biodiesel production was economically analyzed from the perspective of the value chain (primary phase and industrial phase) by adapting the computational package called biodiesel/FAO (Da Silva *et al*., 2009), this system through mathematical calculations for a period of 20 years, it was possible to obtain a series of social and financial indicators of both agricultural and industrial production in an integrated manner, thereby determining economic and financial viability at the production chain level (Figure 3). The system also allowed for the preparation of sensitivity analyzes and the creation of scenarios for the comparison of different projects and the visualization of the impact of some variables with respect to these indicators.

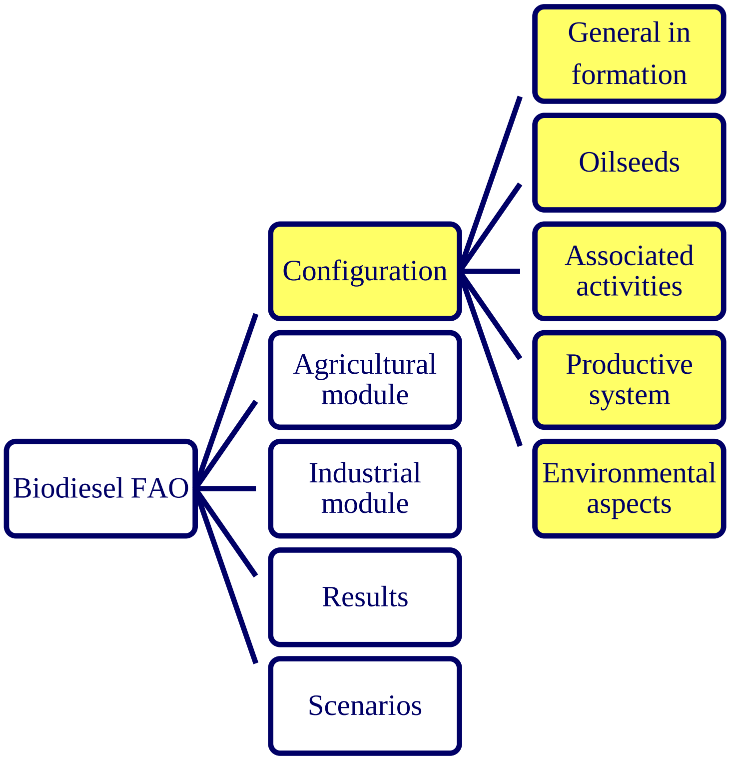

Figure 3. Structuring of the modules and submodules of the FAO biodiesel system.

The information of the technical coefficients of the industrial phase that fed the evaluation system was obtained by recording data from various production runs in a pilot plant owned by INIFAP, whose process is described below:

Before the extraction of the oil, the beneficiation of the grains was carried out in order to eliminate the impurities and make the extraction process more efficient, after this phase and to start the extraction process of the oil, it was necessary to prepare the raw material by means of the following procedures outlined in Figure 4.

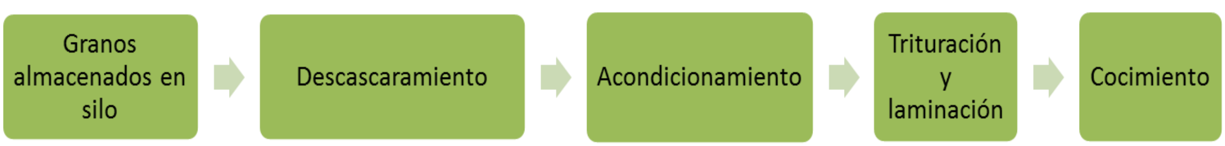

Figure 4. Preparation of the raw material for the extraction of moringa oil.

To obtain the biodiesel, the removal of the oil was carried out by means of mechanical extraction by pressing and because the crude oil contains undesirable compounds such as phosphatides or gums, sterols, waxes, carotenoid pigments and antioxidants, a process of refinement through filtration, degumming and neutralization as shown in Figure 5.

