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Cálculo del balance de energía para higuerilla (Ricinus communis L.) desde las etapas de producción en campo hasta el valor energético de cada componente de la planta
Calculating energy balance for higuerilla (Ricinus communis L.) from field productive stages to energy value for whole plant constituents

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México

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Resumen

Introducción: Pruebas de balance de energía permiten redirigir los insumos desde las etapas de producción de un cultivo, e igualmente, precesar la cantidad de energía utilizada para cada proceso y así, verificar la eficiencia al transformar la energía contenida en el cultivo cuando debe cumplir con una función deseada.

Método: la planta de higuerilla (Ricinus communis L.) con propósitos de cultivo energético fue sembrada en campo y sometida a procesos de mantenimiento del cultivo y en la cosecha, la planta completa fue colectada para análisis energético, donde cada una de sus partes incluidas las semillas fueron evaluadas en función de su contenido de energía. Así, para determinar el balance de energía; los valores de la energía biológica de la planta fueron comparados con la energía aplicada en cada uno de los procesos técnicos y físicos para la producción del cultivo y en su procesamiento.

Resultados: La energía aplicada para producir el cultivo resulta un 28% superior a la energía a obtener de la planta. Asimismo, la biomasa de la planta completa de higuerilla, sin contar las semillas genera el doble de energía comparado con el aceite de las semillas, por lo que, conviene utilizar toda la planta en términos de energía.

Conclusión: Es recomendable utilizar el aceite de las seillas como biomaterial, ya que el balance es positivo en un 15%.

Palabras Clave: energía renovable, potencial energético, cultivo energético, biomasa

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Abstract

Introduction: Energy balance trial allows to carefully allocating any inputs for field production of the crop as well as, dosing precisely the amount of energy required for each process, thus determining the efficiency when energy transformation inside the crop is required for a certain task.

Method: Castor oil plant (Ricinus communis L.) as an energetic crop was field drillet and cultural practices were undertaken for crop growth and at harvest, the whole plant was collected where each constituent was tested for its energy concentration. Thus, to reach for an energy balance calculation; bilological energy figures from higuerilla plant were compared with technical and physical energy application for crop cultivation and processing.

Results: Entire energy applied for crop growth is 28% higher that energy obtained from higuerilla plant. Also, biomass of whole castor oil plant except seeds generates twice energy than oil from seeds, so whole crop harvesting has to be promoted.

Conclusion: Oil from sedes should de used as biomaterial, since there is a positive balance by 15%.

Keywords: renewable energy, energetic potential, energy crop, biomass.

Introduction

Rural farming provides food, fiber and raw matter for sustaining human beings. However, global population is constantly increasing and it is been estimated that in year 2050, it will be required to produce doublé quantity of food and consequently, it will be needed doublé amount of energy and wáter to feed these people. In order to tackle this scenario, alternate energy source are to be supplied and more efficient methods for using that energy and wáter have to be devised where savings are a priority (Hall, 1997). A study was undertaken for detecting áreas with high potential for energy development in order to encourage technology applications, especially to renewable energies relevance; although energy chemical substances and human energy intervention on all conversión processes are also important (Girard and Fallot, 2006). Thus, marginal household communities, small agricultural businesses or semi-industrial enterprises are sectors where renewable energies application has the greatest potential for a feasible development.

First perceived inconveniences for developing plants small enough become big advantages in a shaped structure where energy is discrecentally produced. This feature makes energy to be straightforwardly consumed by thirsty, marginal and disperse rural communities. First bioenergy feedstocks are crop residues while, forest and cellulosic biomass are feasible feedstocks to produce biofuels which rural population already use directly, mainly for heating and cooking; furthermore those low cost and readily available biofuels contribute to alleviate the energy shortage at rural level for isolated communities (Borjesson, 1996; Girard and Fallot, 2006).

