Advances in Bioresearch
Adv. Biores., Vol 8 (4) July 2017: 05-10

Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
DOI: 10.15515/abr.0976-4585.8.4.510

Advances in Bioresearch

ORIGINAL ARTICLE

Energy Analysis of Canola Production in Iran using Linear Programming

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ABSTRACT
The aim of this study was conducted to essay energy use efficiency in the canola production systems in Kermanshah province of Iran. For this study data was collected using questionnaires and face to face interview with 120 farmers. Results showed that total inputs energy in canola production systems was 37944 MJ ha-1.The amount of energy use efficiency, Energy productivity and net energy was 2.1, 0.08 Kg/MJ and 42213 MJ/ha respectively. result of this study show that by optimization of energy inputs total energy input reduced 6781 MJ/ha. It was concluded that extension activities are needed to improve the efficiency of energy consumption in maize production.
Key Words: *canola, energy, productivity and linear programming*

Received 14/02/2017 Revised 10/05/2017 Accepted 08/06/2017

How to cite this article:
S A Abadi, A M Damghani. Energy Analysis of Canola Production in Iran using Linear Programming. Adv. Biores., Vol 8 [4] July 2017: 05-10.

INTRODUCTION

The high rate of population growth and reducing the extent of fertile land due to the increasing development of urban and industrial areas induce more efficient use of existing facilities. The effective and efficient use of limited resources like water, soil and human power that are of particular importance to provide food requirements for people in developing countries, including Iran [1]. In the developed countries, an increase in the crop yield was mainly due to an increase in the commercial energy inputs in addition to improved crop varieties [2]. Generally, land productivity is measured as the total measure of crop productivity. The yield that is the amount of crop produced per unit area (Kg ha-1), has been considered as the total measure of productivity [3]. Many experimental works have been conducted on energy use in agriculture [4]. Cetin and Vardar [5] studied on differentiation of direct and indirect energy inputs in agro-industrial production of tomatoes. Erdal *et al* [6] have studied on energy consumption and economical analysis of sugar beet production. Damirjan *et al.* [7] studied the energy and economic analysis of sweet cherry production. Alam *et al.* [8] studied the energy flow in agriculture of Bangladesh for a period of 20 years.
Canola is an important oil crop growing in many part of the world. Canola in Iran is mostly cultivated as a winter annual for oil production and rarely livestock feed. It can be planted in spring as well as can be grown in summer but the seed yield would be decreased due to short growing season and lack of enough water at the end of growing season, thus, winter cropping is preferred. [9].The energy consumption in the agricultural sector depends to the population employed in the agriculture, the amount of cultivable land and the level of mechanization [10]. An energy analysis is vital for proper management of scarce resources to improve agricultural production. On account of this, we will have efficient and economic production. Moreover, determination of energy consumption in every level of production, help us to obtain which level has the minimum input energy [11]. Nowadays, in addition common methods, some new methods are invented. One of these modern methods is linear programming.

The objective of the present study was to energy analysis in canola production on in Iran in terms of energy use efficiency, energy productivity, specific energy, and net energy.

MATERIALS AND METHODS

The total area of Kermanshah province is 2499800 ha, and the farming area is 880095 ha. canola is the important agricultural commodity in Kermanshah province.

The study investigated 120 canola producers in Kangavar County. The size of each sample was determined using Eq. (1) derived from Neyman technique [21].

$$n = \frac{(\sum N_h S_h)}{N^2 D^2 + \sum N_h S^2{}_h} \qquad (1)$$

where n is the required sample size; N is the number of holdings in target population; Nh is the number of the population in the h stratification; Sh is the standard deviation in the h stratification, Sh2 is the variance of h stratification; d is the precision where $(\bar{y} - \bar{Y})$ is the reliability coefficient (1.96 which represents the 95% reliability); D2=d2/z2. For calculation of sample size, criteria of 5% deviation from population mean and 95% confidence level were used. Thus, the number of 120 was considered as sampling size, and these 120 farms were selected randomly. In canola production agro-ecosystems of this region input energy sources included human labor, machinery, diesel fuel, fertilizers (N, P), chemicals, irrigation water and seeds; while output energy sources was canola grain yield. In this study energy use efficiency, energy productivity, net energy, water productivity and water-energy productivity together were determined applying standard equations 2-4 [3, 12-14].