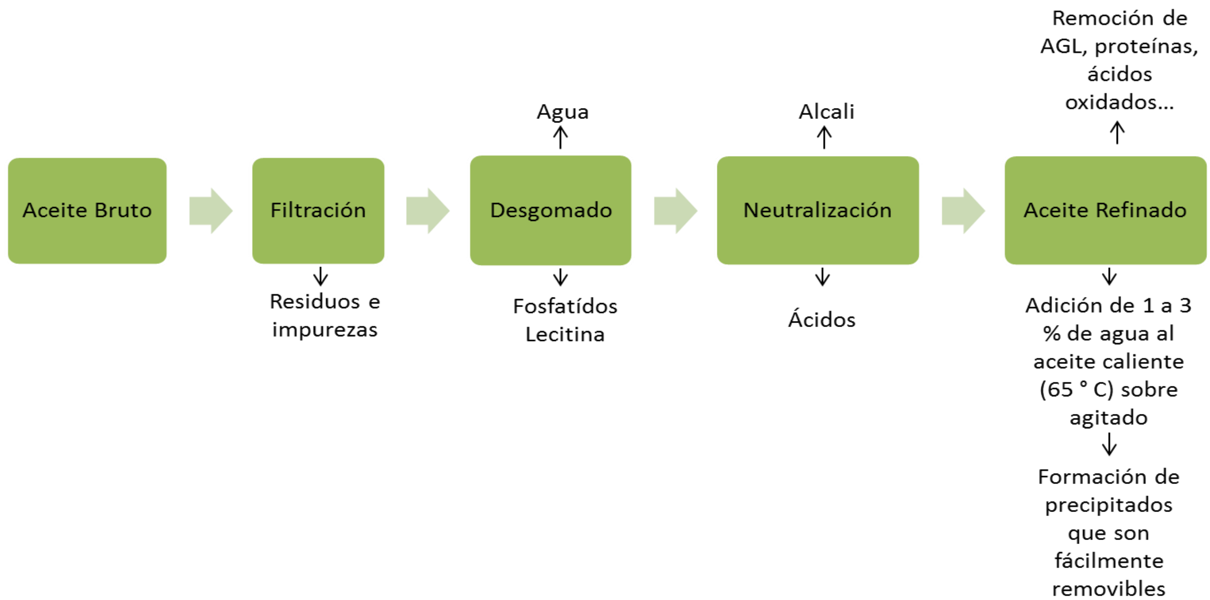

Figure 5. Moringa oil refining process.

The refined oil was converted to biodiesel, which was obtained by transesterification, which consisted in the transformation of triglycerides (vegetable oil) by the addition of alcohol (methanol or ethanol) through a catalyst to obtain esters or biodiesel plus glycerin (Posada, 2010).

Derived from this process, the coefficients of the inputs required for a liter of biodiesel were obtained, which are shown in Table 1.

Table 1. Matrix of technical coefficients for the production of biodiesel from moringa grains.

Inputs	Unit per liter of biodiesel	Value of the coefficient	Price ($)
Raw material	kg	2.61	5
Electricity (extraction)	kWh	0.0917	3.65
Methanol	kg	0.1198	13.5
Sodium hydroxide	kg	0.019	8.6
Sulfuric acid	kg	0.0057	9
Resin	kg	0.0013	375
Antioxidant	kg	0.00214	350
Electricity (transesterification)	kWh	0.032	3.65

The processing coefficient; that is, the amount of raw material that was required to obtain a liter of biodiesel according to the experimental tests was determined at a level of 2.61 kilos of moringa grains to obtain a liter of biodiesel. Additionally, the minimum sale price of the raw material for the industry was determined, which was $5.00 per kilo. An average grain yield per hectare of 2 000 kg for Yucatan and 1 160 kg for Chiapas was also considered and finally, according to Madrigal (2015), annual production cycles were considered for a period of 20 years.

