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Energy input-output analysis of guar (*Cyamopsis tetragonoloba*) and lupin (*Lupinus albus* L.) production in Turkey

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ABSTRACT

The aim of this research is to compose an energy input-output of guar and lupin production during the production season of 2015 in Bingol province of Turkey. The energy input in guar and lupin production have been computed as 14 619.97 MJ ha^{-1} and 23 486.73 MJ ha^{-1}, respectively. The energy output in guar and lupin production have been calculated as 43 767.21 MJ ha $^{-1}$ and 16 554.41 MJ ha^{-1}, respectively. Energy usage efficiency, specific energy, energy productivity and net energy in guar production have been calculated as 2.99, 6.42 MJ kg^{-1}, 0.16 kg MJ^{-1} and 29 147.24 MJ ha^{-1}, respectively. Energy usage efficiency, specific energy, energy productivity and net energy in lupin production have been calculated as 0.70, 31.95 MJ kg^{-1}, 0.04 kg MJ^{-1} and -6932.32 MJ ha^{-1}, respectively. The total energy input used up in guar production could be classified as 51.31 % direct, 48.69 % indirect, 22.24 % renewable and 77.76 % non-renewable. The total energy input used up in lupin production could be classified as 31.35 % direct, 68.65 % indirect, 33.68 % renewable and 66.32 % non-renewable.

Key words: Energy input-output analysis, Guar, Lupin, Specific energy.

INTRODUCTION

Guar (*Cyamopsis tetragonoloba*) crop is a legume cultivated through natural methods by Indian farmers, and it is also known as castor bean. It is being used as a raw material in pharmaceutical, cosmetics and food industry, it is also a sought-after fodder crop in stockbreeding, as it has about 42 % to 65 % protein in its leaves and seed. Guar is a summer crop and it grows within 3 months, without needing any pesticides, planted during the months of May, June, harvested during August, September and because it leaves behind nitrogen in the field, it regulates the soil hence saving fertilizer when another crop is planted (Anonymous, 2016a).

Lupine (*Lupinus albus* L.) is an annual crop, whose herbaceous body provides green manure and fodder crop, and seeds are used for human and animal nutrition (Baytop, 1994, Yorgancilar *et al.,* 2009). Even though soya ranks first in terms of vegetable protein production, if production and productivity quantities are increased, lupine provides good competition for soya with high protein 28 % to 47.6 % content (Williams, 1979; Sator, 1983; Yorgancilar *et al.,* 2009). Lupine plant contains alkaloids such as lupanin, sparteine and anagyrine, and it is also an important plant for the pharmaceutical industry (Kayserilioglu, 1990; Yorgancilar *et al.,* 2009). In addition, even though it is being used in the world as a raw material in bread, biscuit, muffin, pasta, candy, soya sauce and other similar products, soya alternative, and also used as good quality vegetable oil with high antioxidant content, gluten-free flour, emulsifier matter, alternative product to milk, it is being used as an appetizer and for its alkaloids in Turkey (Mulayim ve Acar, 2008; Yorgancilar *et al.,* 2009).

Nowadays, agricultural systems rely on fossil energies seriously and crop production level is characterized by the high quantity input of it (Tabatabaie *et al.,* 2013; Beigi *et al.,* 2016). However, some public health and environmental problems such as global warming, greenhouse gaseous emission, water source contamination and land degradation are emerged by extra use of energy sources. On the other hand, continual growth of energy prices threats the global agricultural sector. Hence, in order to promote the agriculture section as an economical system; it is necessary for efficient use of energy sources (Mohammadi *et al.,* 2010; Beigi *et al.,* 2016).

Energy efficiency (energy input-output analysis) is closely associated with economic (profitability) and ecological aspects of the chosen farming systems. Energy efficiency and energy balance can be accepted as a vital tool

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to determine the environmental impacts of farming systems. Determination of the energy efficiency makes it possible to compare different farming systems in environment friendly production as well as sustainability of non-renewable natural resources (Celik *et al*., 2010). To determine energy efficiency, energy input–output analyses are usually conducted. These analyses determine how efficiently energy is used (Pervanchon *et al.,* 2002; Beigi *et al.,* 2016).

