THE ENERGY BALANCE IN THE PRODUCTION OF PALM OIL BIODIESEL - TWO CASE STUDIES: BRAZIL AND COLOMBIA.

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ABSTRACT: The use of the biodiesel produced through the transesterification of vegetable oils with methanol and ethanol is seen as an interesting alternative. The energy output/input relation in biodiesel production life cycle can be an important index for the techno-economical and environmental feasibility evaluation of biodiesel production out of different oleaginous plants. Due to the increasing environmental concerns related to the emissions of fuel derived atmospheric pollutants alternative sources of energy have been receiving greater attention. This work intends to carry out the energy analysis in the production of the Oil Palm Biodiesel for the conditions of Brazil and Colombia and show the differences between the results attained for the two cases. The objective of this work is also to carry out the energy analysis of Palm Oil biodiesel production, considering the methyl route, for Brazilian and Colombian conditions. This paper presents the results of this analysis and discusses the differences between the results of the two case studies. The output/input energy relation for evaluated case studies is in the range 6-8.

Keywords: Palm Oil Biodiesel, Energy Balance, Biodiesel Production.

1 - INTRODUCTION

The use of the biofuels produced through the transesterification of vegetable oils with methanol and ethanol, is currently considered to be a feasible alternative, presenting advantages such as its potential contribution to the reduction in the emissions of carbon dioxide, carbon monoxide, hydrocarbons and sulfur oxides. From an economic point of view the continuing increase in the oil market prices and the possibility of receiving financial resources through the commercialization of carbon credits as it was established by the Clean Development Mechanism - CDM should be considered. Moreover, strategic questions as job and income generation and energy self-sufficiency in rural areas come to reinforce the need for biofuels programs.

The energy input/output relation in biodiesel production can be used as an index of techno-economic and environmental feasibility analysis during the comparison between the different oleaginous plants as a way to determine the best type of culture for biodiesel production in a determined geographical and economical scenario.

The energy balance for a biofuel production system can be defined as the relation between the energy produced (output/kg biodiesel) and the energy consumed (input/kg biodiesel) for each unit of product and that is an important index for the economic and environmental feasibility of a biofuel project.

LCA studies for biodiesel production were carried out in Europe by (ITC) Italian Thermo-Technical Committee - (2000), for rapeseed and sunflower oleaginous plants, and in the EUA by SHEEHAN (1998) for soybean. The energy consumption for each kg of produced biodiesel ranges from 12.17 to 16.7 for Europe and output/input relations in energy balance ranges from 3.2 to 3.4 for the EUA. Rapeseed oil methyl ester life cycle energy ratios in Lithuanian [11] conditions have been calculated as a function of rapeseed productivity, oil extraction and transesterification technologies used. Average values for output/input relations in energy balance range between 2.41 and 5.23, when rapeseed productivity is 3 t/ha.

In Germany studies considering the ethyl route for maize and beetroot [17], attaining an input/output relation ranging between 1.7 and 3.

In Brazil studies considering the methyl and ethyl route related to the castor culture were carried out by NETO (2004), attaining an input/output relation ranging between 2 and 2.9. A productivity of 1800 kg/ha was taken into account.

This work intends to carry out the energy analysis of Palm Oil biodiesel production considering the methyl route for Brazilian and Colombian conditions. This paper presents the results of this analysis and discusses the differences between the two case studies results.

2 - METHODOLOGY

In this work, the energy consumption along the life cycle of palm oil biodiesel was studied by considering the methyl route. This way, the energy and materials input/output data during the stages of agricultural production and transport for processing (agricultural stage); the stage of oil extraction and its transport (oil extraction stage) and of the biodiesel production were used. These data used were collected at two crop areas and at three palm oil mills, in the South of the state of Bahia, in Northeast of Brazil and at three mills and crop areas from different regions in Colombia

The energy consumption calculation for the biodiesel production system will be the sum of the energy consumed for each kilogram of produced biodiesel in the different stages of its production chain. The studied system starts at the agricultural production and goes on until the biodiesel production, considering the stages of transport of the agricultural production and vegetable oil extraction. In this study, the stages of biodiesel supply to distribution companies, fuel stations and final consumers were not considered.