The biodiesel/FAO system generated the following indicators:

Internal rate of return (TIR): mathematically it is defined as the interest rate that causes in the flow of funds of a project, that the income in equivalent values in time are equal to the expenses also in equivalent terms in time. It is defined as the discount rate that reduces to zero the net present value of the sum of a series of income and expenses (FIRA, 1993). Therefore, for an investment proposal, the TIR is the interest rate i^* that satisfies the following equation:

$$0= VPN (i^*) = \sum \frac{(Bt - Ct)}{(1+i)t} = \sum (B_t-C_t) \frac{1}{(1+i^*)t}$$

Where: VPN (i)= net present value at an interest rate i; Bt= total benefits in year t; Ct= total costs in year t; t= time in years, it takes values that go from t= 0 to t= n (number of periods of economic life of the project).

Net present value (VAN): the current or present value of the net cash flows of an investment project, understood as net cash flows, the difference between the current value of the cash inflows of a project and the current value of the exits (FIRA, 1993). Through, the VAN it was possible to determine if the project is acceptable or not. The net present value was calculated through the following equation:

$$VAN (i) = \sum (B_t-C_t) \frac{1}{(1+i)t}$$

Where: Bt= total benefits in year t; Ct= total costs in year t; t= time in years, it takes values that go from t= 0 to t= n (number of periods of economic life of the project); i= discount rate that represents the minimum required rate of return.

$\frac{1}{(1+i)}^{t}$ = Value factor present single payment.

Balance point (PE): is the level of production in percentage or units of production that exists when costs and income are equal; at this point, the company does not experience losses or profits (Martínez *et al*., 2015). The following formula was used:

$$PE= \frac{CF}{P - CV}$$

Where: PE= equilibrium point; CF= fixed costs; P= unit price; CV= unit variable costs.

Results

Economic indicators of the policy analysis matrix

In the Table 2 shows the economic indicators per hectare of the agricultural phase in the two study regions, according to this information, the productivity of moringa grains was higher in Yucatán due to better soil and temperature conditions for this species, while in Chiapas productivity was lower because the type of soil and high rainfall allowed lower yields compared to Yucatan. The monetary income from the sale of grain and dry foliage in the two study sites was favorable since the production costs were recovered and a considerable and attractive net gain was generated in both cases: the goodness of the crop was demonstrated with the results of the indicator benefit ratio cost higher than six. The competitiveness of the moringa production system was high.

Table 2. Economic indicators of the cultivation of moringa in the states of Yucatán and Chiapas.

Indicator	Soconusco, Chiapas	Uxmal, Yucatán
Grain yield (kg ha^{-1} $year^{-1}$)	1 160	2 000
Leaf yield (kg ha^{-1} $year^{-1}$)	456	456
Total income ($ ha^{-1} $year^{-1}$)	91 097	105 725
Total costs ($ ha^{-1} $year^{-1}$)	14 154	16 901
Net profit ($ ha^{-1} $year^{-1}$)	76 943	88 824
Benefit/cost ratio	6.44	6.26
Private cost ratio	0.09	0.11

Regarding the private cost ratio indicator, in Chiapas a competitiveness (RCP) of 0.09 was obtained, which indicates that the added value reached to cover the factors of production and the producer had a net gain, in Yucatán this indicator was of 0.11 due to higher production costs, in general terms, these RCP levels showed the high competitiveness of the production of moringa in both sites, which means economic spillover and significant contribution to the regional gross domestic product (PIB).

Comprehensive analysis of profitability

From the integral perspective of evaluation, both of the production of raw material and its transformation into biodiesel, the results obtained for the agricultural sector were satisfactory. In Table 3 it is observed that the unit cost of moringa grain production was influenced by productivity, so that for Chiapas a production cost of $8.92 per kg of dry grain was obtained and in Yucatán the cost was $4.48, the difference is due to the higher yield obtained in Yucatan, the dry leaf of Moringa in the state of Chiapas cost $28.93 per kg, while in Yucatán $26.90. The equilibrium point was low due to the high profitability of the production system, which confirms the goodness of the project for agricultural producers.

Table 3. Financial indicators of the agricultural phase of the biodiesel production project with Moringa grain in Chiapas and Yucatán.

