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Energy Quantification for Sorghum Production to Obtain First and Second Ethanol Generation

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Abstract: The rapid growth of world population increases food demand and consequently a higher consumption of fossil fuel, which leads to search for alternatives form of clean energy technologies. The current situation of oil production, rising prices and market volatility, environmental pollution, climate change and the state of world reserves of this non-renewable resource, is leading some countries to develop strong programs of production of alternative fuels from energy crops, among others options. The use of energy crops has advantages in income generation, employment creation and enables an alternative to reduce dependence on fossil fuels. By contrast, production of energy crops also has negative effects in consumers particularly in food and agricultural markets. Biofuel production requires the use of resources that are generally used for food production, including land, water, labor and other electromechanical energy resources allocated in this production, of which there exists only a limited documented accurate information. Additional energy production demands may cause the prices of agricultural products present a rising trend and structure of the agricultural sector can change. Therefore, development and increased production of biofuels requires careful plans that addresses the broader impacts of production and analyze the resources required to produce crops used as food and fuel and the amount of energy required compared with the energy produced. The objective of this research was to quantify the energy demand required in traditional activities and agricultural practices for the production of sweet sorghum, used as raw material for ethanol production from first and second generation (input). Also, compared to the energy obtained as a biofuel and reported in literature (output), which will determine the feasibility and viability to develop plans for adoption and development. The results show a yield of 29.50 fresh ton ha^{-1} (first generation) and 8.55 ton ha^{-1} waste (second generation) with 14,696 $Mjha^{-1}$ requirements.

Key words: energy crops, energy balance, bioethanol

1. Introduction

The rapid growth of world population and increasing fuel consumption are increasing the demand for food and biofuels. Globally, approximately 90% of the energy consumed comes from non-renewable sources, causing fossil resources are rapidly being depleted and the rate of decline is increasing [1]. The present situation of production, the increase in the prices of oil, environmental pollution, climate change and the status of world reserves of this non-renewable resource, is leading some countries to develop strong programs production of alternative fuels from energy crops, among other technological options. However, this research effort, only it has come to produce a quantity of renewable energy replacing approximately 12.9% of total world energy consumed and presented in the report on climate change [2]; this percentage was broken down into: energy generated biomass or organic elements derivatives crop (10.2%); hydraulic (2.3%); wind energy (0.2%); geothermal and solar (0.2%).

In Mexico, only 9.5% of the total energy supply is renewable, while in Brazil 38.7% of its energy from renewable sources. In addition, it should be clarified that the little renewable energy produced in Mexico, unlike Brazil, is mainly hydro, solar and wind, and a

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small percentage is used not quantified commercial production of biofuels from agricultural and forestry crops [3]. Biofuel production is part of a competitive strategy within the international agricultural market. The emphasis on biofuels has been developed worldwide, including crops such as corn, sugarcane and sorghum, considered by some researchers as renewable energy sources. Wood and crop residues are also used as fuel [4].

The little unity in the acceptance of biofuels originating from foods like corn requires the company to analyze the various options for alternative energy. Another option is agricultural residues, which are attractive because of their low cost and abundance [5]; Demirbas (2011) [6], BNDES-CGEE (2008) [7] studied the use of biofuels as a renewable energy produced from natural materials containing sugar or starch that can be converted into bioethanol and even as indicated generate ethanol is sought [8] from products such as pineapple, apple and grape. The use of staples as sugarcane and corn for ethanol production is controversial. Integrating the concept of sustainability in the design of the supply chain of biofuels is just beginning [9]. Biofuels production recorded a conflict with food production [10]. Some studies show a relationship between the increase in food prices and biofuel production [11]. There is proof that energy market instability is transferred to the food market since 2000, when the Administration & Finance International Magazine, published the biofuels industry [12] arises. This aspect registers [13] when establishing the existence of a relationship between energy and food prices.

The energy crisis has led to a decline in food demand [14], so to implement policies aimed at achieving sustainable development is vital to integrate the concepts of power and energy. The current need for a fully modern, sustainable agriculture, has led to mechanization as a strategy to increase arable land contributing to the increase in yields. Most farmers spend more on fuel for their agricultural practices that used to cost inputs such as fertilizers, seeds and agrochemicals [15, 16].