The energy flows during biodiesel LCA are divided in direct and indirect ones. A direct energy flow corresponds to the energy consumed in the form of fossil fuel, methanol, electricity and steam in all the stages of biofuel production. As far as electricity and methanol are concerned, they are calculated as the consumed primary energy in its production. For diesel and other fossil fuels the low calorific value (LCV) is used. The indirect energy is the energy consumed in the form of agricultural inputs (such as fertilizers and pesticides), equipment, machines and transport. It is calculated through the consumption of energy in the production of each product, and regarding the transport, it is estimated based on the distance and specific fuel consumption.

The calculations were carried by using energy coefficients with the quantification of the energy flows by multiplying the physical product quantities by the respective conversion index. The results were obtained in MJ/kg Biodiesel. The energy flows considered by this work are presented in the tables below.

3 - DATA

The presented data correspond to the stages comprising the agricultural production, vegetable oil extraction and biodiesel production. Data related to cultivated area and productive capacity of each analyzed company are presented in Table 1.

Table 1: General data of the companies analyzed in the case studies

Company - Colombia	**Cultivated Area (ha)**		**FFB processing capacity (ton FFB*/year)**
	Nursery	**Palms**	
A	1100	1200	101,323. 77
B	64,1	3435,9	80,000.00
C	130	4765	154,352.00
Company - Brazil	**Cultivate Area (ha)**		**FFB processing capacity (ton FFB*/year)**
	Nursery	**Palms**	
A	111	1800	16,200.00
B	-	-	26,700.00
C	5.8	4000	22,068.28

* FFB: Fresh Fruit Bunches

The Index used for electricity considers this electricity as being generated in hydroelectric power plants of 3.6 MJ/kWh, (Walnut, 1987).

Tables 2, 3, 4, 5 and 6 present the energy coefficients used during data elaboration.

In the present study a 20-year useful life for the crops, a 25-year useful life for heavy equipment and a10-year useful life for the light equipment were considered. The useful life of the buildings was considered to be 25 years.

In the industrial stage the peculiarity of each company was considered, taking its electricity generating systems, the fraction of use of industrial biomass residues in the industrial process and in the agricultural stage into account.

Table 2: Energy coefficients used for energy balance in the stage of agricultural production

Energy coefficient	**Unit**	**Energy coefficient**	**Unit**
Fertilizers [9]	**MJ/kg**	**Fungicides [10]**	**MJ/kg**
Nitrogen (N)	48.9	Fungicide	97.13
Phosphorus (P_2O_5)	17.43	**Tractor [6]**	69.83
Potassium (K_2O)	10.38	**Truck [6]**	62.8
Calcium (CaO)	2.32	**Other Equipment [6]**	57.2
Herbicides[10	245.57	**Human labor [17]**	**MJ/day**
Insecticides [10]	184.71	Harvesting activity	15

Table 3: Percent Value of nutrients in EFB, considering their use as substitutes for inorganic fertilizers.

Fertilizer active element [17]	**(%) On EFB wt**
N	0.32
P_2O_5	0.09
K_2O	1.16
MgO	0.12

Table 4: Energy coefficients for the energy balance in the stage of vegetable oil extraction

Energy coefficient [11]	**Unit**
Constructions	**MJ/m^2**
Buildings	7117.56
Offices	18840.6
Workshop, laboratories	7117.56
Material	**MJ/kg**
Cast steel	117.23
Structural steel	69.50
Turbines	40.19
Tractors	59.87
Boilers	55.09
Stainless Steel	79.96

Table 5: Energy coefficients for the stage of biodiesel production

Energy coefficients	**MJ/kg**
Methanol [7]	19.7
Glycerin [7]	18.05
Steam [1]	**MJ/ton Biodiesel**
	1360

Table 6: Calorific value of products, fuels and lubricants used for this study

Item	MJ/l
Diesel [15]	38.45
Gasoline [12]	42.32
Lubricant [4]	35.94
Item	**MJ/kg**
Biodiesel [7]	39.6
Shell	18.42
Fiber	11.2
EFB [17]	19,3

Thus, for the conditions of Brazil, the following were considered:

Consumption of electricity: company B generates electricity for its own consumption; companies A and C purchase all the necessary electricity from power companies.

