Determination of Energy Use Efficiency of Sesame Production

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In this research it was aimed to determine an energy use efficiency of sesame production in Şanlıurfa province, during the production season of 2015. In order to determine the energy use efficiency of sesame production, trials and measurement were performed in sesame farm in the Bozova district of Şanlıurfa province. As energy inputs, human labour energy, machinery energy, chemical fertilizers energy, irrigation water energy, chemicals energy, diesel fuel energy and seed energy as were calculated. As output energy, sesame grain was calculated. The energy input and output were calculated as 9627.21 MJ ha^{-1} and as 14625 MJ ha^{-1} in sesame production. Energy inputs consist of chemical fertilizers energy by 5511.30 MJ ha^{-1} (57.25%), diesel fuel energy by 2083.47 MJ ha^{-1} (21.64%), machinery energy by 1289.52 MJ ha^{-1} (13.39%), human labour energy by 487.84 MJ ha^{-1} (5.07%), irrigation water energy by 136.08 MJ ha^{-1} (1.41%), seed energy by 68.40 MJ ha^{-1} (0.71%) and chemicals energy by 50.60 MJ ha^{-1} (0.53%), respectively. Energy use efficiency, specific energy, energy productivity and net energy in sesame production were calculated as 1.52, 19.98 MJ kg^{-1}, 0.06 kg MJ^{-1} and 4997.79 MJ ha^{-1}, respectively.

Key Words: Energy use efficiency, specific energy, sesame

Susam Üretiminde Enerji Kullanım Etkinliğinin Belirlenmesi

Bu araştırmada, Şanlıurfa ilinde 2015 yılı üretim sezonunda susam üretiminde enerji kullanım etkinliğinin belirlenmesi amaçlanmıştır. Susam üretiminin enerji kullanım etkinliğini belirlemek için denemeler ve ölçümler Şanlıurfa ilinin Bozova ilçesindeki susam işletmesinde yapılmıştır. Enerji girdileri olarak insan işgücü enerjisi, makine enerjisi, kimyasal gübre enerjisi, sulama suyu enerjisi, kimyasal enerji, dizel yakıt enerjisi ve tohum enerjisi hesaplanmıştır. Çıktı enerjisi olarak ise susam ürünü hesaplanmıştır. Susam üretiminde toplam enerji girdisi 9627.21 MJ ha^{-1} ve toplam enerji çıktısı 14625 MJ ha^{-1} olarak hesaplanmıştır. Enerji girdileri sırasıyla kimyasal gübre enerjisi 5511.30 MJ ha^{-1} (%57.25), dizel yakıt enerjisi 2083.47 MJ ha^{-1} (%21.64), makine enerjisi 1289.52 MJ ha^{-1} (%13.39), insan işgücü enerjisi 487.84 MJ ha^{-1} (%5.07), sulama suyu enerjisi 136.08 MJ ha^{-1} (%1.41), tohum enerjisi 68.40 MJ ha^{-1} (%0.71) ve kimyasal ilaç enerjisi 50.60 MJ ha^{-1} (%0.53)'dır. Susam üretiminde enerji kullanım etkinliği, spesifik enerji, enerji verimliliği ve net enerji hesaplamaları sırasıyla 1.52, 19.98 MJ kg^{-1}, 0.06 kg MJ^{-1} ve 4997.79 MJ ha^{-1} olarak hesaplanmıştır.

Anahtar Kelimeler: Enerji kullanım etkinliği, spesifik enerji, susam

Introduction

Sesame (*Sesamum indicum*) is an important oil seed crop believed to have originated from tropical Africa. The name sesame is used in literature world wide. Sesame can be used for confectionery, biscuits, animal feeds, fertilizers, medicinal treatment and as solvents (Ibrahim 2011). Agriculture is considered as an energy conversion process – the conversion of solar energy through the photosynthetic process to grow food and fibber for human and feed for animals. Ancient agriculture included strewing seeds on the land and accepting the deficient yields that resulted. Today's agriculture, on the other hand, is the application of energy to get required yield results (Stout 1990; Khan et al. 2010). Efficient use of energy in agriculture will minimize environmental problems, prevent devastation of natural resources, and advance sustainable agriculture as an economic production system (Erdal et al. 2007).Energy performs a key role in economic and social growth, but rural energy growth policies that focus on agriculture have not been pointed. Not only agriculture serves a dual role as an energy user, but also energy supplier in the form of bio-energy. Agriculture offers important rural growth opportunities as well as one means of climate change emission by substituting bio-energy for fossil fuels (FAO, 2000; Özkan et al. 2011).