At present, a viable strategy is to search for profitable alternative energy sources or renewable bioenergy as well as deeply consideration is for saving water and energy. The latter by increasing effective usage and reduce wastes. Nowadays, almost everything drives from energy so managing and generating energy is of global concern. Worldwide, farming uses around 70 to 75% of fresh water so any technology developed for saving it makes a great contribution, i.e. pressurized irrigation systems (Chang et al., 2003). Equally, a method for systematically saving energy is by calculating the energy balance for each process involved, which includes the energy measurement for each component, in an input-output assessment. Using a suitable methodology allows to detailed adjust those large inputs going to the process as well as monitor the energy conversion efficiency when an productive task demands it.

Main is constantly interacting with energy flows, thus the calculation of energy balances shoul be a priority when efficiency and profitability are the main concern. Last decade saw the most recent energy crisis, activating the interest in biofuels, however, financing is an obstacle for their development (Girard and Fallot, 2006). Furthermore, it is very important to undertake a diagnosis about the features and performances from those biofuels; expressly referring to the way they are to be used, starting by making a precise calculation of energy balance from all those factors that intervene in order to identify which contribute for the highest efficiency (Saribiyik et al, 2010). Regarding biofuels development, special attention is given to energy crops and bioenergetics biomass, particularly using the whole plant and their residues (Meier, 2007; Fuentes-Martínez et al, 2013; Nunes da Silva et al., 2010). Some energy balances untaken to energy crops are only partial, most of the time they are referred as life cycle (Sepúlveda González, 2012; Yusuf et al., 2015) or including environmental issues (Amaya Ramirez et al., 2008).

Energy analysis is a way to evaluate the sustainability of production systems. Thus, this study deals mainly with agroenergy obtained from biomass coming from castor oil plant (Ricinus communis L.), so the aim was to evaluate the productive potential of the castor plant, using an energetic view against net energy gain from the whole plant, i.e. energy gain over the invested energy.

Method

Calculating energy balance considers all the energy sources provided for crop production, such as electricity, fuels, energy consumed by the manufacturing processes or other inputs, (chemicals – fertilizers and pesticides) as well as the labor employed in the production and transformation processes involved, which is compared with energy obtained from fruit, biomass or an end transformed product.

Any process or technology to obtain renewable energies faces new challenges. procedures for crop production make use of technical energy and the required amount varies according to the processes employed, intensity of land preparation, fertilizers and pesticides application, cultivation practices and harvesting and the generated energy at the end of the route, it widely offers different features from the technical energy supplied (Nunes da Silva et al., 2010; Delgado et al., 2013). Therefore, it was useful to start making a simple comparison regarding enthalpy figures among bioenergetic feedstocks and other energy sources (Table 1). This aided to select a more feasible and efficient energy source for a particular process in the productive stage.

Table 1. Average heat values from some vegetable oils and fuels.

Product	**Minimum energy (kcal/kg)**	**Maxumum energy (kcal/kg)**
Gasoline	9529.89	10095.36
Diesel	10145.55	10278.91
Biodiesel	8939.60	9212.02
Palm oil	8769.39	
Soybean oil	8791.38	
Jatropha oil	8787.31	
Oil from castor oil plant	9880.72 (8852.06)	
Ethylic alcohol	6500.00	
Biogas	4500.00	

Table 1 shows that enthalpy from vegetable oils is relatively small when compared to other technical energy sources, therefore, it is more useful to utilize the vegetative oil without any processing, i.e. using it as biomaterial is energetically more fuctional as it express its highest efficirncy (Lago, 2009). While, when vegetative oil is transformed into biodiesel around 27%, of energy is utilized just for moving forward the required procedures for the conversion.

For clarifying the above statement, Table 2 shows the energy balance for an oil seed rape crop, which includesthe technical energy required for manufacturing the chemical energy contained into the agrochemical products, but does not considers the internal energy inside these individual chemicals components.

