academicJournals

Vol. 13(29), pp. 3008-3016, 16 July, 2014
DOI: 10.5897/AJB2013.12250
Article Number: B58F3CD46096
ISSN 1684-5315

http://www.academicjournals.org/AJB

African Journal of Biotechnology

Full Length Research Paper

Energetic assessment of soybean biodiesel obtainment in West Paraná, Brasil

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Received 8 March, 2013; Accepted 6 May, 2014

This work presents the result of a research that aimed to assess soybean-based biodiesel production in the West region of Paraná State, showing that the growing usage of these fuels happens due to the need for alternatives to the use of fossil fuels, once biomass-based fuels have been an environmentally-friendly energetic alternative. The methodology consisted of determining the energetic consumption of biodiesel production. Energetic consumption was performed by considering the stages involved in soybean farming, oil extraction and production of pure biodiesel (B100); results were presented in megajoules (MJ). The energetic outputs obtained show that the energetic inputs in the farming stage totalized 2,411.53 MJ. Energetic outputs added up to 3,003.75 MJ and energy balance was 57,132.54 MJ. In the oil extraction stage, energetic inputs corresponded to a total of 16.80 MJ and energetic outputs to 17.29 MJ. Energetic balance presented a total of 5.14 MJ. In the soybean biodiesel production stage, energetic input was 59.06 MJ and energetic output, 39.69 MJ. Energetic balance corresponded to 33.26 MJ. The highest energetic consumption for soybean biodiesel production, contemplating all three stages, occurred in the farming stage, with 76% of the total energetic consumption, followed by energetic consumption in the production stage, with 21% of the total consumption.

Key words: Soybean production, energetic consumption, soybean biodiesel.

INTRODUCTION

The Brazilian energetic matrix presents the largest index of renewable sources in the world. According to the Ministry of Mines and Energy (MME, 2008), the internal offer of energy for 2007 was 45.9%, regarding renewable sources. However, non-renewable sources showed internal offer of 54.1% in the same year. The increase in the usage of such fuels mainly happens due to the need for alternatives to fossil fuels. Rocha and Neto (2007) states that the use of biomass-based fuels has been an environmentally friendly, or at least less impactful, and alternative. Biodiesel is produced from feedstock such as vegetable oils, animal fat, residual frying oil and fatty materials with high acidity Knothe et al. (2006). The main feedstocks for biodiesel production in Brazil are

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Table 1. Energy expenditure for different types of work.

Work type	Energy expenditure
Tractor, harvester and truck driving	3/6 of the EER
Sowing and fertilization	5/6 of the EER
Cover fertilization	6/6 ofthe EER
Transport of seeds and fertilizers	7/6 ofthe EER
Limestoneapplication	8/6 ofthe EER
Manual weeding	9/6 ofthe EER
Animal Tractionweeding	14/6 ofthe EER

Source: Bueno (2002). EER, Energetic expenditure during rest.

respectively: soybean (which represents 90% of the Brazilian production of vegetable oils), corn, sunflower, peanuts, cotton, canola, castor beans, babassu, palm and macauba. It is important to highlight that many crops in Brazil still have an extractive character, that is, do not have a competitive technology in their production system (Paulillo et al., 2007).

However, one may notice that there are many challenges when trying to boost biodiesel production in Brazil, especially the need for more researches, due to biodiesel's feedstock diversity, processes and usages. In that sense, the energetic analysis of biodiesel production may contribute as a tool to a formulation of environmental and technical-economic feasibility indicators in the comparison between oilseeds, as a way of diagnosing the best kind of crop for biodiesel production.

The objective of this study was to assess the energetic consumption in the production of biodiesel in the city of Cascavel, located in the west region of Paraná State, Brasil.

MATERIALS AND METHODS

This study was carried out in the municipality of Cascavel, in the west region of Paraná State, Brasil. The research took place at the Center of Development and Diffusion of technologies (CEDETEC, Portuguese acronym), at Faculdade Assis Gurgacz's (FAG) School Farm, in the period from November 2011 to July 2012. The CEDETEC works with research in the areas of production of biodiesel using vegetable oils and animal fats, technical feasibility, as well as performance testing of engines with different compositions of biodiesel.