Use of residues in the process: all the companies use 100% of fiber for steam generation. EFB is/are 100% used by companies A and C as fertilizer and company B uses it as boiler fuel for electricity production.

Company A uses 100% of the fiber for burning in the boiler, whereas company B delivers 70% to activated coal manufacturing and the remaining is used as boiler fuel. In company C, 60% of the available husks are used as boiler fuel and the remaining is delivered to the manufacturing of activated coal as well.

For the conditions of Colombia, the following particularities were considered:

Consumption of electricity: companies A and the C generate 75% of the required electricity and company B do not have a generation system, purchasing all the necessary electricity from power companies.

Use of the process biomass residues: All the companies use 100 % of the available fiber as boiler fuel. Company A used 63% of the available husks and companies B and C 75% and 71%, respectively. The EFB is 100% used as fertilizer in the agricultural stage.

4 - RESULTS AND DISCUSSIONS

4.1 Total energy consumption in the agricultural stage.

In Figure 1 it is possible to observe that the greatest energy contribution in agricultural stage is related to fertilizers, followed by fuels.

In the energy analysis of the Brazilian cases the herbicides and the irrigation system have a negligible contribution, as adult palms are not irrigated and herbicides are used only sporadically in isolated crop areas, only a few times during the year.

In the Energy analysis of the agricultural stage in the Colombian cases, the fuel consumption and the irrigation systems have a significant contribution, for differently from the Brazilian cases, the adult palms are irrigated and the fertilization is carried out intensively along all the years of the crop useful life.

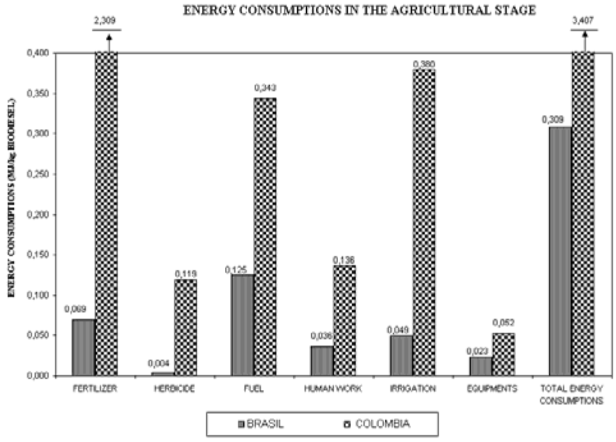

Figure 1: Average energy consumption related to fuels and agrochemicals for the Brazilian and Columbian case studies during the agricultural production stage.

4.2 - Total energy Consumption of the vegetable oil extraction stage

Figure 2 presents the comparative energy consumptions for the oil extraction stage.

In the analysis of the industrial phase, Figure 2, it is noticed that the greatest contributions correspond to the steam consumption in the process.

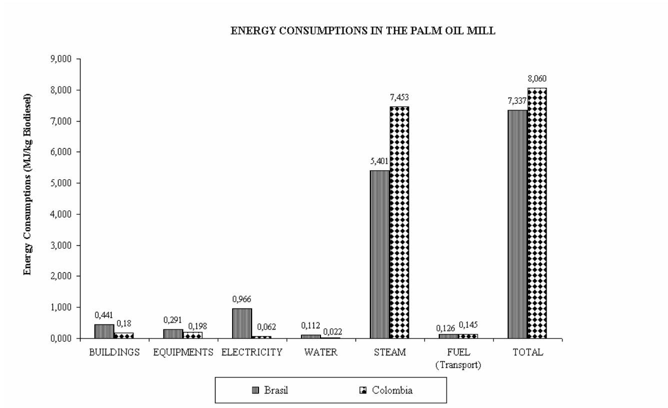

Figure 2: Average energy consumption related to different items for the Brazilian and Columbian case studies during the oil extraction stage.

In the analysis of the final energy balance, it was considered for all the cases that 100% of the fibers produced in the process are used as boiler fuel for steam generation

It is possible to observe that the highest energy consumption in the production of biodiesel out of oil palm corresponds to the industrial stage (oil mill and biodiesel) from Brazil and to the agricultural stage and biodiesel production from Colombia.