$$Energy\ use\ \ efficienc\ y = \frac{Output\ Ene\ rgy\ (MJha^{-1})}{Input\ Ener\ gy\ (MJha^{-1})} \qquad (2)$$

$$Energy\ pro\ ductivity = \frac{Grain\ yiel\ d\ (Kgha^{-1})}{input\ ener\ gy\ (MJha^{-1})} \qquad (3)$$

$$Net\ energy = output\ energy\ (MJha^{-1})\text{-}input\ energy\ (MJha^{-1}) \qquad (4)$$

The input and output were calculated per hectare and then, these input and output data were multiplied by the coefficient of energy equivalent. The data was transformed to energy term by appropriate energy equivalent factors given in Table 1.

Table1. Energy equivalents of input and output in canola production systems.

Equipment /Inputs	*Unit*	*Energy equivalents*	*Reference*
A. Inputs			
Human Labor	H	1.96	[15]
Machinery	H	62.7	[6, 16]
Diesel fuel	L	47.8	[17]
Chemical Fertilizer	Kg		
(a) Nitrogen		64.4	[18]
(b) Phosphate (P2O5)		11.6	[10]
Pesticides	*Kg*	*114*	[10]
Electricity	*MJ*	*1*	[19]
Water for Irrigation	M^3	0.63	[16, 20]
Seed	Kg	3.6	[3]
Output			
yield	Kg	25	[10]

In order to optimization of energy productivity linear programming was used. Linear programming is the most powerful technique that can resolve various issues with regard to the conditions apply. A linear programming model has objective function and constrains. Objective function is a mathematical function that consists of decision variables and shown with (Z). It is indicator of model Objective. This function represents maximize utility or minimize the cost as following (Sidho *et al.*, 2004).

$$\text{Max } Z = f(x_j) \qquad j = (1, \ldots, n) \qquad (5)$$

OR

$$\text{Min } Z = f(x_j) \qquad j = (1, \ldots, n) \qquad (6)$$

$$Z = c_1 x_1 + c_2 x_2 + \ldots + c_n x_n \quad (7)$$

Constrains consisting of an equation or no equation from decision variables that express the limitations of the model or decision in order to research the model objectives and shown with (C).
Status of decision variables is similar to one of two following case:

$$x_j \geq 0 \qquad j = (1, \ldots, n) \quad (8)$$

or free mark decision variable (xj) that can be in the case of positive values, negative or zero.
Constrain include all limitation can be met on each inputs consumption or yield production. Constrains are as follows;

$$\begin{aligned} & a_{11}\, x_1 + a_{12}\, x_2 + \ldots + a_{1n}\, x_n \ (\leq \text{OR} \geq \text{OR} =)\ b_1 \\ & \vdots \\ & a_{i1}\, x_1 + a_{i2}\, x_2 + \ldots + a_{in}\, x_n \ (\leq \text{OR} \geq \text{OR} =)\ b_i \\ & \vdots \\ & a_{m1}\, x_1 + a_{m2}\, x_2 + \ldots + a_{mn}\, x_n \ (\leq \text{OR} \geq \text{OR} =)\ b_m \\ & \vdots \\ & x_1, x_2, \ldots, x_n \geq 0 \ \text{OR (free mark decision variables)} \end{aligned} \quad (9)$$

In this study with linear programming and considering all the conditions and limitations the optimal pattern were determining. Solving of problem was done by the WINQSB software.

RESULTS AND DISCUSSION

Analysis of Input-Output Energy Use

The number of 120 farms was considered as sampling farms and the inputs used and output in canola production systems in the studied area and their energy equivalents with output energy rates are shown in the Table 2.

Table2. Energy equivalents of input and output in canola production systems.

Equipment /Inputs	*Quantity used per unit area (ha)*	*Energy equivalents*
Human Labor	23	42.6
Machinery	16	1012.6
Diesel fuel	119.8	5730.4
Nitrogen Fertilizer	71.25	4573.6
Phosphate (P2O5) Fertilizer	29.9	331.8
Pesticides	*2.4*	280.7
Seed	8.9	32.2
Water for Irrigation	4012	2528
Electricity	*23408*	23408
Total energy input		37944
B. total energy Output	3246	81158