Energetic balance of soybean biodiesel production

In order to determine the energetic balance of the soybean biodiesel, the study was divided into three stages: soybean farming, oil extraction and biodiesel production. In the farming stage, the objective was to search for the energetic consumption of one hectare of soybean. Cultural efficiency was performed according to Bueno (2002), who used two measures to express their results when working on an energetic analysis of a corn crop: cultural efficiency (equation 1) and liquid cultural energy (equation 2).

$$Cultural\ Efficiency = \frac{Useful\ Outputs}{Cultural\ Inputs} \qquad 1$$

$$Liquid\ Cultural\ Energy = \frac{Useful\ Outputs}{Cultural\ Inputs} \qquad 2$$

In order to calculate the energetic balance and energetic efficiency, the methodology suggested by Risoud (1999) was adopted. The same measures that capture the use of renewable energies were considered, as in equations 3 and 4.

$$\mathrm{EB} = \sum \mathrm{PGE} - \sum \mathrm{NREI} \qquad 3$$

$$\mathrm{EEF} = \frac{\sum \mathrm{PGE}}{\sum \mathrm{NREI}} \qquad 4$$

Where, EB is the Energetic Balance (MJ); PGE is the Products' Gross Energy (MJ); $NREI$ is the Non-Renewable Energy Inputs (MJ) and; EEF is the Energetic Efficiency.

In order to extract soybean oil, the energetic consumption was measured for the milling of 1 kg of soybean grains. The production stage considered the energetic consumption expended in the production of 1 L of soybean biodiesel.

Farming production

Determination of consumed energy by labor

To determine the consumed energy in the farming stage, the energetic consumption of the soybean crop was determined, considering energetic consumptions with labor, seeds, diesel oil, lubricant, grease, machinery and implements, fertilizers and agricultural defensives. As for the determination of daily consumptions, a sum of the activities in three periods of time was performed, according to the occupancy mode in number of hours for: resting time, working time, and non-professional occupation time (meals, hygiene, leisure and travel), by using the methodology applied by Risoud (1999) and Campos (2001). In order to calculate the energy expended with labor by human work, the methodology proposed by Mahan and Escott-Stump (1998) was used. As for the determination of the energetic consumption during rest, data for gender, weight, height and age were identified and associated to the developed operations, as shown in equations 5 and 6.

$$EER_M = 66.5 + 13.75 \text{ x } W + 5.0 \text{ x } H - 6.78 \text{ x } A \qquad 5$$

$$EER_F = 66.5 + 9.56 \text{ x } W + 1.85 \text{ x } H - 4.68 \text{ x } A \qquad 6$$

Where, EER_M is the Male Energetic Expenditure during Rest (MJ); EER_F is the Female Energetic Expenditure during Rest (MJ); W is the Weight (kg); H is the height (cm) and; A is the age, in complete years.

According to the methodology proposed by Carvalho (1974), all of the following were established: one third of the energetic expenditure during rest (EER), the fraction related to sleeping time, and half of the EER to the non-professional occupations. As seen in Carvalho (1974), and adapted by Bueno (2002), The determination of the EER related to working time was calculated based on the type of work performed by the farmer, as shown in Table 1. In order to calculate EER, the following were taken into account: H(cm), W(kg) and A(complete years). Labor was used in the farming stage, being one tractorist and common labor. The actions were divided into sowing and fertilization, application of pesticides and harvest.

Fuel, lubricant oil and grease

In order to calculate diesel oil's calorific power, the value 40.88 $MJ.L^{-1}$ was considered; as for lubricant oils, the value was 37.75

Table 2. Machines and equipments.