For the particular case of raising a castor oil plant; soil preparation, drilling and growing the crop requires technology, energy, inputs and intervention of man for the whole process. The objective is to generate chemical energy contained inside the plant's biological mass, although, inputs coming from physical and chemical energy are larger that the energy required for the non-biological processes.

Generally, there are at least four typical ways for energy consumption during castor oil plant developing; a) technical energy required for mechanizing crop production, it was estimated to be equal to 12123968.96 kcal operating on one hectare plot, b) expenditure of energy other than just for wellbeing supplied by human beings themselves within all processes (Kristen, 2009), their work was concentrated on managing the whole mechanized operations and decision making, being equal to 356402 kcal/ha, c) chemical energy when introducing the chemical components, there was not application of agrochemicals to the crop so there was only energy from photosynthesis converted into chemical energy through biological matter, therefore, the latter does not account for the calculation and d) technical energy expenditure because of transportating all kind of goods, it was calculated to be equal to 2864036.77 kcal. Thus, total energy provided to produce the crop amounted 15344407.77 kcal/ha.

Table 2. Energy balance for an oil seed rape crop projected to obtain biodiesel.

	Energy (MJ/ha[*1])	**Energy (MJ/t.m.s.[*2])**
Cultural practices	1632.64	1168.67
Loading	450.76	322.66
Fertilizing	112.94	80.85
Harrow	141.18	101.06
Cultivator	262.18	187.68
Seeding	166.39	119.10
Harrow	141.18	101.06
Protection treatments	254.12	181.90
Harvesting	262.18	187.68
Fertilizer manufacturing	5385.67	3855.17
Pesticides manufacturing	658.40	471.29
Transportation	626.83	448.69
Total	**8303.53**	**5943.83**

[*1]production of seed is included, coefficient 1.0089 [*2]oil seed rape, yield of 1397 tone of dry matter/ha.

The above types of energy can be categorized into three general kinds, according to the technological point of view: a) sources or type of energy, b) to generate energy useful for tasks that are to be realized by man and c) energy inside the products or items produced or as a result from the activities of man.

Results

Throughout the analysis of energy flows, it can be established the energy flows, the identification of individual and entire energy demand and determinate the whole energy performance, which is revealed by means of the net gain and also by the ratio of energy made available over the invested energy.

Table 3 shows the final results obtained when measuring the technical energy from a trademark calorimeter LECD-350 for the castor oil palm are: a) net energy generated from the oil per hectare is 1,434.42 Mcalories and b) the energy generated from the whole castor oil plant per hectare is 4,801.17 Mcalories. Thus the net energy generated from the whole castor oil plant plus oil obtained from seeds is 6,235.59 Mcalories (González-Muñoz, 2014).

Therefore, only 29.86% of this technical energy generated from the plant in the form of biological mass is equal to the chemical energy that can be used from the oil, where 27% of that energy is utilized for the whole processing for converting it into biodiesel. Figure 1 shows that castor oil plant's seeds have the largest concentration of energy.

Thus, using raw oil has a better energy balance than biodiesel which has an additional lost of 27% energy required for conversion process (Ortíz-Laurel et al., 2012). On the other hand, processing the whole castor plant in a pyrolysis reactor has a much better energy balance with 27% less losses and contains double energy compared to that of pure raw oil. Also, seeds have the best contribution as in the pyrolysis reactor they got 25% more energy than pure raw oil and there is an energy saving instead of energy waste for seed preparation for oil extraction and equally for the oil extraction process itself.

Table 3. Energy determination for each part from the castor oil plant.

Part of the plant	**Energy (cal/g)**	**Energy (%)**
Seed (44% of oil)	6,331.14	35.2
Stem	4,267.07	25.9
Roots	4,900.03	10.0
Skin from seed pods and seeds' skin	3,812.80	8.6

(residue) - 99.9% (oil extraction)		
Leaves	3,637.72	20.3
Whole castor oil plant	4,589.75	100.0
oil	9,880.72 (8.852.06)	29.86

Thus, for this study the result for the energy balance is a simple calculation among total input energy to produce the castor oil crop (15344407.77 kcal/ha) less total energy the crop could provide (6235588.4 kcal/ha), which equals to 9108819.37 kcal/ha. So, energy balance is negative as 146% dditional energy is provided to produce the crop.