Several researches were performed on energy analysis of agricultural products. Some of these researches may be listed as those on the energy usage activities of sesame(Akpınar et al. 2009), soybean (Mandal et al. 2002), sugar beet (Hacıseferoğulları et al. 2003), wheat (Shahan et al. 2008), corn (Öztürk et al. 2006), lentil (Moraditochaee et al. 2014), corn silage (Barut et al. 2011), cotton (Polat et al. 2006), wheat and maize (Karaağaç et al. 2011),carrot (Çelik et al. 2010), chick pea (Marakoğlu et al. 2010), sunflower (Baran et al. 2016), mustard (Mandal et al. 2002), rice (Pishgar-Komleh et al. 2011), bean (Yaldız et al. 1993), walnut (Gündoğmuş, 2013), lavender (Gökdoğan 2016), barley (Baran and Gökdoğan 2014) etc. There is no published study on the energy use efficiency analysis of sesame production in Bozova-Şanlıurfa. In this research was performed to determine an energy efficiency analysis of sesame production in Şanlıurfa province in 2015.

Material and Method

Material

Bozova is a district of Şanlıurfa Province in the South-eastern Anatolian Region, surrounded by Halfeti district in the west, Birecik in southwest, Suruç in south, Central Şanlıurfa in southeast and east, Hilvan in northeast, and the Province of Adıyaman in the north. Soil of the district is being irrigated by Bitik Creek and Macunlu Creek, branches of the Euphrates River. 38 km away from the central province, the district has a land area of 1.550 km^2. Dominated by continental climate, summer months are arid and very hot winter months are wet and partially mild (Anonym 2016a). General soil structure are brown forest soil and alluvium soil (Anonymous 1971).

The province has continental climate characteristics and during the 1929-2012 period the average precipitation level was 453.7 kg m^{-2}, but in 2012 this value has been measured as 622.7 kg m^{-2}. Şanlıurfa had an average temperature value of 18.4 during the 1929-2012 period, but in 2012 this value has increased to 19.3 °C. The highest temperature during the 1929-2012 period was 46.8 °C and in 2012, the highest temperature was 44.2 °C, while the lowest temperature during the 1929-2012 period was -12.4 °C, in 2012, it was measured as -4.3 °C(Anonym 2016b). To perform the energy usage efficiency analysis of sesame, a farm located in Bozova in the province of Şanlıurfa in Turkey in 2015. The research on trials plot 300 m^2 were applied in complete randomized parcel design and three replicates were applied in this research. Human labour energy, machinery energy, chemical fertilizers energy, chemicals energy, diesel fuel energy, irrigation water energy and seed energy were calculated as inputs. Sesame grain was calculated as output.

Method

Total fuel consumption of each parcel was calculated as l ha^{-1}. Full tank method was used to measure the amount of fuel was used (Göktürk 1999; El-Saleh 2000; Sonmete 2006). Labor yield of each parcel (ha h^{-1}) was calculated by quantity the total time calculated for in parcel of the trial to the area amount. Using the effective labour time (t_{ef}), while experiments in parcels were conducted (Güzel 1986; Özcan 1986; Sonmete 2006). Measuringthe time spent duringagricultural operations in the parcels was with the aid of chronometer (Sonmete 2006). Following the measures conducted in sesame in Şanlıurfa province, energy input and output values were performed. In the sesame agricultural production was given in Table 1, energy equivalents of input and output were taken as energy values. Energy efficiency calculations were made to determine the productivity levels of sesame production. The energy ratio (energy efficiency), energy productivity, specific energy and net energy were calculated by using the following formulates (Mandal et al. 2002; Mohammadi et al. 2008; Mohammadi et al. 2010).