The use of biomass for energy production is an aspect that it is necessary because of the different energy sources, composition of these sources and energy potential [17-19]. Energy assessment is a process of analysis involves the identification and reference to the amounts of energy in the production of a particular good. Each of the processes has a number of demands, the total power sum of the partial each process [20]. The fuel consumed to perform a certain task the culture depends on a number of variables among which we highlight the soil type and its state or condition at the time of being styled, the power tractor, therefore described, the present research aimed quantifying or consumed energy required for the production of raw material for the cultivation of sweet sorghum, with the purpose of obtaining ethanol from first and second generation. The evaluation was done in each of the production processes for growing sweet sorghum, with a description of resources and activities involved in this production.

2. Materials and Methods

Location and characteristics of the site. The research was conducted at Cotaxtla experimental station belonging to the National Institute of Forestry, Agricultural and Livestock Research (INIFAP), in the municipality of Medellin de Bravo; Veracruz México. The studies were carried out on a system with a productive agricultural site located in the geographical coordinates (18°56'24" N and 96°11'52" W) using an area of one hectare for establishing sweet sorghum. The soil was classified as loamy-float as the textural classification of soils [21], with 37.20% sand, 24.80% clay and 38% loamy. This soil was strategically selected, because compaction values recorded or mechanical impedance than 3 Mpa from a depth between 0.10 and 0.15 meters. Soil moisture at the time the work was 11.98%, 13.96% and 16.26% for the layers of the soil to a depth of 0.10, 0.20 and 0.30 meters, respectively.

Description of the evaluation. The study was to quantify the energy required or consumed in Mjha-1 (input) of farming machined (machine) and manual (man) made for the production of raw material sorghum crop sweet for obtaining ethanol from first and second generation, and compared with the energy produced (output). A randomize complete block design was used for energy quantifying agricultural activities, with four established replications during the rainfall period of 2018 year. The size of the experimental plot for the site was of 2500 m^2 with four experimental units and a surface of 10,000 m^2. Differentiated technologies were used for primary soil preparation T1: Vertical Tillage (VT) with chisel plow and T2: Conventional tillage (CT) with disking. The rest of the activities and cultural practices were the same for sorghum production. A single dosage of fertilization in two applications were used: the first application to the time of seeding, was 150 kg of nitrogen (Urea), 100 kg of Phosphorus (Dap) and 50 kg of Potassium Chloride (KCl) and the second fertilization at 28 days after planting 200 kg of nitrogen, were used. In addition, they were applied four auxiliary irrigation system with furrow irrigation (gravity) at a flow rate of 11 liters per second for a total of 108 hours. The criteria used for irrigation moment was when the plant water deficiency manifested. Seed used for planting sweet sorghum, was the Rb-Cañero material with a dosage of 225,000 seeds per hectare material belonging to the INIFAP brand.

To calculate fresh biomass, they were taken to the random eight replications per treatment in each of the crops, which consisted of a groove with 10 meters long and counting the number of plants. Then its weight was calculated. Finally, the obtained grain weight per hectare panicle and leaves before proceeding to the drying of the sample in an oven at 50°C for three days to calculate the percentage of dry matter was estimated.

2.1 Machinery, Implements and Equipment Used

Quantification for energy farming sheet of machinery and implements used was recorded. Table 1 is listed in chronological order the tasks, equipment used, power, working widths and depths used in the evaluation.

Table 1 Technical description for agricultural operations and cultural work for the production of raw materials sorghum. The source 2018: information obtained by the author of the technical data submitted by the manufacturer.