Total energy requirement for producing the canola crops was 37944 MJ ha-1. Ozkan *et al* [22] reported that the total input energy in greenhouse and open field grape production were 24513.0 and 23640.9MJha^{-1} that of this amount the highest share was related to electricity(28%) in greenhouse cucumber production and diesel fuel(32%) in open-field systems. In this study the average annual yield for canola production systems were found to be 3246 kg ha^{-1} and that their total energy equivalent was 81158 MJha^{-1}.
The share of important energy inputs of total inputs energy are shown approximately in Figure 1. The highest share of total energy input was recorded for electricity (61.1%), diesel fuel (15%) and N fertilizer (12%) respectively. Ozkan *et al* [10] reported that the highest share of total input energy for greenhouse tomato, cucumber and eggplant was related to diesel fuel by 32.17, 42.64, and 31.30 percent, respectively.
Indicators of energy use in canola production systems are shown in table 3. The amount of energy use efficiency was 2.1. Energy use efficiency in open-field systems was reported 2.80 for maize in Turkey [23], 1.04 for chickpea in Iran [24], 2.12 and 2.05 for organic and non organic lentil [25], 1.58 for kiwifruit in Iran [26]. Energy use efficiency was 0.32, 0.19, 0.31, and 0.23 for greenhouse tomato, pepper, cucumber and eggplant respectively [23]. Energy use efficiency can be increased by improving crop biomass

production or reducing energy application. Energy productivity was 0.08 $KgMJ^{-1}$. Amount of energy productivity was 0.65 $MJkg^{-1}$ for sugar beet [6], 10.43 $MJkg^{-1}$ for irrigated wheat [27], and 5.87 $MJkg^{-1}$ for rainfed wheat in Turkey [28]. Net energy (total output energy minus total input energy), in canola production systems was 43213 $MJha^{-1}$.

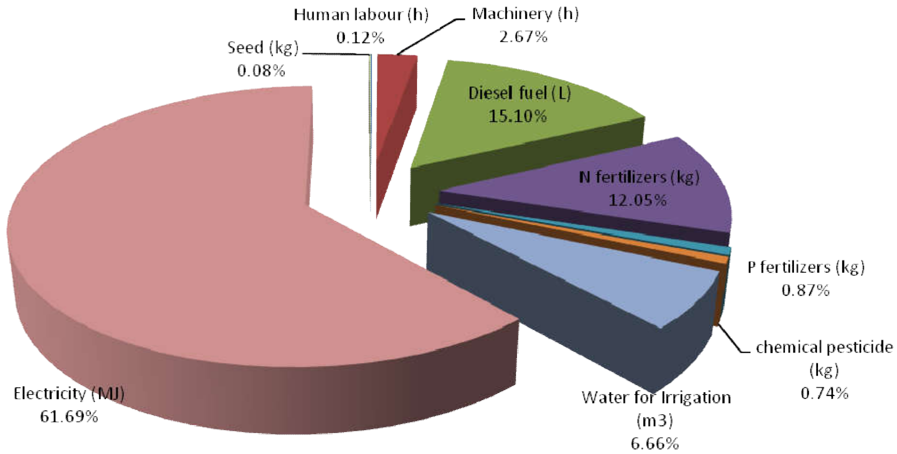

Figure 1- Share of important energy inputs of total input energy

Table 3. Indicators of energy use in canola production systems.

Indicators	*Quantity*	*Unit*
Inputs Energy	37944	MJ ha^{-1}
Output Energy	81158	MJ ha^{-1}
Grain Yield	3246	Kg ha^{-1}
Energy Use Efficiency	2.1	%
Energy Productivity	0.08	Kg MJ^{-1}
Net Energy	43213	MJ ha^{-1}

Optimization energy consumption pattern

For optimizing of energy consumption pattern WINQSB Software was used. To solving the problem an objective function with constraints was designed. Solving of problem was done by Simplex method. Generally, inputs used in canola production in this region was divided into 9 groups including that: labor (x1), machinery (x2), diesel fuel (x3), N fertilizer (x4), P fertilizer (x5), Pesticides (x6), seed (x7), water for irrigation (x8) and Electricity(x9). In this study objective function is maximizing energy productivity. One of the ways for the maximizing energy productivity is minimizing amount of energy input. Objective function is equal to;

$$Z = \text{Maximize } E_p = \text{Maximize} \frac{y}{\sum x_i e_i} \qquad i = (1, 2, \ldots, 8) \qquad (10)$$