The proportions of energy inputs, energy usage efficiency, specific energy, energy productivity, net energy, direct energy, indirect energy, renewable, non-renewable energy etc. computations have been done and in the guar and lupin researches. Several researches have been done on wheat, corn and other plant's energy usage efficiency in agricultural production. Some of these researches may be listed as those on the energy usage researches of corn (Ozturk *et al.,* 2006), maize (Vural and Efecan, 2012), canola (Unakitan *et al.,* 2010), soybean (Mandal *et al.,* 2002), wheat (Marakoglu and Carman, 2010; Tipi *et al.,* 2009), sesame (Akpinar *et al.,* 2009), potato (Mohammadi *et al.,* 2008), barley (Mobtaker *et al.,* 2010), grape (Kocturk and Engindeniz, 2009), sugar beet (Haciseferogullari *et al.,* 2003), sunflower (Davoodi and Houshyar, 2009), barley (Azizi and Heidari, 2013; Baran and Gokdogan, 2014), corn silage (Barut *et al.,* 2011) etc. This study does not contain any research regarding the energy input-output analysis of guar and lupin production in Turkey.

MATERIALS AND METHODS

This research has been applied for the whole Bingol province of Turkey (E 41°-20′-39°-56°; N 39°-31′; 36°-28° 1151 m above sea level Anonymous (2016b). The daily difference between highest temperature and lowest temperature has about 20 °C. The annual average temperature of the province is 12.1° C while the annual average precipitation level is 873.70 mm (Anonym, 2016c). Soil structure of the province is clay-loam and loamy (Ates and Turan, 2015). The researches done on trials area have 262.50 (guar) and 102 (lupin) square meters, located at Bingol in 2015. Randomized Complete-Block Design with three replicates has been applied in this research. Human labour, machinery, chemical fertilizers, diesel fuel, irrigation (sprinkler for guar) and seed energy have been calculated inputs. Guar and lupin yields have been computed as output.

In Table 1, the agricultural production inputs, energy equivalents of input and output have been considered as energy values. By adding energy equivalents of all inputs in MJ unit, the total energy equivalents have been computed. Mohammadi *et al.* (2010) reported that, "The energy ratio (energy usage efficiency), energy productivity, specific energy and net energy have been computed by using the following formulates (Mandal *et al.,* 2002; Mohammadi *et al.,* 2008)".

Energy efficiency =
Energy output (MJ ha^{-1}) / Energy input (MJ ha^{-1}) (1)

Energy productivity =
Yield output (kg ha^{-1}) / Energy input (MJ ha^{-1}) (2)

Specific energy =
Energy input (MJ ha^{-1}) / Yield output (kg ha^{-1}) (3)

Net energy =
Energy output (MJ ha^{-1}) - Energy input (MJ ha^{-1}) (4)

Following the analysis of data through Microsoft Excel program, by referring to the inputs, the results have been tabulated. Guar and lupin energy input-output have been done and the computations have been given in Table 2. Kocturk and Engindeniz (2009) reported that; "The input energy can also be classified into direct, indirect, renewable and non-renewable forms (Mandal *et al.,* 2002; Singh *et al.,* 2003)". Energy usage efficiency computations in guar and lupin production have been given in Table 3.

Total fuel consumption of each parcel has been computed as L ha^{-1}. Full tank method has been used to measure the amount of fuel used (Gokturk, 1999; El Saleh, 2000; Sonmete, 2006). Labor time of each parcel (ha h^{-1}) has been calculated by proportion the total time computed for in area of the trial to the areas amount. Using the effective labour time (t_{ef}), while experiments in parcels have been done

Table 1: Energy equivalents of inputs and outputs in guar and lupin production

Inputs and outputs	Unit	Energy equivalentcoefficient	Sources
Inputs	Unit	Values(MJ $unit^{-1}$)	Sources
Human labour	h	1.96	(Karaagac *et al.,* 2011; Mani *et al.,* 2007)
Machinery	h	64.80	(Singh, 2002; Kizilaslan, 2009)
Chemical fertilizers			
Nitrogen	kg	60.60	(Singh, 2002)
Phosphorous	kg	11.10	(Singh, 2002)
Diesel fuel	l	56.31	(Singh, 2002; Demircan *et al.,* 2006)
Irrigation (Sprinkler)	m^3	4.20	(Mrini, 1999; Mrini *et al.,* 2002)
Guar seed	kg	19.213	Measured
Lupin seed	kg	22.523	Measured
Outputs	Unit	Values (MJ $unit^{-1}$)	Sources
Guar yield	kg	19.213	Measured
Lupin yield	kg	22.523	Measured