Agricultural activities	Agricultural Machinery	^{1} Power, ^{2} Working Width and ^{3} Working depth	Technical Data
Power Drive	Tractor	^{1}84 hp	Four cylinders and 3247 kg mass Ocima NMX-0-0207 SCFI-2004
Plating	Devastator	^{2}2.10 m	Flatbed
Plow	Chisels Disking	^{2}1.80 m, ^{3}0.30 m ^{2}0.70 m , ^{3}0.20 m	Three Chisels rigid semi-straight shallow and deep chisels two finned reversible/Three Discs
Tracking Cross	Dredge Shooting	^{2}3.60 m	Discs 32 and 2182 kg mass Three units of 145 kg mass
Groove Tracing	Furrower	^{2}1.60 m	Spaced 0.80 m
Sowing-Fertilization	Seeder for Sorghum	^{2}2.40 m	Semi-precision four planting units to 0.80 m between rows
Borders for Irrigation	Border Making Machine	^{2}0.80 m	Simple groove and four albums
Irrigation	Bomb and 29.84 kW/h motor/Three with showers for with 11 l Gravity flow		
Agrochemical application	Sprayer	^{2}10 m	Type boom
Double Cultivation	Cultivator	^{2}0.80 m	Three are behind bars 0.35m
Panic	Cultivator	^{2}0.80 m	Three are behind bars 0.45m
Harvest	Manual/Energy	Na	8 hours daily wages

The procedure proposed by Bowers (1992) [22], a similar method also proposed by Bridges and Smith (1979) [23], described by Hetz and Barrios (1997) [24] and previously supported by ASAE (1993) [25]; Doering (1980) [26]; Fluck (1992) [27] and Stout (1990) [28], and evaluated by Ruiz et al. (2009) [16]; in which the total energy consumed ($MJha^{-1}$) is calculated, taking into account the direct and indirect use energies.

In the own case of this research, only direct energy consumed (Edc) was quantitated by each agricultural operation in liters per hectare, the measurement was performed by the method of the full tank, which is supported as a valid test and accepted by the NTTL (Nebraska Tractor Test Lab) and referred to the OECD (2016) [29]. Therefore, described each work were counted as described below:

1) Direct energy (Ed) includes that which is associated with fuel consumption and labor employed in different tasks:

a) Energy associated with fuel consumption (EDC) ($MJha^{-1}$)

$$E\,dc\ \text{Cc} = \text{Eeg} \tag{1}$$

Where:

Cc: fuel consumption (lha^{-1})

Eeg: the energy equivalent of the oil (41 MJl^{-1})

b) Energy associated with electricity consumption (Ede) ($MJha^{-1}$)

$$E\ \text{de} = \text{CcEeg} \tag{2}$$

Where:

DC Is the electricity consumption (kWh ha^{-1})

Eee It is the energy equivalent of electricity (11.93 MJ Kwh^{-1})

c) Energy associated with labor employed (Edh) ($MJha^{-1}$)

$$\text{E dh} = \text{Eh nob/Ctob} \tag{3}$$

Where:

Eh: Is the energy equivalent of human labor (1.96 for man), nob: Is the number of workers involved in a particular task and Ctob: is the working capacity of agricultural workers has h-1.

3. Results and Discussion

The specific values of energy quantitation for work done with machinery and agricultural implements as well as manual labor for the production of sorghum sweet are described in Table 2. In the results, it is observed that the preparation of the bed of roots (plow) shows significant savings in fuel consumption of at least 22% and the 50% saving in operating time effective per hectare to the use tined over conventional tillage applied discs. These values are consistent with that described by Hesel and Oguntunde (1985) [30] and Reynolds and Lopez (2018) [31], to the A similar assessment. This result is important to note that the disc depth only reached 0.20 meters as the ground labor had layers compact and could not penetrate to the desired depth. Moreover, tillage with chisels obtained a depth of 0.30 meters. Another comparison of the use of deep tillage, is the difference in preparing the seed bed (drag) in which a fuel was observed about 6% to do this work which was used previously chisel plow compared to disking. Ruiz et al. (2009) [16], presented similar data in the quantification of the energy balance in agriculture.

The total energy consumed in work machined for growing sweet sorghum was approximately 87% of the total employee and the remaining percentage was for the work done by man, showing the high dependence of mechanization for the production of crops. Another important parameter was the result of the quantification of energy consumed for applying five auxiliary irrigations with a total of 108 hours' irrigation with pumping equipment and flow 11 Lps where 10,789 MJ ha-1 were used for the production of raw material for growing sorghum.