Equipments/Features	Life cycle (Years)	Annual use (Hours)
Massey Ferguson tractor, model MF 283(4X2 TDA), power 63.2 kW (86 cv) in the engine, board weight 2,850 kg (3,431 kg with ballast), front tires 12.4-24 R1 (39 kg) and rear tires 18.4-30 R1 (83 kg), used to perform pulverization and raw material transportation.	10	1000
Bar pulverizer by Jacto, model Condor, assembled, capacity 600 L, weight 400 kg, bar length 12 m, with 24 beaks, fan type, model DG 110-03, with spacings of 0.50 m.	10	480
Self-propelled grain cart by Massey Ferguson, model MF 3640, power 95.6kW (130 cv) in the engine, board weight 6,760 kg (7,193 kg with reel cut platform), front tires 23.1-30 R1 (138 kg) and rear tires 14.9-24 R1 (59 kg).	15	480
Precision seeder–fertilizer, by TatuMarchesan, model PST[3], spacing 450 mm, weight 3,170 kg.	10	480

Source: Massey Ferguson Manual, (2012).

MJ.L^{-1} (Brasil, 2004). Energetic expenditure was obtained by means of the expenditure in operations by the energetic coefficient of each energetic outlay.

Machinery and implements

Operations involving energetic consumption were divided into three stages as follows: sowing and fertilization, application of pesticides and harvest. The Table 2 presents the machines and implements used for soybean farming with features, life cycle and hours of annual use. As for the calculation of energetic depreciation, the methodology proposed by Beber (1989) was applied according to equation 7.

$$ED = \frac{(M - 10\,\%\text{ x } M)}{(L_u \text{x} T_u)} \quad 7$$

Where, ED is the Energetic Depreciation; M is the Machinery or implement mass (kg); L_u is the Machinery or implement life cycle (hours) and; T_u is the Usage time (hours).

Regarding the calculation of energy used, the methodology proposed by Santos (2004) was applied, as follows in equation 8.

$$E_{mi} = \frac{ED}{EC} \quad 8$$

Where, E_{mi} is the Machinery and implements Energy (MJ); ED is the Energetic Depreciation (kg) and; EC is the Energetic Coefficient (MJ.kg^{-1}).

As for the sowing and fertilizing stage, the period of 1.5 h was considered; 0.5 h for pesticide application and 1.5 h for the harvest stage, according to data from FAG (2012). Energetic coefficients proposed by Comitre (1993) were used, considering the values of 14.62 and 13.012 MJ.kg^{-1}, respectively, for tractor and harvester. As for the energetic coefficients of implements and other equipments used in the operations until sowing, the value 8.62 MJ.kg^{-1} was adopted; regarding post-plantation operations using equipments, the value used was 8.35 MJ.kg^{-1}, as presented by the same author.

Fertilizers

In order to calculate energetic outlay with fertilizers, energetic coefficients presented by Bueno (2002) were used, considering for the soybean production system's energetic outlay coefficients 62.61, 9.63 and 9.21 MJ.kg^{-1}, respectively, for Nitrogen (N), Phosphorus (P_2O_5) and Potassium (K_2O). As for the determination of energetic consumption with fertilizers, the dosage of 300 kg.ha^{-1} of the formulation 02.20.20 was considered, according to data from FAG (2012), thus, for soybean cultivation, 6 kg.ha^{-1}of N, 60 kg.ha^{-1} of P and 60 kg.ha^{-1} of K were used.

Pesticides

Regarding pesticides, the energetic coefficients indicated by Pimentel (1980) were used, being 347.88 MJ kg^{-1}for herbicides; 311.07 MJkg^{-1} for insecticides; and 216.03 MJkg^{-1}for fungicides. Both herbicides and pesticides were applied twice; insecticides were applied once, according to data from FAG (2012). Quantities used were: 2.9 l ha^{-1} of herbicides, 0.643 l ha^{-1} of fungicides, and 0.30 l ha^{-1} of insecticides.