Indicator	Soconusco, Chiapas	Uxmal, Yucatán
Cost of moringa production ($ kg^{-1})	8.92	4.48
Production cost sheet ($ kg^{-1})	28.93	26.90
Breakeven (%)	6.85	4.28
TIR (%)	109.03	130.37
TRC (Years)	2.28	2.12
Net present value (thousands $)	2 435 165.72	1 508 724.88

The project proved highly profitable for the agricultural producers of both sites studied, which is consistent with the results of the policy analysis matrix. In the case of the TIR, this was 109.03% and 130.37% for Chiapas and Yucatán respectively, whose level was much higher than the opportunity cost of the capital; this situation is confirmed with the equilibrium point that was of 6.85% and 4.28% for Chiapas and Yucatan respectively and the time of recovery of capital (TRC) was a little over two years. The net present value was greater than zero.

Table 4 shows that financial indicators for the industrial phase were generally favorable, although at a level not as high as for the agricultural phase. The production cost of a liter of biodiesel with moringa grains was $8.25 for the case of Chiapas and practically the same in the case of Yucatán, while the break-even point was practically 5% for both sites. The internal rate of return was better in Yucatán with 53.33%, while in Chiapas it was 37.94% with an average capital recovery time (TRC) of 3 years. The net present value was greater than zero.

Table 4. Financial indicators of the industrial phase of biodiesel production with moringa grains in Chiapas and Yucatán, Mexico.

Indicator	Soconusco, Chiapas	Uxmal, Yucatán
Cost of biodiesel production ($ L^{-1})	8.25	8.29
Breakeven (%)	4.97	5
TIR (%)	37.94	53.33
TRC (years)	3.44	2.58
Net present value (thousands $)	92 322.95	128 684.78

Sensitivity analysis of the TIR

In relation to the behavior of the TIR for both agriculture and industry in the face of possible changes in the prices of moringa as a raw material for the production of biodiesel, it was observed that there is a direct relationship between the TIR of the agricultural sector and the sale price of the grain; that is to say, if the sales prices of the moringa grain increase, the agricultural TIR also increases and viceversa, therefore it is convenient for the agricultural producers that the sale price of the grain be increased since their profits would increase and for so its profitability. In contrast, the TIR of the industrial sector presented an inverse relationship with the price of moringa; that is, in the face of increases in the prices of moringa, the TIR in industry decreases and vice versa, this means that the industrialists who transform the raw material from moringa into biodiesel should benefit from the low prices of moringa, because It contributes to your profits and profitability.

In the case of the study area of Soconusco, Chiapas, it was observed that the profitability of the agricultural phase supported possible price reductions, obtaining rates of return above 100%, while in the industrial phase it is highly favored when the price of the raw material decreases, but the increase of it from 15% affects the profitability of this sector, which places this phase in a vulnerable condition. Figure 6 refers to this behavior.

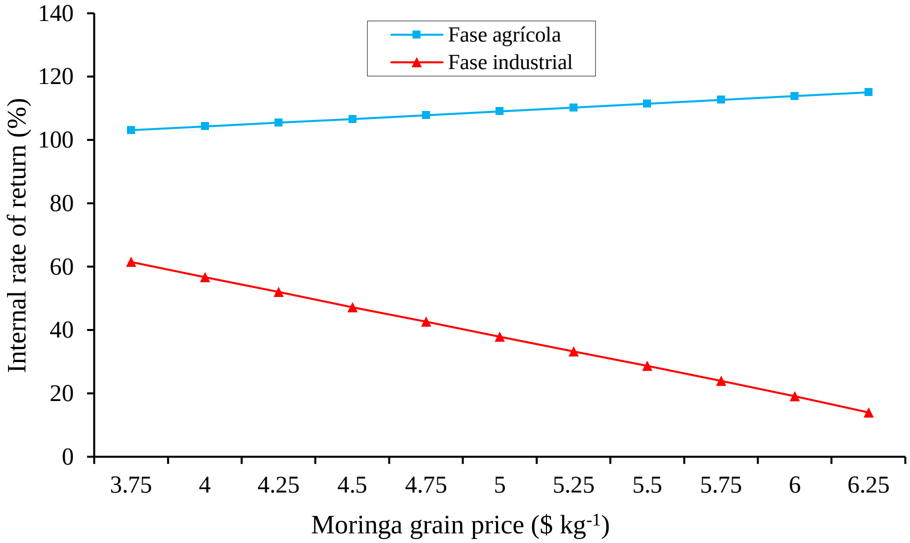

Figure 6. Behavior of the internal rate of agricultural and industrial return before changes in the price of the raw material for biodiesel. Chiapas case.