In tables 7 and 8, it is possible to observe that all the companies had positive results regarding the energy balance.

Table 7: Result of the energy balance for biodiesel production for the conditions of Brazil

COMPANY - A		
	INPUT (MJ/kg biodiesel)	OUTPUT (MJ/kg biodiesel)
Agricultural Production and Transport	0.015	
Industrial Phase and Transport	1.746	
Palm kernel cake		0.884
Palm kernel oil		1.466
Biodiesel Production	3.673	
Biodiesel (LCV)		39.600
Glycerin Production		2,094
TOTAL	5.433	44.043
O/I	8.106	
COMPANY – B		
	INPUT (MJ/kg biodiesel)	OUTPUT (MJ/kg biodiesel)
Agricultural Production and Transport	0.079	
Industrial Phase and Transport	1.060	
Shell		4.576
Palm kernel cake		0.973
Palm kernel oil		2.418
Biodiesel Production	3.673	
Biodiesel (LCV)		39.600
Glycerine Production		2.094
TOTAL	4.812	49.661
O/I	10.319	
COMPANY – C		
	INPUT (MJ/kg biodiesel)	OUTPUT (MJ/kg biodiesel)
Agricultural Production and Transport	0.035	
Industrial Phase and Transport	3.001	
Shell		7.068
Palm kernel cake		0.973
Palm kernel oil		2.418
Biodiesel Production	3.673	
Biodiesel (LVC)		39.600
Glicerine Production		2.094
TOTAL	6.709	52.153
O/I	7.774	

Table 8: Result of the energy balance for biodiesel production for the conditions of Colombia

COMPANY - A		
	INPUT (MJ/kg biodiesel)	OUTPUT (MJ/kg biodiesel)
Agricultural Production and Transport	3.166	
Industrial Phase and Transport	0.525	
Shell		1.565
Palm kernel cake		2.947
Palm kernel oil		4.885
Biodiesel Production	3.673	
Biodiesel (LVC)		39.600
Glycerin Production		2.094
TOTAL	7.364	51.091
O/I	6.938	
COMPANY - B		
	INPUT (MJ/kg biodiesel)	OUTPUT (MJ/kg biodiesel)
Agricultural Production and Transport	3.927	
Industrial Phase and Transport	0.829	
Shell		1.103
Palm kernel cake		2.768
Palm kernel oil		4.613
Biodiesel Production	3.673	
Biodiesel (LCV)		39.600
Glycerin Production		2.094
TOTAL	8.429	50.178
O/I	5,953	
COMPANY - C		
	INPUT (MJ/kg biodiesel)	OUTPUT (MJ/kg biodiesel)
Agricultural Production and Transport	2.116	
Industrial Phase and Transport	0.576	
Shell		1.323
Production Kernel		0.006
Biodiesel Production	3.673	
Biodiesel (LCV)		39.600
Glycerin Production		2.094
TOTAL	6.364	43.022
O/I	6.760	

5 - CONCLUSIONS

The present work made it possible to measure the energy consumption during the biodiesel production out of oil palm.

In the agricultural stage, for the two studied cases, the greatest contributions came from fertilizers. It is necessary to highlight that for the Brazilian conditions this consumption is considerably less expressive, as the adult palms are not fertilized, in contrast with Colombian crops, where the fertilization is carried out in all along the life stages of oil palm.

In the analysis of the energy balance for the conditions of Brazil, company B presents the best results, because this company produces surplus electricity out of biomass residues. In the same analysis carried out for Colombia, the best results came from company A. These results are similar to those attained by company C. Company B achieved less expressive results, due to the fact that it does not produce electricity from residues and the fertilizer consumption is higher.

Obtained output/Input values for energy balances in the range 6,0-8,0 are higher/in the same range/lower than the ones obtained in references European and EUA LCA studies.

In the comparison of the energy balance values for palm oil biodiesel and the values of Europe's Rapeseed Oil Methyl Ester (RME), the USA's Oil Methyl Ester (SME) and castor in Brazil, it is possible to notice that the palm biodiesel has a better efficiency in the fossil/renewable relation. This takes place because of the allocation of the by-products in the palm biodiesel production chain.

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