Seeds

In order to determine soybean seeds' energetic consumption, the present work referred to the methodology proposed by Pimentel (1980), who assigned the soybean seed to the energetic value that corresponds to the fossil energy applied to its production, measuring up to 16.736 MJ.ha^{-1}. During soybean sowing, the quantity of 50 kg.ha^{-1} seeds was considered, as found in data from FAG (2012).

Extraction stage

Data used for the determination of soybean oil extraction were obtained in FAG (2012); such data indicate that from 1 kg of soybean grains, one can obtain 13% of soybean oil, 81% of soybean bran and 6% of losses.

Soybean grain energetic expenditure

In this study soybean grains were considered as an energetic entrance in the soybean oil extraction process. Based on data from the oil extraction stage, it was possible to assess that 1 kg of soybean grains yielded 0.13 kg of soybean oil and 0.81 kg of

Table 3. Energetic coefficients of raw materials used in soybean biodiesel production.

Raw material	Unit	Energetic coefficient (MJ)
Firewood [1]	$MJ.kg^{-1}$	19.88
Glycerin [1]	$MJ.kg^{-1}$	32.81
Catalyst (NaOH) [1]	$MJ.kg^{-1}$	44.45
Methanol [2]	$MJ.kg^{-1}$	22.70
SoybeanOil [2]	$MJ.kg^{-1}$	47.80
Electric Energy [3]	$MJ.kWh^{-1}$	3.60
SoybeanBiodiesel [4]	$MJ.kg^{-1}$	39.11

Sources: [1] Bonometo (2009); [2] Sheehan and Camobreco, (1998); [3] Nogueira (1987); [4].

soybean bran. The calculation of the grain's energetic expenditure in the oil extraction process happened by multiplying the quantity of soybean grains used by the energetic coefficient, which was used for soybean grains of 16.80 $MJ.kg^{-1}$, as presented by Cavalett (2008).

Soybean oil energetic expenditure

As for the determination of the soybean oil energetic expenditure, it was necessary to consider that during the extraction stage, the value found was 0.13 kg of soybean oil per kilogram of soybean grains. The calculation of soybean oil energetic expenditure in the process was performed by multiplying the quantity of soybean oil used by the energetic coefficient, according to Cavalett (2008) is 39.60 $MJ.kg^{-1}$.

Soybean bran energetic expenditure

As for the determination of the soybean bran energetic expenditure, it was taken into account that during the extraction stage, the value found was 0.81 kg of soybean bran per kilogram of soybean grains. According to Mourad (2008), soybean bran's energetic coefficient is 15.00 $MJ.kg^{-1}$. Energetic consumption was determined from the product between the energetic coefficient and the quantity of soybean bran used in the extraction process.

Energetic consumption in biodiesel production

In order to determine energetic consumption, it is considered that for biodiesel production, the methylic route was used; as energetic inputs, the following were considered: firewood, catalyst, methanol, soybean oil and electric energy. Energetic outputs were glycerin and biodiesel. The coefficients for each raw material used in biodiesel production are represented in Table 3, according to values presented by Bonometo (2009); Sheehan and Camobreco, (1998); Nogueira (1987). Data for calculating energetic consumption were determined based on the production of 1 L of pure soybean biodiesel (B100), as seen in data from FAG (2012). The firewood used for biodiesel production was Bracatinga (*Mimossa scabrella*). Quantity used was 19.88 kg to produce 1 L of biodiesel. Energetic consumption was obtained by the product between the quantities of wood used in the process by the energetic coefficient. The NaOH was used as the catalyst for biodiesel production. The quantity used in the process was 0.055 kg of NaOH for the production of 1 L of biodiesel. The process of soybean biodiesel production happened by means of transesterification by methylic route, using 0.18 kg of methanol. In order to produce 1 L of soybean biodiesel, 0.9 kg of soybean oil was used.