In the case of the Uxmal, Yucatán study area, it was observed that, due to the good agro-ecological conditions for the production of moringa grains, the project can withstand considerable decreases in the sale price of the raw material, which places agricultural producers in a favorable situation to be able to negotiate with the industrial sector the sale price. Even if the sale price decreases 25%, the TIR continues to be favorable. The opposite situation was observed in the industrial sector, since the TIR is very sensitive to the change of prices of the moringa grain. If the price increases 25% the TIR decreases to levels below 20%, so it can be said that the profitability of the industrial phase is more vulnerable to possible increases in the price of the raw material and the industrialists would have to negotiate with the farmer's chord prices so that both sectors earn profits. Figure 7 shows the behavior of these indicators.

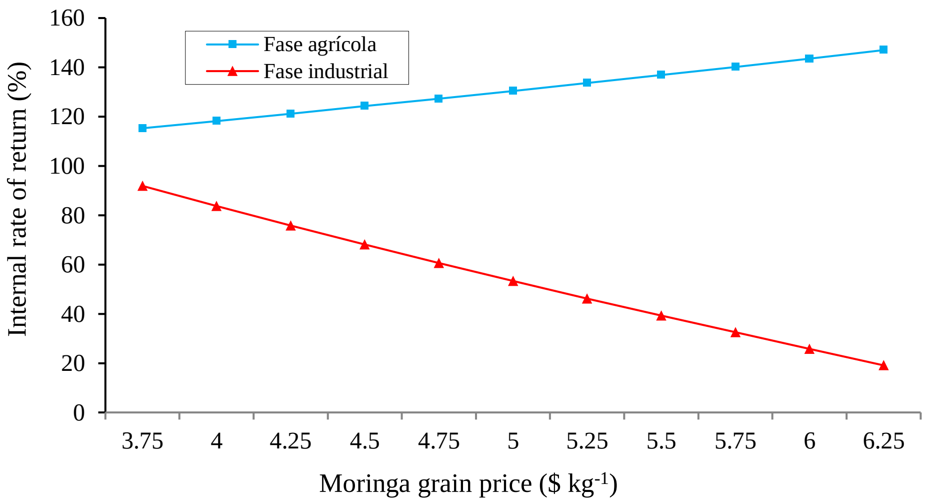

Figure 7. Behavior of the internal rate of agricultural and industrial return before changes in the price of the raw material for biodiesel. Yucatán case.

Conclusions

According to this study, the cultivation of moringa in the states of Chiapas and Yucatán was a profitable and competitive activity for the primary producer, this is because it is potentially generating added value, which implies that it could trigger economic spillover in the sector rural and consequently with a significant contribution to the agricultural gross domestic product, in addition to implying net gains for the producer. In Yucatán, the agroecological conditions allowed to obtain better results of production and therefore economic, what implied greater benefit for the producer through his income in relation to Chiapas. The greater proportion of the monetary income for the cultivation of moringa comes from the use of the foliage due to the high price for its nutritional properties, it foresees a potential of important market of this coproduct.

The industrial phase that consists in transforming the moringa grains into biodiesel turned out to be profitable, but it was placed in a condition of vulnerability to possible increases in the price of the raw material; that is, industrialists would not be able to withstand increases in the price of grain. A negotiation process of the sale price of the raw material is required for both sectors to obtain profits. The cost of biodiesel production was 41% lower than the current consumer price of conventional diesel. Under the technical and economic parameters considered in this study, to supply a plant with a capacity of 20 000 liters of biodiesel per day, an area of 7 830 hectares planted with moringa in Yucatan and 13 500 hectares in Chiapas is required.

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