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# Determination of Energy Balance of Lentil Production in Adıyaman Province

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**Abstract:** In this study was aimed to determine an the energy usage efficiency of lentil production in Adıyaman province, during the production season of 2014-2015. In order to determine the energy usage efficiency of lentil, trials were done in lentil farm producing in the province of Adıyaman. The energy input and output were calculated as 15555.01 MJ ha$^{-1}$ and as 29378.70 MJ ha$^{-1}$ in lentil production. Energy inputs consist of diesel fuel energy by 5884.39 MJ ha$^{-1}$, machinery energy by 3596.40 MJ ha$^{-1}$, chemical fertilizers energy by 3040.95 MJ ha$^{-1}$, seed energy by 2448.22 MJ ha$^{-1}$, human labour energy by 402.89 MJ ha$^{-1}$ and chemicals energy by 182.16 MJ ha$^{-1}$. Energy usage efficiency, specific energy, energy productivity and net energy in lentil production were calculated as 1.88, 9.60 MJ kg$^{-1}$, 0.10 kg MJ$^{-1}$ and 13823.69 MJ ha$^{-1}$, respectively.

**Keywords:** Adıyaman, energy usage efficiency, lentil, specific energy

# Adıyaman İlinde Mercimek Üretiminde Enerji Bilançosunun Belirlenmesi

**Özet:** Bu çalışmada Adıyaman ilinde 2014-2015 üretim sezonunda mercimek üretiminde enerji kullanım etkinliğinin belirlenmesi amaçlanmıştır. Mercimeğin enerji kullanım etkinliğini belirlemek için denemeler Adıyaman ilinde mercimek işletmesinde yapılmıştır. Mercimek üretiminde enerji girdisi 15555.01 MJ ha$^{-1}$ ve enerji çıktısı 29378.70 MJ ha$^{-1}$ olarak hesaplanmıştır. Enerji girdileri olarak diesel enerji 5884.39 MJ ha$^{-1}$, makine enerjisi 3596.40 MJ ha$^{-1}$, kimyasal gübre enerjisi 3040.95 MJ ha$^{-1}$, tohum enerjisi 2448.22 MJ ha$^{-1}$, insan işgücü enerjisi 402.89 MJ ha$^{-1}$ ve kimyasal ilaç enerjisi 182.16 MJ ha$^{-1}$'dır. Mercimek üretiminde enerji kullanım etkinliği, spesifik enerji, enerji verimliliği ve net enerji sırasıyla 1.88, 9.60 MJ kg$^{-1}$, 0.10 kg MJ$^{-1}$ ve 13823.69 MJ ha$^{-1}$ olarak hesaplanmıştır.

**Anahtar Kelimeler:** Adıyaman, enerji kullanım etkinliği, mercimek, spesifik enerji

## 1. Introduction

Moraditochaee et al (2014) reported that, "lentil (Lens culinaris medik) is one of the most important pulse crops in semiarid regions of Iran, India, Turkey and Canadian. The mean of protein of seed is 26%, thereby very important for nutrition human and animal. Production under dry land farming systems in Iran is restricted by moisture deficiency and lake of plant available nutrients in the soil. Plant nutrient have significant effects on yield and yield components, also suitable cultivars and correct consumption of fertilizers lead to optimum uses of soil and environmental factors that produce high yield and yield components (Sarker et al. 2003; Karadavut and Palta 2010; Dashadi et al. 2013)". Lentil is one of the major legumes crops in Turkey, grown in non-irrigation conditions. Different lens varieties showed some genetic variation for plant height, number of branch, number of pod per plant, number of seed per plant, harvest index and biological yield. Lentil may be helpful in meeting the protein need of diet (Karadavut and Genç 2010).

Energy input-output relationships in cropping systems vary with crops grown in sequence, type of soils, nature of tillage operations for seedbed preparation, the nature and the amount of organic manure, the chemical fertilizer used, plant protection measures, harvesting and finally, yield levels (Çelik et al. 2010). Efficient usage of energy in agriculture will minimize environmental problems, prevent destruction of natural resources, and promote sustainable agriculture as an economical production system (Erdal et al. 2007). Several studies were done on energy efficiency analysis of agricultural products. Some of these studies may be listed as those on the energy usage activities of lentil (Moraditochaee et al. 2014; Asakereh et al. 2010), sweet cherry (Demircan et al. 2006), greenhouse vegetable (Çanakcı and Akıncı 2006), sugar beet (Hacıseferoğulları et al. 2003), pomegranate (Çanakcı 2010), wheat (Tipi et al. 2009), barley (Baran and Gökdoğan 2014), cherry (Kızılaslan 2009), potato (Mohammadi et al. 2008), garlic (Samavatean et al. 2011), lemon (Bilgili 2012), canola (Baran et al. 2014), black carrot (Çelik et al. 2010), corn (Öztürk et al. 2006), corn silage (Barut et al. 2011), sunflower (Baran and Karaağaç 2014), wheat and maize (Karaağaç et al. 2011), grape (Koçtürk and Engindeniz 2009), apple (Yılmaz et al. 2010), miscanthus x giganteus (Acaroğlu and Aksoy 2005) etc. In this study was aimed to determine an energy usage efficiency analysis of lentil production in dry conditions in Adıyaman province during the production season of 2014-2015.

