Determination of input-output energy and economic analysis of lavender production in Turkey

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Abstract: This research aims to perform an energy input-output analysis of lavender plant production in Isparta Province of Turkey. In order to determine the energy use efficiency of lavender plant, experiments and trials have been conducted on 10 lavender farms around Keçiborlu region of Isparta Province. Keçiborlu region of Isparta Province is an important location for lavender production. On these 10 lavender farms, energy input-output has also been calculated through trial and measurement methods during the production season of 2013. In lavender production, energy input has been calculated as 6336.50 MJ/hm^2 and energy output has been calculated as 17 528.81 MJ/hm^2. Energy inputs consist of chemical fertilizers energy by 52.88%, diesel energy by 33.32%, machinery energy by 9.72%, human labour energy by 2.85% and chemicals by 1.23%. Energy use efficiency, energy productivity, specific energy and net energy in lavender production have been calculated as 2.77; 0.75 kg/MJ, 1.34 MJ/kg and 11 192.31 MJ/hm^2, respectively. Benefit-cost ratio has been calculated as 3.41 by dividing the gross value of production by the total cost of production per hectare.

Keywords: output/input ratio, energy, specific energy, lavender, Turkey
DOI: 10.3965/j.ijabe.20160903.1774

Citation: Gökdoğan O. Determination of input-output energy and economic analysis of Lavender production in Turkey. Int J Agric & Biol Eng, 2016; 9(3): 154－161.

1 Introduction

Lavender is planted as a foliage plant in Turkey, particularly in the Mediterranean Region. With its unique pleasant odour, it is used in perfumery and cosmetics industry. However, the two most important aspects of lavender flower are the positive effects on liver metabolism and the positive effect against hair loss[1]. Lavender essential oil is most commonly used in the cosmetics and perfume industry. Due to its pleasant odour it is also used for soap making and in other fields of the industry, while its pain killing, anti-anxiety and sleep disorder eliminating characteristics make it a sought after product in pharmaceutical and aromatherapy industries. Lavender improves urine production, while it also kills off rheumatism pain. Due to its sedative nature, lavender flowers are used to make tea[2]. Zheljazkov et al.[3] reported that, "Lavender (*Lavandula angustifolia* Mill.) and hyssop (*Hyssopus officinalis* L.) are widely 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 amounts are Bulgaria and France, with lesser amounts produced by Morocco, Yugoslavia, Hungary, Italy, Russia, Spain, Romania, Ukraine, Turkey and others. The essential oils of lavender and hyssop are used in perfumery and cosmetics, eco-friendly pesticides, foods, beverages, liqueurs and pharmaceuticals[4, 5]."

Lavender plant can grow up to 1 m in length, it is semi-bushy and a multi-year plant. The part of the

Received date: 2015-03-04 **Accepted date:** 2016-04-07
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lavender plant which is being used for economic purposes is its flower. The essential oil extracted from the flower and pedicle of the plant is one of the 15 most highly traded essential oils. Composition of the essential oil; there is mostly linalool and linalyl acetate. The quality of the essential oil is determined in accordance with the linalyl acetate ratio. Lavender is not a choosy plant when it comes to selecting soil. The plant displays sound development in dry and calcareous soil, rich in lime, with a pH of 5.8-8.3. It is highly resistant against arid, hot and cold climate. However, in areas with harsh winters, certain damage is observed at times[2]. Kara and Baydar[6] reported that, "Each year, there is an essential oil export of approximately 1.90-2.00 billion dollars in the world, and of this figure, approximately 50 million dollars consists of lavender oil[7]." Even though it is being used in many areas ranging from perfumery to food, the cultured production of lavender plant is only made around Isparta-Keçiborlu in Turkey. The total lavender production area in Isparta is about 3000 decares, and lavender oil production is 5 t[8].

Energy is a vital resource for agricultural production, agro processing, and agriculture is a resource for energy. Agriculture in Turkey has become more energy intensive in order to supply more food and provide sufficient nutrition for the steadily increasing population[9]. Energy use in agriculture has become more intensive in response to increasing population, limited supply of arable land and a desire for higher living standards. In order to meet the nutritional needs of the ever growing population, chemical fertilizers, pesticides, farm tractors and machineries, electricity and other natural resources are being used. But intensive use of these sources causes environmental problems, which threaten public health. So, efficient use of energy sources in agricultural production will minimize environmental problems, prevent destruction of natural resources and improve sustainable agriculture[10-14].