In the process of producing 1 L of biodiesel, according to data from FAG's School Farm's Biodiesel laboratory, 0.045 kWh of electric energy was consumed. Electric energy was calculated by considering the energy consumed in function of the engines' power by the usage time of each engine during the process. During the process of producing 1 L of soybean biodiesel, according to data from FAG's School Farm's Biodiesel Laboratory, 0.0955 kg of glycerin was produced as sub product. Glycerin energetic value was calculated, considering it as an energetic output, by the product between the energetic coefficient and the quantity of glycerin generated in the production of 1 L of biodiesel. The pure biodiesel was considered, produced by means of the methylic route as an energetic output of the process. The liter of biodiesel produced corresponded to 0.955 kg of pure soybean biodiesel (B100).

RESULTS AND DISCUSSION

Energetic consumption in sowing and fertilization

In the operation of sowing and fertilization presented in Table 4, one may notice that the highest energetic consumption found during such operation was under indirect energy, due to the use of chemical fertilizers; such energy was responsible for more than 58% of the consumption. Jasper (2009), when analyzing a crambe crop, stated that chemical fertilizers present the highest caloric consumption, with more than 71% of indirect energy. Bueno (2002), in a study on a corn crop, found the following values: 28.31% for direct energy and 71.69% for indirect energy. Diesel oil, which is a fossil-based component of direct energy, stands out for its large participation in direct energy expended: 37.64%. Ferreira (2010), in a study carried out in the state of Rio Grande do Sul on the energetic and economic matrix of soybean crops, states that diesel oil represents 49% of the total consumption of direct energies.

Energetic consumption in harvest

Harvest operations significantly consume direct energy. Direct energy superiority (98.16%) occurs due to the broad use of fossil sources, particularly represented by the energetic expenditure with diesel oil. The value found

Table 4. Energy inputs in the operation of sowing and fertilization, MJ. ha^{-1}.

Type, source and method	Cultural inputs (MJ)	Participation (%)
Directenergy	**1.048.74**	**40.96**
Biological		
Labor		
Tractorist	9.54	0.37
Common	23.52	0.91
Seed	836.8	32.67
Fossil		
Diesel oil	168.92	6.59
Lubricant	3.02	0.11
Grease	6.94	0.27
Indirectenergy	**1.511.92**	**59.04**
Industrial		
Tractor	2.5	0.09
Seeder	3.36	0.13
Fertilizer	1.506.06	58.81
Total	**2,560.66**	**100**

by Jasper (2009) for direct energies in the energetic study of crambe was 96.46% of the total consumption. Bueno (2000) also found a close value for direct energies (90.37%) in a study on corn crops. The seed, component of the biologically based direct energy, stands out for its elevated participation in the expended direct energy, corresponding to 32.67%, followed by diesel oil caloric expenditure of 6.59%.

Energetic consumption in the application of pesticides

In the operation of pesticide application presented in Table 5, one can verify that the energetic consumption under indirect energy happens due to the use of herbicides, once this type of energy was responsible for more than 44.97% of the total consumption. Jasper (2009), when analyzing a crambe crop, also relates the herbicide to the highest energetic consumption, with 44.31%. In the indirect energy analysis, one may highlight the high value of the industrial energetic source represented by the harvester, which stands for 1.84% of the energy consumption.

Energetic consumption in soybean production

Energetic consumption in soybean production showed in Table 7 first presents sowing and fertilization consumption, with 47.20% of the total, followed by herbicides, fungicides and insecticides, with 45.01%. The operations which present the highest energetic consumption are sowing and fertilization, adding up to 47.20% of the total consumption.

Energetic balance in soybean production

In Table 8 one can find values for soybean production cultural efficiency, by means of the energetic outlay structure, in which energy inputs and outputs are quantified and presented in energetic units by relating soybean production to the technical schedule shown, considering an average productivity of 3,500 kg.ha^{-1}; total productivity was 58.35 sacks (60 kg per sacks) per hectare, what characterizes a built-in energy in production equal to 58,576.00 MJ. Direct energies represent 44.53% of the total energetic consumption and indirect energies represent a value which is somewhat over it, with 55.47% Bueno (2002), when studying a corn crop, found relative balance with 47.19% for direct energies and 52.81% for indirect energies. One may notice in Table 8 that the liquid cultural energy was 53,160.72 MJ, what led to a cultural efficiency of 10.82 MJ.