## 2. Materials and methods

Southern part of the Adıyaman province is hot and dry during summer months and rainy and cold during winter months. Central Adıyaman is located at 37° 45’ north latitude and 38° 16’ eastern longitude. Adıyaman’s elevation from sea level is 672 m. The daily difference between highest temperature and lowest temperature is about 10 °C (Anonym 2016a). General soil structure of the province is ¾ clayed-loamy (Anonym 2016b). To determine the energy usage efficiency analysis of lentil, a farm producing an area of 6 hectares located in a central village in the province of Adıyaman in Turkey, during the production season of 2014-2015. The study carried out on treatments plot 300 $m^2$ were planned in completely randomized parcel design and three replications were used. Total energy input in unit area (ha) constitutes each total of input energy. Human labour energy, machinery energy, chemical fertilizers energy, chemicals energy, diesel fuel energy and seed energy were calculated as inputs. Lentil grain was calculated as output. Total fuel consumption of each parcel was calculated as l $ha^{-1}$. Full tank method was used to measure the amount of fuel used (Göktürk 1999; Saleh 2000; Sonmete 2006). Labor yield of each parcel (ha $h^{-1}$) was calculated by proportion 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). Measuring the time spent during agricultural operations in the parcels has been done with the aid of chronometer (Sonmete 2006). Following the measures conducted in lentil in Adıyaman province, energy input and output values were defined. In the lentil agricultural production was given in Table 1, energy equivalents of input and output were taken as energy values. Energy usage efficiency calculations were made to determine the productivity levels of lentil production. Mohammadi et al. (2010) reported that, “The energy ratio (energy usage efficiency), energy productivity, specific energy and net energy were calculated by using the following formulates (Mohammadi et al. 2008; Mandal et al. 2002)”.

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

$$\text{Specific energy} = \frac{\text{Energy input } \left(\frac{MJ}{ha}\right)}{\text{Lentil output } \left(\frac{kg}{ha}\right)} \quad (2)$$

$$\text{Energy productivity} = \frac{\text{Lentil output } (\frac{kg}{ha})}{\text{Energy input } (\frac{MJ}{ha})} \quad (3)$$

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

**Table 1.** Energy equivalents of inputs and outputs in lentil production

| Inputs and outputs | Unit | Energy equivalent coefficient | Sources |
|---|---|---|---|
| Inputs | Unit | Values (MJ/unit) | Sources |
| 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 |
| Chemicals | kg | 101.20 | Yaldız et al., 1993 |
| Diesel fuel | l | 56.31 | Demircan et al., 2006; Singh, 2002 |
| Seed | kg | 18.135 | Measured |
| Outputs | Unit | Values (MJ/unit) | Sources |
| Lentil grain | kg | 18.135 | Measured |

Lentil input-output values were determined and the calculations were given in Table 2. Koçtürk and Engindeniz (2009) reported that, "The input energy can also be classified into direct and indirect and renewable and non-renewable forms. 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 lentil 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, 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 $^oC \pm 1^oC$). 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. The device can perform calorific value measurement in accordance with EN 61010, EN 50082, EN 55014 and EN 60555 standards. For samples, reading of the calorific value was measured repetitively for 3 times and then the average value was reported in this study. The method employed by Gökdoğan et al. (2015) for the energy balance calculation of Nigella Sativa L. oil was used in this study to determine the energy values of lentil.

### 3. Results and Discussion

The energy output-input analysis of lentil production were given in Table 2. The amount of lentil produced per hectare during the 2014-2015 production season was calculated as an average of 1620 kg. The amount of chemical fertilizers used for lentil production were 104.50 kg $ha^{-1}$. Nitrogen was used for 38 kg $ha^{-1}$, phosphorus of 66.50 kg $ha^{-1}$ and chemicals of 1.80 kg $ha^{-1}$ in lentil production. The 135 kg of lentil seed per hectare was used for sowing. Human labour and machinery energy was used for tractor and farm operations (Table 2). Energy inputs in lentil production are diesel fuel energy by 5884.39 MJ $ha^{-1}$ (37.83%), machinery energy by 3596.40 MJ $ha^{-1}$ (23.12%), chemical fertilizers energy by 3040.95 MJ $ha^{-1}$ (19.55%), seed energy by 1984.50 MJ $ha^{-1}$ (15.74%), human labour energy by 402.89 (2.59%) and chemicals energy by 182.16 (1.17%). Similarly, Moraditochaee et al. (2014) determinated that in lentil study, the diesel fuel energy had the biggest share with 6250.41 MJ $ha^{-1}$ (33.28%); Asakereh et al. (2010) determinated that in lentil study, the diesel fuel energy had the biggest share with 3609.50 MJ $ha^{-1}$ (71.30%).

