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Energy balance of the lavender oil production

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Abstract

This research was carried out to determine the energy input-output analysis of lavender oil production. Data from agricultural farms in Isparta province was used. Energy input was calculated as 1993.89 MJ and energy output was calculated as 2925.51 MJ. Wood energy, fresh stalked lavender flower energy, equipment energy, human labour energy, electricity energy, and water energy inputs were 54.22 %, 41.86 %, 3.40 %, 0.23 %, 0.18 %, and 0.10 % of energy inputs, respectively. In this production, it is noteworthy that wood was used as fuel in the lavender oil production distillation process as the highest input. In the energy outputs, an average of 3.10 kg lavender oil and 130 kg lavender water were extracted by processing 234 kg fresh stalked lavender flower. Energy use efficiency, specific energy, energy productivity, and net energy for lavender oil production were calculated as 1.47, 643.19 MJ kg^{-1}, 0.002 kg MJ^{-1} and 931.62 MJ, respectively.

Keywords: Energy, Energy use efficiency, Lavender oil, Specific energy

Lavanta yağı üretiminde enerji bilançosu

Öz

Bu araştırmada lavanta yağı üretiminde enerji girdi çıktı analizinin yapılması amaçlanmıştır. Isparta ilindeki işletmedeki verilere göre hesaplamalar yapılmıştır. Lavanta yağı üretiminde enerji girdisi 1993.89 MJ, enerji çıktısı ise 2925.51 MJ olarak hesaplanmıştır. Enerji girdisi olarak sırasıyla % 54.22 odun enerjisi, % 41.86 lavanta çiçeği enerjisi, % 3.40 ekipman enerjisi, % 0.23 insan işgücü enerjisi, % 0.18 elektrik enerjisi ve % 0.10 su enerjisi oluşturmaktadır. Distilasyon işleminde en yüksek girdi yakıt olarak odun girdisidir. 234 kg lavanta bitkisinin işlenmesi sonucu enerji çıktısı olarak, 3.10 kg lavanta yağı ve 130 kg lavanta suyu elde edilmiştir. Lavanta yağı

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üretiminde sırasıyla enerji kullanım etkinliği, spesifik (özgül) enerji, enerji verimliliği ve net enerji 1.47, 643.19 MJ kg^{-1}, 0.002 kg MJ^{-1} ve 931.62 MJ olarak hesaplanmıştır.

Anahtar kelimeler: Enerji, Enerji kullanım etkinliği, Lavanta yağı, Spesifik enerji

1. Introduction

Energy is an input used for various purposes such as increasing productivity, enhancing food security and contributing to rural economic development in the agricultural sector. 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 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. Additionally, 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 (Celik et al., 2010).

Lavender essential oil is most commonly used in cosmetics and perfume industry. Besides this, it is being also used in soap and other industry branches due to its pleasant odour, in pharmaceutical industry, and in aromatherapy due to its pain killing, anti-anxiety and sleep eliminating aspects. It also has urine increasing and rheumatism pain killing aspects. Due to its sedative nature, lavender flowers are also used as tea (Anonymous, 2013a). Lavender is planted as a foliage plant in Turkey, especially in Mediterranean Region (Anonymous, 2016).

Lavender (*Lavandula angustifolia* Mill.) and hyssop (*Hyssopus officinalis* L.) are grown essential oil crops in Europe, the Middle East, Asia, and Northern Africa. Both species are perennial and widely adapted, with natural distribution ranging from Asia to Southern Europe. Countries that produce the most are Bulgaria and France, with lesser amounts produced by Morocco, Hungary, Italy, Russia, Spain, Romania, Ukraine, Turkey, and others. The essential oils of lavender and hyssop are used in perfumery and cosmetics, ecofriendly pesticides, foods, beverages, liqueurs, and pharmaceuticals (Topalov, 1989; Tonutti and Liddle, 2010; Zheljazkov et al., 2012). Each year, there is an essential oil export between 1.9-2.0 billion dollars in the world, and of this figure, approximately 50.0 million dollars is made up by lavender oil (Anonymous, 2007; Kara and Baydar, 2011).