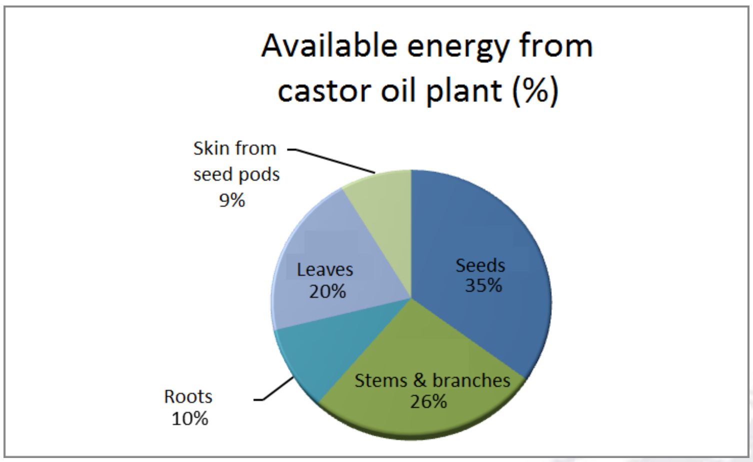

Figure 1. Average energy concentration from castor oil plant's sections.

On average, the dry matter figure for one year old entire castor oil plant is 0.984 kg, while for considering specific parts from the plant, the following figures are: seeds have a dry matter of 0.212 kg; steam and branches have a figure of 0.342 kg; leaves represent a dry matter of 0.331 kg; while skin of seed pods stand for 0.126 kg. the above determination was realized from sampling castor oil plants from a plot having 1952 plants per hectare.

During the study there was the opportunity for collecting seeds from castor oil plants in the central region of México. Although, weight of sample was to be almost constant, there was difference between seeds, regarding quantity, size and color which coincide with Nunes da Silva (2010). The aim was to evaluate their heat value and reviewing the results, detect factors that contribute to any difference which will aid to select the most promising plant, in order to research for genetic potential. Seeds were tested in a trademark calorimeter LECO-350 by following the manufacturer standard procedure and Table 4 shows heat values from those seeds. Average heat values indicate that there is not a real difference between figures for different seeds (mean equals to 6,474.12 cal/g and standard deviation equals to 1.98%). therefore, it can be said that on average, different seeds have the same energy regardless the site of origin for the central region of México.

Table 4. Measured heat value in the calorimeter LECO-350 for regional samples of seeds from castor oil plants.

Origin sites	**Seeds (weight of sample, g)**	**Calories/g**
Fraacionamiento Soledad, Ags	7.030	6416.9
Tecuan, Jalisco	7.079	6603.0
Calvillo, Ags	6.976	6513.6
Moctezuma, SLP	7.061	6434.7
Venado, SLP	7.058	6384.1
Corte Primero – Mexquitic, SLP	7.079	6420.2
Capulines, SLP	7.066	6546.9
Luis Moya, Zac	7.030	6418.6
El Orito, ZAC	7.039	6447.4
Noria San Marcos, Zac	7.006	6501.3
Villa Hgo., Jal	6.998	6319.7
Encarnación de Díaz, Jal	7.039	6628.6
Salinas, SLP	6.992	6532.5
Milpillas, Mexquitic, SLP	7.005	6355.2
Ranchería Guadalupe, Mexquitix, SLP	7.057	6376.9
San José de Gracia, Ags	7.043	6884.1
Tepezala, Ags	7.051	6497.4
Las Moras, Mexquitic, SLP	7.037	6379.1
Francia Chica, Cd. Del Maíz, SLP	7.023	6346.9
San Antonio, Cd. Del Maíz, SLP	6.993	6475.2