Energy usage efficiency $= \dfrac{\text{Energy output } (\frac{\text{MJ}}{\text{ha}})}{\text{Energy input } (\frac{\text{MJ}}{\text{ha}})}$ (1)

Specific energy $= \dfrac{\text{Energy input } (\frac{\text{MJ}}{\text{ha}})}{\text{Sesame energy output } (\frac{\text{kg}}{\text{ha}})}$ (2)

Energy productivity $= \dfrac{\text{Sesame energy output } (\frac{\text{kg}}{\text{ha}})}{\text{Energy input } (\frac{\text{MJ}}{\text{ha}})}$ (3)

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

Table 1. Energy equivalents of in sesame production

Inputs and outputs	Unit	Energy equivalent coefficient	References
Inputs	Unit	Values (MJ/unit)	References
Human labour	h	1.96	Karaağaç et al. 2011; Mani et al. 2007
Machinery	h	64.80	Kızılaslan 2009; Singh 2002
Chemical fertilizers			
Nitrogen	kg	60.60	Singh 2002
Phosphorous	kg	11.10	Singh 2002
Potassium	kg	6.70	Singh 2002
Sulphur	kg	1.12	Nagy 1999; Mohammadi et al. 2010
Chemicals	kg	101.20	Yaldız et al. 1993
Diesel fuel	l	56.31	Singh 2002; Demircan et al. 2006
Seed	kg	15.20	Singh 2002; Akpınar et al. 2009
Irrigation water	m^3	0.63	Yaldız et al. 1993
Outputs	Unit	Values (MJ/unit)	Sources
Sesame grain	kg	30.356	Measured

Sesame input-output values were defined and the calculations were given in Table 2. The input energy can also be classified into direct and indirect and renewable and non-renewable forms (Koçtürk and Engindeniz 2009). The indirect energy consists of pesticide and fertilizer while the direct energy includes human and animal power, diesel and electricity energy used in the production process. On the other hand, non-renewable energy includes petrol, diesel, electricity, chemicals, fertilizers, machinery, while renewable energy consists of human and animal labour (Mandal et al. 2002; Singh et al. 2003)".For calorific values of sesameIKA brand C200 model bomb calorimeter device was used. For measuring purposes, the amount of fuel (~0.1 g) was combusted inside the calorimeter bomb, which was filled with oxygen for full combustion with adequate pressure (~30 bars), the filled bomb calorimeter was put in the device and surrounded by an adequate amount of ordinary water (~2000 mL at 18-25 °C ± 1°C). The heat of combustion was transferred to the water and measured through the rising temperature in the calorimeter. The device was given a calorific value in MJ kg^{-1} unit. For samples, reading of the calorific value was measured repetitively for 3 times and then the average value was reported in this research.

Results and Discussion

The energy input-output analysis of sesame production wasgiven in Table 2. The amount of sesame produced per hectare in 2015 was calculated as an average of 481.78 kg. The amount of chemical fertilizers used for sesame production were 231 kg ha^{-1}. Nitrogenwas used for 66 kg $ha^{-1}$and chemicals of 0.50 kg ha^{-1}in sesame production. The 4.50 kg of sesame seed per hectare was used for sowing (Table 2). Energy inputs consist of chemical fertilizers energy by 5511.30 MJ ha^{-1} (57.25%), diesel fuel energy by 2083.47 MJ ha^{-1} (21.64%), machinery energy by 1289.52 MJ ha^{-1} (13.39%), human labour energy by 487.84 MJ ha^{-1} (5.07%), irrigation water energy by 136.08 MJ ha^{-1} (1.41%), seed energy by 68.40 MJ ha^{-1} (0.71%) and chemicals energy by 50.60 MJ ha^{-1} (0.53%), respectively. Similarly,Akpınar et al. (2009) defined that in sesame study, the chemical fertilizers energy had the biggest share with 3910.80 MJ ha^{-1} (39.03%);Shahan et al. (2008) determinated that in wheat study, the chemical fertilizers energy had the biggest share with 14653.67 MJ ha^{-1} (31.19%); Bayhan (2016)defined that in sunflowerstudy, the chemical fertilizers energy had the biggest share with2868 MJ ha^{-1} (44.94%).