Lentil, energy input, energy output, energy usage efficiency, specific energy, energy productivity and net energy in lentil production were calculated as 1620 kg $ha^{-1}$, 15555.01 MJ $ha^{-1}$, 29378.70 MJ $ha^{-1}$, 1.88, 9.60 MJ $kg^{-1}$, 0.10 kg $MJ^{-1}$ and 13823.69 MJ $ha^{-1}$, respectively. In previous studies, Moraditochaee et al. (2014) calculated the energy usage efficiency in lentil study as 0.47, Asakereh et al. (2010) calculated the energy usage efficiency in lentil study as 2.12. Inputs were determinated in terms of direct, indirect, renewable and non-renewable forms of energy groups (Table 3). The total energy input consumed in lentil production could be classified as 40.42% direct, 59.58% indirect, 18.33% renewable, and 81.67% non-renewable. Similarly, in previous studies, it was determinated that the ratio of indirect energy is higher than the ratio of direct energy in lentil (Moraditochaee et al. 2014), in grape (Koçtürk and Engindeniz 2009), black carrot (Çelik et al. 2010) and sweet cherry (Demircan et al. 2006). Similarly, in previous studies, it was determinated that the ratio of non-renewable energy is higher than the ratio of renewable energy in lentil (Moraditochaee et al., 2014; Asakereh et al. 2010), in sugar beet (Erdal et al. 2007) and walnut (Banaeian and Zangeneh 2011).

**Table 2.** Energy input-output analysis in lentil 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 | 205.56 | 402.89 | 2.59 |
| Machinery | h | 64.80 | 55.50 | 3596.40 | 23.12 |
| Chemical fertilizers | | | 104.50 | 3040.95 | 19.55 |
| Nitrogen | kg | 60.60 | 38 | 2302.80 | |
| Phosphorous | kg | 11.10 | 66.50 | 738.15 | |
| Chemicals | kg | 101.20 | 1.80 | 182.16 | 1.17 |
| Diesel fuel | l | 56.31 | 104.50 | 5884.39 | 37.83 |
| Seed | kg | 18.135 | 135 | 2448.22 | 15.74 |
| Total inputs | | | | 15555.01 | 100 |
| Outputs | Unit | Energy equivalent (MJ / unit) | Output per hectare (unit ha$^{-1}$) | Energy value (MJ ha$^{-1}$) | Ratio (%) |
| Lentil grain | kg | 18.135 | 1620 | 29378.70 | 100 |
| Calculations | Unit | | | | Values |
| Energy usage efficienc | | | | 1.88 | |
| Specific energy | MJ kg$^{-1}$ | | | | 9.60 |
| Energy productivity | kg MJ$^{-1}$ | | | | 0.10 |
| Net energy | MJ ha$^{-1}$ | | | | 13823.69 |

**Table 3.** Energy input in the forms energy for lentil production

| Type of energy | Energy input (MJ ha$^{-1}$) | Ratio (%) |
|---|---|---|
| Direct energy [a] | 6287.28 | 40.42 |
| Indirect energy [b] | 9267.73 | 59.58 |
| Total | 15555.01 | 100 |
| Renewable energy [c] | 2851.11 | 18.33 |
| Non-renewable energy [d] | 12703.90 | 81.67 |
| Total | 15555.01 | 100 |

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

In this study, energy usage efficiency in lentil production was determinated. According to results, energy usage efficiency, specific energy, energy productivity and net energy in lentil production were calculated as 1.88, 9.60 MJ $kg^{-1}$, 0.10 kg $MJ^{-1}$ and 13823.69 MJ $ha^{-1}$, respectively. The highest energy inputs in lentil production are diesel fuel energy by 5884.39 MJ $ha^{-1}$ (37.83%), machinery energy by 3596.40 MJ $ha^{-1}$ (23.12%) and chemical fertilizers energy by 3040.95 MJ $ha^{-1}$ (19.55%). The study results indicate that, the ratio of non-renewable energy is higher than the ratio of renewable energy. Farm fertilizers can also be used in lentil production, instead of chemical fertilizers, which make up an important part of the inputs. Tipi et al. (2009) reported that, "Energy management should be considered an important field in terms of efficient, sustainable and economical usage of energy". Similarly, these conclusions may be taken into in lentil production.

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