$$Z = \text{Minimize } E_{in} = \text{Minimize} \sum x_i e_i \qquad i = (1, 2, \ldots, 8) \qquad (11)$$

$$x_i e_i \geq e_i \qquad (12)$$

$$x_i \geq A_i \qquad (13)$$

$$e_i \geq 0 \qquad (14)$$

$$Z = \text{Minimize}(1.96x_1 + 62.7x_2 + 47.8x_3 + 64.4x_4 + 11.1x_5 + 114x_6 + 3.6x_7 + 0.63x_8 + 1x9) \qquad (15)$$

where EP is energy productivity, E_{in} is total energy input, x_i is amount of used input, Ai is the minimum amount recommended, e_i is energy equivalent of x_i, and x1, x2, x3, x4, x5, x6, x7, x8 and x9 is quantity of labor, machinery, diesel fuel, N fertilizer, P fertilizer, Pesticides, seed, water for irrigation and Electricity respectively.

Constrains result from regional conditions, expert analysis's and production system by interview with growers and including:

$$C_1 : 16 \leq x_1 \leq 35 \quad (16)$$
$$C_2 : 10 \leq x_2 \leq 23 \quad (17)$$
$$C_3 : 100 \leq x_3 \leq 145 \quad (18)$$
$$C_4 : 49.5 \leq x_4 \leq 99 \quad (19)$$
$$C_5 : 23 \leq x_5 \leq 46 \quad (20)$$
$$C_6 : 1.5 \leq x_6 \leq 3.5 \quad (21)$$
$$C_7 : 6 \leq x_7 \leq 12 \quad (22)$$
$$C_8 : 3400 \leq x_8 \leq 4600 \quad (23)$$
$$C_9 : 19833 \leq x_9 \leq 26833 \quad (24)$$
$$C_{10} : x_1 + x_2 \geq 27 \quad (25)$$
$$C_{11} : x_3 + x_4 + x_5 \geq 182.5 \quad (26)$$
$$C_{12} : x_6 + x_7 \geq 8 \quad (27)$$
$$C_{13} : x_8 + x_9 \geq 23233 \quad (28)$$

Results of optimization energy consumption pattern were shown in Table 4.

Table 4.Optimized amount of energy inputs and energy saved.

Equipment /Inputs	*Optimize quantity*	*Energy equivalents (MJ/ha)*	*Energy saved(MJ/ha)*
Human Labor (h)	17	33.3	12.9
Machinery (h)	10	627	399
Diesel fuel (l)	100	4780	950
Nitrogen Fertilizer(kg)	49.5	3187	1386
Phosphate (P2O5) Fertilizer (kg)	33	366	-
Pesticides (kg)	*1.5*	*171*	109
Seed (kg)	6.5	23.4	8.8
Water for Irrigation (m3)	3400	2142	386
Electricity (MJ)	*19833*	*19833*	3575
Total energy input (MJ)		31163	6781

By optimization of energy inputs(Human labor, Machinery, Diesel fuel, Nitrogen Fertilizer, Pesticides, seed, water for irrigation and Electricity) reduced 12.9, 399, 950, 1386,109, 8.8, 386 and 3575 MJ ha^{-1} respectively. Total energy input reduced 6781 MJ ha^{-1}. In this status energy efficiency, energy productivityand net energy were 2.6, 0.1 Kg $MJ^{-1}$and 49995 MJ ha^{-1}respectively. Indicators of energy use in canola production systems with optimized status are shown in table 5.

Table 5. Indicators of energy use in canola production systems with optimized status

Indicators	*Quantity*	*Unit*
Inputs Energy	31163.8	MJ ha^{-1}
Output Energy	81158	MJ ha^{-1}
Energy Use Efficiency	2.6	%
Energy Productivity	0.1	Kg MJ^{-1}
Net Energy	49995	MJ ha^{-1}

CONCLUSION

In this study, the energy flow of canola production systems in Kermanshah province, western part of Iran has been investigated. Total energy consumption in canola production was 37944MJ/ha MJ ha-1. The energy input of electricity had the biggest share (61%) of total energy inputs. Results shows that reduce in electricity consumptions are important for energy saving and decreasing the environmental risk problem in the area. By optimization of energy input total energy reduces to 6781 MJ ha-1. The results of this study indicate that in order to optimize energy pattern all of the energy inputs except Phosphate (P_2O_5) Fertilizer must be reduce.

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