Table 2: Energy input-output analysis in guar and lupin production

		Guar			Lupin		
Inputs	**Unit**	**Input used per hectare (unit ha $^{-1}$)**	**Energy value (MJ ha $^{-1}$)**	**Ratio (%)**	**Input used per hectare (unit ha $^{-1}$)**	**Energy value (MJ ha $^{-1}$)**	**Ratio (%)**
Human labour	h	685.71	1 343.99	9.19	588.24	1 152.95	4.91
Machinery	h	57.14	3 702.67	25.32	73.52	4 764.09	20.28
Chemical fertilizers		79.22	2 840.03	19.43	158.84	4 602.93	19.59
Nitrogen	kg	39.61	2 400.36	16.42	57.37	3 476.62	14.80
Phosphorous	kg	39.61	439.67	3.01	101.47	1 126.31	4.79
Diesel fuel	l	85.71	4 826.33	33.01	110.28	6 209.86	26.45
Irrigation (Sprinkler)	m^3	316.80	1 330.56	9.11	-	-	-
Seed	kg	30	576.39	3.94	300	6 756.90	28.77
Total inputs			14 619.97	100		23 486.73	100
Outputs	Unit	Output per hectare (unit ha $^{-1}$)	Energy value (MJ ha $^{-1}$)	Ratio (%)	Output per hectare (unit ha $^{-1}$)	Energy value (MJ ha $^{-1}$)	Ratio (%)
Yields	kg	2 278	43 767.21	100	735	16 554.41	100

Table 3: Energy usage efficiency computations in guar and lupin production

		Guar	Lupin
Computes	**Unit**	**Values**	**Values**
Yields	kg ha $^{-1}$	2 278	735
Energy input	MJ ha $^{-1}$	14 619.97	23 486.73
Energy output	MJ ha $^{-1}$	43 767.21	16 554.41
Energy usage efficiency		2.99	0.70
Specific energy	MJ kg $^{-1}$	6.42	22.52
Energy productivity	kg MJ $^{-1}$	0.16	0.04
Net energy	MJ ha $^{-1}$	29 147.24	-6 932.32

(Sonmete, 2006; Guzel, 1986; Ozcan, 1986). Measuring the time spent during agricultural operations in the parcels have been performed with the aid of chronometer (Sonmete, 2006). For calorific values of guar and lupin IKA brand C200 model bomb calorimeter device has been used. For measuring purposes, the amount of fuel (~0.1 g) has been combusted inside the calorimeter bomb. The device has been given a calorific value in MJ kg $^{-1}$ unit. For samples, reading of the calorific value has been measured repetitively for three times and then the average value have been reported in guar and lupin research.

RESULTS AND DISCUSSION

The amounts of guar and lupin produced per hectare during the 2015 production season have been computed as an average of 2 278 kg and 735 kg, respectively. The energy input-output of guar and lupin production related to this study have been showed in Table 2. It can be seen that the highest energy inputs in guar production are as follows: diesel fuel energy by 33.01 %, machinery energy by 25.32 %, chemical fertilizers energy by 19.43 %, human labour energy by 9.19 %, irrigation (sprinkler) energy by 9.11 % and seed energy by 3.94 %. It can be seen that the highest energy inputs in lupin production are as follows: diesel fuel energy by 26.45 %, machinery energy by 20.28 %, chemical fertilizers energy by 19.59 %, seed energy 28.77 % and human labour energy by 4.91 %.

Human labour and diesel fuel energy have been used for tractor and farm operations. According to Table 2, the amounts of chemical fertilizers have been used for guar and lupin producing has 79.22 kg ha $^{-1}$ and 158.84 kg ha $^{-1}$. Guar yield, energy input, energy output, energy usage efficiency, specific energy, energy productivity and net energy in guar production have been computed as 2 278 kg ha $^{-1}$, 14 619.97 MJ ha $^{-1}$, 43 767.21 MJ ha $^{-1}$, 2.99, 6.42 MJ kg $^{-1}$, 0.16 kg MJ $^{-1}$ and 29 147.24 MJ ha $^{-1}$, respectively. Lupin yield, energy input, energy output, energy efficiency, specific energy, energy productivity and net energy in lupin production have been computed as 735 kg ha $^{-1}$, 23 486.73 MJ ha $^{-1}$, 16 554.41 MJ ha $^{-1}$, 0.70, 31.95 MJ kg $^{-1}$, 0.04 kg MJ $^{-1}$ and -6 932.32 MJ ha $^{-1}$, respectively.