Table 2. Energy analysis in sesame production

Inputs	Unit	Energy equivalent (MJ/unit)	Input used per hectare (unit ha^{-1})	Energy value (MJ ha^{-1})	Ratio (%)
Human labour	h	1.96	248.90	487.84	5.07
Machinery	h	64.80	19.90	1289.52	13.39
Chemical fertilizers			231	5511.30	57.25
Nitrogen	kg	60.60	66	3999.60	41.54
Phosphorous	kg	11.10	105	1165.50	12.11
Potassium	kg	6.70	50	335	3.48
Sulphur	kg	1.12	10	11.20	0.12
Chemicals	kg	101.20	0.50	50.60	0.53
Diesel fuel	l	56.31	37	2083.47	21.64
Seed	kg	15.20	4.50	68.40	0.71
Irrigation water	m^3	0.63	216	136.08	1.41
Total inputs				9627.21	100
Outputs	**Unit**	**Energy equivalent (MJ / unit)**	**Output per hectare (unit ha^{-1})**	**Energy value (MJ ha^{-1})**	**Ratio (%)**
Sesame grain	kg	30.356	481.78	14625	100
Total outputs				14625	100

Sesame grain, energy input, energy output, energy usage efficiency, specific energy, energy productivity and net energy in sesame production were calculated as 481.78 kg ha^{-1}, 9627.21 MJ ha^{-1}, 14625 MJ ha^{-1}, 1.52, 19.98 MJ kg^{-1}, 0.06 kg MJ^{-1} and 4997.79MJ ha^{-1}, respectively (Table 3). In previous studies, Akpınar et al. (2009) calculated the energy usage efficiency in sesame study as 1.80 and 1.40, Shahan et al. (2008)calculated the energy usage efficiency inwheat study as 1.97, Baran and Gökdoğan (2014) calculated the energy usage efficiency in barley study as 5.44. Inputs were determinated in terms of direct, indirect, renewable and non-renewable forms of energy groups in sesame production(Table 4).

Table 3. Energy calculations for sesame production

Calculations	Unit	Values
Energy use efficiency	-	1.52
Specific energy	MJ kg^{-1}	19.98
Energy productivity	kg MJ^{-1}	0.06
Net energy	MJ ha^{-1}	4997.79

The total energy input consumed in sesame production could be classified as 28.12% direct, 71.88% indirect, 7.19% renewable and 92.81% non-renewable. Similarly, in previous studies, it was determinated that the ratio of indirect energy is higher than the ratio of direct energy in canola

(Unakıtan et al. 2010), potato (Mohammadi et al. 2008), wheat (Tipi et al. 2009), maize (Vural and Efecan 2012) and wheat and maize (Karaağaç et al., 2011) etc. Similarly, in previous studies, it was determinated that the ratio of non-renewable energy is higher than the ratio of renewable energy in sesame (Akpınar et al. 2009), maize (Vural and Efecan 2012), potato (Mohammadi et al. 2008), wheat (Gökdoğan and Sevim 2016) and barley (Baran and Gökdoğan 2014).

Table 4. Energy input in the forms energy for sesame production

Type of energy	Energy input (MJ ha^{-1})	Ratio (%)
Direct energy [a]	2707.39	28.12
Indirect energy [b]	6919.82	71.88
Total	9627.21	100
Renewable energy [c]	692.32	7.19
Non-renewable energy [d]	8934.89	92.81
Total	9627.21	100

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

Conclusion

In this research, energy efficiency in sesame production was defined. According to research results, energy efficiency, specific energy, energy productivity and net energy in sesame production were calculated as 1.52, 19.98 MJ kg^{-1}, 0.06 kg MJ^{-1} and 4997.79 MJ ha^{-1}, respectively. The highest energy inputs in sesame production are chemical fertilizers energy by 5511.30 MJ ha^{-1} (57.25%), diesel fuel energy by 2083.47 MJ ha^{-1} (21.64%) and machinery energy by 1289.52 MJ ha^{-1} (13.39%).The study results indicate that, the ratio of non-renewable energy is higher than the ratio of renewable energy.Farm fertilizers may be used in sesame production, instead of chemical fertilizers, which carry out an important part of the inputs. Energy management should be considered an important field in terms of efficient, sustainable and economical use of energy (Tipi et. 2009). Similarly, these conclusions may be taken into in sesame production.

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