Energetic balance in soybean oil extraction

In Table 9, one can observe the results regarding inputs with 16.80 MJ of the energetic consumption of the total researched, as well as outputs with 17.29 MJ for the production of 1 kg of soybean grains. Serrão and Ocácia (2007) determined close values for energetic production of both soybean bran and oil, which were respectively 10.929 and 6.799 MJ. Energy balance followed Risoud's (1999) methodology, in which the sum of gross energy in the process is subtracted from the sum of non-renewable inputs. Once the gross energy used in the system was soybean oil and energy inputs were not considered in this process, it was possible to define the energetic balance value for soybean oil production, which was 5.148 MJ.

Table 5. Energy input, in MJ.ha^{-1}, in the operation of herbicide, fungicide and insecticide application.

Type, source and method	Cultural inputs (MJ)	Participation (%)
Direct energy	**957.55**	**42.66**
Biological		
Labor		
Tractorist	20.70	0.92
Common	42.45	1.89
Fossil		
Diesel oil	844.60	37.64
Lubricant	15.10	0.67
Grease	34.70	1.54
Indirectenergy	**1.286.22**	**57.34**
Industrial		
Tractor	37.5	1.67
Sprayer	7.65	0.34
Herbicide	1.008.85	44.97
Fungicide	138.9	6.20
Insecticide	93.32	4.16
Total	**2.243.77**	**100.00**

Table 6. Energy inputs, in MJ. ha^{-1}, participations in harvest.

Type, source and method	Cultural inputs (MJ)	Participation (%)
Directenergy	**414.81**	**98.16**
Biological		
Labor		
Tractorist	7.62	1.81
Common	27.44	6.5
Fossil		
Diesel oil	368.73	87.25
Lubricant	4.07	0.96
Grease	6.94	1.64
Indirectenergy	**7.79**	**1.84**
Industrial		
Harvester	7.79	1.84
TOTAL	**422.60**	**100**

Energetic balance in the production of soybean biodiesel

The analyzed soybean biodiesel was obtained in a methylic route (using methanol). Analyzed inputs were: electricity, firewood, catalyst, soybean oil and methanol. Energetic outputs were: soybean biodiesel and glycerin. Energy balance may be restricted to only one industrial stage of biodiesel production, in which the basic raw materials are: oil, alcohol, catalyst, electric energy and heat (Nogueira, 1987). Based on the raw materials assigned for the production of 1 L of soybean biodiesel, the energetic consumption for soybean biodiesel production was then determined, as shown in Table 10. The energy balance was characterized by the sum of gross energy in the process subtracted from the sum of

Table 7. Energetic consumption in soybean production under direct drilling system, MJ.ha^{-1}.

Operation	Energetic participation in the production system	
	MJ.ha^{-1}	Percentage (%)
Sowing and fertilization	2.560.66	47.20
Herbicide, fungicide and insecticide application	2.441.59	45.01
Harvest	422.604	7.79
Total	**5.424.854**	**100**

Table 8. Outlay structure by type, source and method; cultural inputs, useful outputs, liquid cultural energy, soybean production cultural efficiency, and energetic balance.

Type, source and method	Cultural inputs (MJ)	Participation (%)
Directenergy	**2.411.53**	**44.53**
Biological		
Labor		
Tractorist	37.86	0.70
Common	93.41	1.72
Seed	836.8	15.45
Fossil		
Diesel oil	1.382.25	25.53
Lubricant	19.29	0.36
Grease	41.91	0.77
Indirectenergy	**3.003.75**	**55.47**
Industrial		
Machinery and implements	58.8	1.09
Herbicide, fungicide and insecticide	1.438.89	26.57
Chemical fertilizers	1.506.06	27.81
Cultural inputs	**5.415.28**	**100.00**
Useful outputs	**58.576.00**	
Liquid cultural energy	**53.160.72**	
Cultural efficiency	**10.82**	
Energeticefficiency	**40.58**	
Energetic balance	**57.132.54**	

Table 9. Energetic balance in soybean production.