The distribution of input energies, applied in the production of guar, in accordance with the direct, indirect, renewable and non-renewable energy groups have been given in Table 4. The total energy input used up in guar production could be classified as 51.31 % direct, 48.69 % indirect, 22.24 % renewable and 77.76 % non-renewable. The total energy input used up in lupin production could be classified as 31.35 % direct, 68.65 % indirect, 33.68 % renewable and 66.32 % non-renewable. Similarly, it has been computed that the ratio of non-renewable energy was higher than the ratio of renewable energy in barley (Mobtaker *et al.,* 2010), wheat (Cicek *et al.,* 2011), sugar beet (Erdal *et al.,* 2007), maize (Vural and Efecan, 2012), sesame (Akpinar *et al.,* 2009), rice (Pisghar-Komleh *et al.,* 2011), lentil (Mirzaee *et al.,* 2011) etc.

In this research, the energy input-output analysis of guar and lupin production have been composed and comparison. As results, guar production is profitable production in terms of energy usage efficiency is 2.99. But,

Table 4: Energy inputs in the form of direct, and direct renewable and non-renewable energy for guar and lupin production

	Guar		Lupin	
Type of energy	**Energy input (MJ ha $^{-1}$)**	**Ratio (%)**	**Energy input (MJ ha $^{-1}$)**	**Ratio (%)**
Direct energy [a]	7 500.88	51.31	7 362.81	31.35
Indirect energy [b]	7 119.09	48.69	16 123.92	68.65
Total	14 619.97	100	23 486.73	100
Renewable energy [c]	3 250.94	22.24	7 909.85	33.68
Non-renewable energy [d]	11 369.03	77.76	15 576.88	66.32
Total	14 619.97	100	23 486.73	100

[a] Includes human labour, diesel fuel and irrigation; [b] Includes seed, chemical fertilizers and machinery;
[c] Includes human labour, seed and irrigation; [d] Includes diesel fuel, chemical fertilizers and machinery.

lupin production is not profitable production in terms of energy usage efficiency is 0.70. Because, guar yields (2 278 kg ha^{-1}) are higher than lupin yields (735 kg ha^{-1}). Lupin energy outputs (16 554.41 MJ ha $^{-1}$) are higher than guar outputs (43 767.21 MJ ha $^{-1}$). And, guar energy inputs (14 619.97 MJ ha^{-1}) are lower than lupin inputs (23486.73 MJ ha^{-1}). According to evaluations of trials results, guar production is more profitable than lupin and guar energy input is lower than lupin energy input. The ratio of non-renewable energy is higher than the ratio of renewable energy in guar and lupin. In previous studies, Marakoglu and Carman (2010) computed energy output / input ratio as 2.81 for wheat, Vural and Efecan (2012) computed energy output / input ratio as 0.76 for maize, Unakitan *et al.* (2010) computed energy output / input ratio as 4.68 for canola, Akpinar *et al.* (2009) computed energy output / input ratio as 1.80 and 1.40 for sesame, Mobtaker *et al.* (2010) computed energy output / input ratio as 2.86 for barley, Karaagac *et al.* (2011) computed energy output / input ratio as 3.50 and 6.54 for wheat and maize etc.

In guar and lupin researches, diesel energy, machinery energy and chemicals fertilizers energy have highest inputs. Demircan *et al.* (2006) pointed out that, "Accurate fertilization management, knowing the correct amount and frequency of fertilization (Kitani, 1999) and proper tractor selection and management of machinery to decrease direct use of diesel fuel (Isik and Sabanci, 1991) have needed to save non-renewable energy sources without impairing the yield or profitability, in order to improve the energy usage efficiency of sweet cherry production". For decrease of inputs of guar and lupin production, these notices may apply for bitter guar and lupin production.

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