Even though it is being used in many areas ranging from perfumery to food, the cultured production of lavender herb is only made around Isparta-Keciborlu in Turkey. The total lavender production area in Isparta is about 3000 da and lavender oil production is 5 t. Lavender herb is easily cultivated in 900-1200 m altitude, non-watered, infertile lands and 750 kg peduncles flower is produced per decare. In case there is an opportunity of irrigation, the productivity level is increased even further (Anonymous, 2013b). This research focused on the energy input-output analysis of lavender oil production in Isparta region. In this research, the energy balance of lavender oil was defined.

2. Material and Methods

The province of Isparta is located in western and central part of the Mediterranean Region. It is the centre of the “Region of Lakes”. The province is located between 30°20’ and 31°33’ East longitudes and 37°18’ and 38°30’ North latitudes (Anonymous, 2013c). In this research, observations and experiments were done at a lavender oil producing enterprise located in Keciborlu district of Isparta province of Turkey. Research works at a lavender oil producing enterprise to determine the lavender oil’s energy input-output analysis were performed in 2014 during the month of August. Lavender flowers are distilled in a boiler with a flower capacity of 0.25 t. After placing 0.25 t fresh stalked lavender flower and 0.40 t water into the distillation boiler and lighting fire, it is boiled for an average 2.50 hours and distillation starts. While the scented water steam goes through the cooler, it hits the cold water surfaces and the steam water condenses with this sudden cooling and comes down to the oily water boiler. Lavender oil goes through the upper part of the Florentine container and the lavender water goes through the bottom part, and they get separated at the cooler. The oil, extracted following the distillation, is collected inside a Florentin (separation container) container, is kept for while and then filtered, and then send for marketing. The water, which accumulates under the lavender oil in the Florentine flask, was used as lavender water. In order to determine energy equivalent of lavender water, the price per kg of lavender water has been proportioned to the price of per kWh of electricity consumed during production (Onal and Tozan, 1986). To calculate energy equivalents of the inputs in lavender oil production, the units in Table 1 were used. Input and output values were multiplied by corresponding energy equivalent coefficients. The total energy input was determined by adding the energy equivalents of all inputs in MJ unit. In order to define their energy equivalents, lavender flowers and lavender oil were combusted in a calorimeter device and their energy values were determined. Calculations were based on lavender flower's dry matter value of 16.66 %.

For calorific values of fresh stalked lavender flower and lavender oil IKA brand C200 model bomb calorimeter device was used. For measuring, the amount of fuel (~0.1 g) was combusted inside the bomb calorimeter which was filled with oxygen for full combustion with adequate pressure (~30 bars), filled bomb calorimeter was put in the device and surrounded by an adequate amount of normal water (~2000 ml at 22°C±3°C). The heat of combustion was transferred to the water and measured thorough the temperature rising in the calorimeter. The device gives the calorific value such as MJ kg^{-1} unit. Calorific value derived from this device is in accordance with EN 61010, EN 50082, EN 55014 and EN 60555 standards. For each samples, reading of the calorific value was measured 3 times and then averaged to report in this research. To determine the moisture content of fresh stalked lavender flower Denver Instrument IR-35-M models brand hygrometer was used (Figure 1 and 2).

Table 1. Energy equivalents of inputs and outputs in lavender oil production

Inputs and outputs	Unit	Energy equivalent coefficient	References
Inputs		Values (MJ $unit^{-1}$)	
Fresh stalked lavender flower	MJ (kg*dry $matter)^{-1}$	21.409	Measured
Human labour	h	1.87	Kaltschmitt and Reinhardt, 1997; Sonmete and Demir, 2007
Wood	kg	10.81	Saracoglu, 1996
Electricity	kWh	3.60	Ozkan et al., 2004
Water	m^3	0.63	Yaldiz et al., 1993
Inputs	Unit	Values (TL $unit^{-1}$)	References
Electricity price	kWh	0.25	Anonymous, 2014
Lavender water	kg	1.50	*
Outputs	Unit	Values (MJ $unit^{-1}$)	References
Lavender oil	kg	37.908	Measured
Lavender water	kg	21.60	Calculated

*: According to the research in region

Figure 1. Calorific value measurement device

Figure 2. Humidity measurement device

In determining the energy equivalent coefficients, the previously made energy analysis researches (references) were used. The energy ratio (energy use efficiency), energy productivity, specific energy and net energy were calculated using the following Table 2 (Eren, 2011; Karaagac et al., 2011). Energy input-output calculations of lavender oil production were given in Table 3. The energy ratio (energy use efficiency), specific energy, energy productivity and net energy calculations were given in Table 4.