Raw materials	Quantity	Energetic coefficient (MJ)	Energetic production (MJ)
Input			**16.80**
Grains	1 kg	16.80	16.80
Output			**17.29**
Soybean oil	0.13 kg	39.60	5.148
Soybean bran	0.81 kg	15.00	12.15
Balance			**5.148**

Note: Energetic balance in soybean oil production.

Table10. Energetic balance of soybean biodiesel.

Raw material	Quantity	Energetic coefficient (MJ)	Energetic production (MJ)
Input			**59.06**
Firewood	0.47	19.88	9.34
Catalyst (NaOH)	0.05	44.45	2.44
Methanol	0.18	22.7	4.09
Soybean oil	0.9	47.8	43.02
Electric energy	0.04	3.6	0.16
Output			**39.69**
Glycerin	0.09	24.44	2.34
Soybean biodiesel	0.95	39.11	37.35
Balance			**33.26**

Note: Energetic balance of soybean Biodiesel.

Table 11. Energetic balance of the production of soybean biodiesel.

Stage	Energetic balance (MJ)	Energetic balance (MJ. Liter^{-1})
Soybean farming	57.132.54	121.96
Oil extraction	5.148	5.642
Biodiesel production	33.26	33.26
Total	**57,170.94**	**160.86**

Note: Energetic balance of each stage in the production of soybean biodiesel.

non-renewable inputs (Risoud, 1999). By having soybean biodiesel as the system's gross energy and methanol as the source of non-renewable energies, it was possible to define the energetic balance for the production of soybean biodiesel, which was 33.26 MJ (Table 11). Pimentel and Patzeck (2005) estimated the energy consumption in the production of 1 ton of soybean biodiesel in the United States of America to be 19.78 MJ. Serão and Ocácia (2007), in a study on soybean biodiesel production in the state of Rio Grande do Sul, estimated the energy balance to be 39.38 MJ.

Energetic balance of each stage for the production of soybean biodiesel

In order to determine soybean biodiesel's energetic balance, it was necessary to use data from soybean production, soybean oil extraction and data from the production of biodiesel obtained in a methylic route, in which it was considered as the production of 1 ha of soybean, 1 kg of soybean grains and 1 L of soybean bio-diesel. The energetic balance of the stages of soybean biodiesel production presented a value of 57,170.94 MJ. Chechetto (2010), in a study on the energetic balance of castor bean biodiesel, found very similar values: 56,830.56 MJ. One must highlight that in the energetic consumption in the obtainment of 1 L of biodiesel, including the three stages, soybean farming presents the highest energetic consumption (76%), followed by energetic expenditure for soybean biodiesel production (21%) and the one with lesser consumption, soybean oil extraction (3%). It is also substantial to point out that the low energetic consumption in the extraction stage happens due to the calculation of energetic consumption being related only to main inputs and outputs (soybean grains, oil and bran), not concerning to other inputs and outputs, such as electric energy, labor, and others.

Conclusion

Based on the results obtained in the conditions in which this work was carried out, one can conclude that, the energetic inputs in the farming stage added up to 2,411.53 MJ. Energetic outputs totalized 3,003.75 MJ, and energy balance was 57,132.54 MJ. In the oil extraction stage, energetic inputs corresponded to 16.80 MJ and energetic outputs to 17.29 MJ. Energetic balance was 5.14 MJ. The soybean biodiesel production stage presented energetic inputs of 59.06 MJ and energetic outputs of 39.69 MJ. In this stage, energetic balance was 33.26 MJ. The highest energetic consumption for soybean biodiesel production, regarding all three stages, occurred in the farming stage, with 76% of the total energetic consumption, followed by energetic consumption in the production stage, with 21% of the total consumption.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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