Conclusions

Energy balance to produce castor oil crop is negative as it requires 146% additional energy. Pure raw castor oil from seeds has better energy balance than converting it to biodiesel. Producing biodiesel from oil generates a loss of 27% to the net balance. Processing the whole castor oil plant inside a pyrolysis reactor has the best energy balance at all, generating twice the energy than by using the pure raw oil. Entire seeds have the leargest contribution to the highest energy balance figure, as the energy coming from the pyrolysis reactor was 25% much better than that obtained from the pure raw oil.

References

Adilson Nunes da Silva, A., Libório Romanelli, and Reichardt, K. (2010). Energy flow in castor bean (Ricinus communis L.) production systems. Sci. Agric. 67(6): 737-742.

Amaya Ramirez B., Becerra Bayona S. y Acevedo Pabón P. (2008). Evaluación del análisis del ciclo de vida para la producción de biodiesel a partir de aceite de higuerilla empleando la metodología “de la cuna a la cuna”. Revista ION. 21(1): 17-26.

Borjesson P. (1996). Energy analysis of biomass production and transportation. Biomass and Bioenergy. 11: 305-318.

Chang j., Dennis Y., Leung C., Wu CZ. (2003). A review on the energy production, consuption and prospect of renewable energy in China. Renewable and Sustainable Energy Reviews. 7: 453-468.

Delgado A., Aperador-Chaparro W. and Parra-Plazas J. (2013). Comparison of the behavior of biofuel base don castor and sunflower oils. TECCIENCIA. 7(14): 54-60.

Fuentes-Martínez E.F., Pérez-Murguía J. and Jiménez-Domínguez R.V. (2013). Energy balance of biodiesel for five sources recommended for México. Proceedings of the 4th International Congress on Alternative Energies. México city. P. 64-69.

Girard, P. and Fallot, A. (2006). Review of existing and emerging technologies for the production of biofuels in developing countries. Energy for Sustainable Development. X(2): 92-108.

González-Muñoz L. (2014). Determination of energy balance for castor oil plant cropping (Ricinus communis). Technical Report. Colegio de Postgraduados, Campus San Luis Potosí, Salinas de Hgo. S.L.P. México. 90p.

Hall DO. (1997). Biomass energy in industrialized counties: a view of the future. Forest Ecology and Management. 91: 17-45.

Kerstin, P. (2009). So viel brauch der mensch: Energiebedarf. Pharmazeutische Zeitung. 6: 36-37.

Lago, R.C.C. (2009). Castor and jatropha oils: production strategies – A review. OCL Journal. 16(4): 241-247.

Meier M.A.R., Metzger O., Schubert U.S. (2007). Plant oil renewable resources as green alternatives in polymer science. Chemical Society Review. 36: 1788-1802.

Ortíz Laurel H., Rossel Kipping D. and Schumann U. (2012). Potencial para el uso directo de los aceites vegetales en los motores de combustion (Feasability for direct usage of vegetable oils as fuel into internal combustion engines). Revista Mexicana de Ciencias Agrícolas. 4: 650-658.

Saribiyik, O.Y., Ozcanli, M., Serin, H., S. and Aydin, K. (2010). Biodiesel production from ricinus communis oil and its blends with soybean biodiesel. Journal of Mechanical Engineering. 56(12): 811-816.

Sepúlveda González I. (2012). Bioturbosina. Producción de cultivos energéticos para la aviación comercial. Rev. Mex. Cienc. Agríc. 3(3): 579-594.

Yusuf, A.K. Mamza, P.A.P. Ahmed, A.S. and Agunwa, U. (2015). Extraction and characterization of castor seed oil from wild ricinus communis linn. International Journal of Science, Environment and technology. 4(5): 1392-1404.