Table 2. Energy efficiency indicators

Energy use efficiency	Energy output/Energy input
Specific energy (MJ kg^{-1})	Total energy input/Total product amount
Energy productivity (kg MJ^{-1})	Total product amount/Total energy input
Net energy (MJ)	Total energy output-Total energy input

Table 3. Lavender oil energy balance

Inputs	Amount	Energy unit (MJ unit^{-1})	Input energy (MJ)	Input energy for 1 kg (MJ)	Distribution (%)
Equipment energy			67.85	21.89	3.40
Fresh stalked lavender flower	234 kg	21.409 MJ kg^{-1} (%16.66 dry matter)	834.62	269.23	41.86
Water	0.40 m^3	0.63 MJ m^{-3}	0.25	0.08	0.01
Water (Cooling)	3.00 m^3	0.63 MJ m^{-3}	1.89	0.61	0.09
Wood	100 kg	10.81 MJ kg^{-1}	1081	348.71	54.22
Electricity	1 kWh	3.60 MJ kWh^{-1}	3.60	1.16	0.18
Human labour	2.50 h	1.87 MJ h^{-1}	4.68	1.51	0.23
Total			1993.89	643.19	100.00
Outputs	**Amount (kg)**	**Energy unit (MJ kg^{-1})**	**Output energy (MJ)**	**Output energy for 1 kg (MJ)**	**Distribution (%)**
Lavender oil	3.10	37.908	117.51	37.91	4.02
Lavender water	130	21.60	2808	905.81	95.98
Total			2925.51	943.72	100.00

Table 4. Energy input-output calculations in lavender oil production

Calculations	Units	Values
Energy use efficiency	-	1.47
Specific energy	MJ kg $^{-1}$	643.19
Energy productivity	kg MJ^{-1}	0.002
Net energy	MJ	931.62

3. Results and Discussion

During the study, the average (three replications) distillation value of the fresh stalked lavender flower, processed during the 2014 production season, was taken as a basis, and based on this, an average of 3.10 kg lavender oil and 130 kg lavender water were extracted by processing 234 kg fresh stalked lavender flower. Based on the findings of this study, the energy balance of lavender oil production for the 2014 period was provided in Table 3. Examining the values in Table 3, input energy for wood, fresh stalked lavender flower and equipment energy were dominant among in lavender oil's inputs. The energy equivalents total of the inputs were calculated as 1993.89 MJ. Of these energy inputs, distribution of the input energy as follows: 54.22% wood energy, 41.86% fresh stalked lavender flower energy, 3.40% equipment energy, 0.23% human labour energy, 0.18% electricity energy and 0.10% water energy. Regarding this production, it is noteworthy that wood, used as fuel, was the highest input during the lavender oil production. In terms of energy outputs, an average of 3.10 kg lavender oil and 130 kg lavender water have been extracted. The energy equivalents total of the outputs were calculated as 2925.51 MJ. If the average values were examined by considering Table 3, an average of 643.19 MJ energy input was used to acquire 1 kg of lavender oil. This value indicates that lavender oil production is productive. Energy use efficiency, specific energy, energy productivity, and net energy in lavender oil production were calculated as 1.47, 643.19 MJ kg^{-1}, 0.002 kg MJ^{-1} and 931.62 MJ, respectively (Table 4).

4. Conclusion

Energy input-output analysis of the lavender oil production was carried out to determine how the energy could be used effectively. In the research, the energy balance of the region's lavender oil production was defined. Oil productivity may be increased by irrigating lands in the region, which would increase the yield of fresh stalked lavender flowers per hectare. Just like rose oil, lavender oil production is one of the most important sources of income in the region, and Research & Development units need to be established for proper distillation techniques. Instead of wood, which makes up an important part of the input for heating the water in the boilers to produce lavender oil, other alternative energy sources need to be explored. For example, more studies need to be conducted on the use of solar energy. To maintain effective lavender oil producing facility, during the off-season period, the other medical and aromatic herbs could be distilled to generate more income and capacity usage.

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