Values, where the type of crop required by tillage used are shown in Table 3, the uniform application of irrigation, the energy consumption of farming and the yields obtained as raw material for ethanol production from first and second generation. Furthermore, the results show that there is no statistically significant

Table 2 Energy values of energy consumed for the production of raw material in sorghum.

Agricultural Activity	Fuel Consumption [l/ha]	Energy Consumption [Mj/ha]	Operation Time [h/ha]
[1]Chatter	9.26	380	2.08
[1]Chisel plow [Ac]	17	697	2.11
[1]Disking Plow [Ad]	22	90	4.24
[1]Dredge after Ac	23.5	964	1.47
[1]Dredge after Ad	25	1025	1.56
[1]Furrowed	4.2	172	0.48
[1]Planting and fertilization	3	123	1.09
[1]Spray Boom *	1.4	57	0.28
[1]Cultured [Weeding]	6	246	1.97
[1]Sprayer Boom **	1.4	57	0.28
[1]Fertilizing 2nd Application	6	246	1.2
[1]Grounding	4.2	172	0.7
[1]Boom Sprayer **	1.4	57	0.28
[2]Sorghum Crop	Na	470	240
Total vertical Tillage	77.36	3641	251.84
Total with convec tillage	83.86	3907	254.16

[1]Mechanized agricultural work (machinery). [2]Manual agricultural work (hours/man) *Application **application weed control pests and diseases.

Table 3 Parameter focus of energy balance for the production of raw material for ethanol production from first and second generation with two different tillages.

Energy crops	Energy consumed [MJ/ha]	Water consumption [l/ha]	1st generation [t/ha]	2nd generation [t/ha]
Sorghum LV	14,430a	4,276,800 *	33.62a	4.43a
Sorghum LC	14,696a	4,276,800 *	33.10a	4.23a

Literal values with different display significant statistical difference between the primary systems of soil preparation, Turkey ($P \leq 0.5$). * It is applied the same volume of water.

difference in the variables observed in tillage systems applied, to the compare performance and power parameters a nominal value of significance of 5% with the Tukey test. In the production of sorghum (CT) shows that requires 129 liters of water to produce one kilogram of matter in green sorghum (stem) and a ton green to produce 80 liters of ethanol (information obtained and provided by production pilot plant UNIDA of the Technological Institute of Veracruz, 2018) for first generation. In the case of second generation ethanol it requires one ton of dry matter or waste to produce 250 liters of ethanol (information plant output pilot attached Institute of Technology Veracruz, 2018) under the conditions described in this evaluation. This situation generates controversy as biofuel production can also significantly affect water resources because of the change in land use, which can affect water runoff, underground, water availability and local climate altering levels of land evapotranspiration [32]. Ethanol production recorded 2,648 liters for the first-generation and for the second-generation 1057.5 liters. Our analysis points to a more energy efficient use of arable land for food production for fuel and large differences in efficiencies attributable to management, suggesting multiple opportunities for improvement.

4. Conclusions

The results showed that the use of a vertical primary tillage used for the preparation of the soil, the system was more efficient in energy for the production of food or biofuel. Savings was observed at the least 15% in fuel consumption and 55% in the effective operating time compared with the conventional system disking.

Agricultural and cultural practices for crop production must be efficiently done in a way so it is necessary to know the natural state of the soil and conditions, conducting an analysis of the soil prior to the establishment.

Currently in the southeastern region of Mexico, the limited technical level of irrigation systems and low brings efficiency high consumption of water used in the production of raw material for the generation of first-generation bioethanol, which generated controversy for decision makers as ecologically and socially is not feasible.

The cost of producing biofuels first generation from crops such as sorghum is still very high, given the volume of water required. You must first formulate a policy for consumptive and non-consumptive use of water.

Recent accomplishments achieved in yields of some crops such as sorghum are not enough compared to high-energy consumption and the volume of water required.

The use of crop residues or derivatives is presented as a viable alternative for the production of second-generation ethanol, so to be estimated production potential and initiate pilot cases for placing operation.

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