Efficient energy use in agriculture is required to sustain agricultural production, since it provides financial savings, preservation of fossil resources and reduction of air pollution[9,15]. In the globalized world and conditions of modern life, the value of money is not constant. When preparing the manufacturing statements of agricultural products, it will be more plausible to create energy audits by using input and output energy equivalents, which have fixed values everywhere, rather than the monetary equivalents of agricultural products' inputs and outputs.

Researches have been conducted on energy input-output analysis of agricultural products. For example, researches have been conducted on energy use activities of sweet cherry[15], black carrot[16], corn[17], citrus[18], maize[19], wheat[20], canola[21], kiwifruit[22], pumpkin seed[23], sugar beet[24], grape[25], apple[26], banana[27], barley[28], sugar beet[29], apricot[30], sunflower[9], cotton[31] and oil rose[32], etc. This study does not contain any research regarding the energy balance of lavender production in Turkey. Following oily plants and rose oil, lavender is the most important livelihood source within Isparta region in macro and micro terms and defining the energy balance is the aim of this study.

2 Materials and methods

Isparta is located in western and central parts 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[33]. Isparta is located in the transitional area between Mediterranean climate and Central Anatolian climate. Therefore, the characteristics of climates could be observed within the province. According to meteorological studies, Isparta's climate structure has been defined as cold-semi continental climate. It is dry and hot in summers, warm and rainy in winters. The annual average temperature of the province is 12.1°C, while the annual average precipitation level is 600.4 mm[34]. Soil in Isparta is generally calcareous. Tectonic subsidence channels have been filled by I. period alluviums; hence the soil making up the basic source of agriculture has surfaced. Inclination varies by up to 40%. Top soil has a depth between 8-40 cm and generally it is in a clayed calcareous granular and diffusible state. Even though the sub soil has the same structure as the top soil, it has a more coarse texture and clayish soil[35].

2.1 Choosing the samples

Keçiborlu region of Isparta Province is an important location for lavender production. Observations and surveys have been performed at Keçiborlu region of Isparta Province, on farms producing lavender, in order to determine the energy balances of lavender plant. Face to face interviews have been conducted with 27 lavender growers, in dense production areas; and all the known lavender growers in the area have been included. Ten of these farms were selected for trial and measurements. Trials and measurements have been conducted on these lavender farms during the production season of 2013.

2.2 Labour success

According to Sonmete[36]: "Full tank method has been used to measure the amount of fuel used[37,38]. First of all, a pre-measured amount of fuel has been placed into an empty fuel tank. Following the completion of agricultural processes, the remaining amount of fuel in the tank has been measured to determine the amount of fuel consumed. Labour efficiency has been calculated in (hm^2/h), using the effective labour time (t_{ef}), while experiments in parcels have been conducted[39,40]. Measuring the time spent during agricultural operations in the parcels has been done with the aid of chronometer".

2.3 Calculating the inputs

To determine the humidity content of lavender flower, Denver Instrument IR-35-M hygrometer has been used. Calculations, based on lavender flower's 18% dry matter value, have been made. In order to define the energy equivalent of lavender flower, they have been burned in a calorie-meter device to define their energy values. To calculate the calorific values of fresh stalked lavender flower, an IKA C200 bomb calorimeter device has been used. For each sample, calorific value reading has been taken for three times, and an average of those three measures has been used in this research. For measurement purposes, fuel (~0.1 g) has been combusted inside the calorimeter bomb, which was filled with oxygen with adequate pressure (~30 bars) for full combustion. Then, the bomb calorimeter has been placed inside the device and surrounded by an adequate amount of regular water (~2000 mL at (18±1)°C - (25±1)°C). The heat generated by the combustion has been transferred to the water, and measured through the temperature rising in the calorimeter. The calorific value unit of the device has been determined to be MJ/kg. The device can measure calorific values in compliance with EN 61010, EN 50082, EN 55014 and EN 60555 standards. The method employed by Gökdoğan et al.[41] for the energy balance calculation of Nigella Sativa L. oil has been used in this study to determine the energy values of lavender plant.

2.4 Defining the energy balances

Following the trials and measures held at lavender facilities in Isparta region, energy input and output values have been defined. As energy inputs, human labour energy, machinery energy, chemical fertilizers energy, chemicals energy and diesel energy values have been taken into consideration. Energy output/input ratio of the enterprises involved in lavender agriculture in Isparta region has been found. In Table 1, related to agricultural production, energy equivalents of input and outputs have been taken as energy values. Energy balance calculations have been made to determine the productivity levels of lavender production. The units given in Table 1 have been used to find out the input values of lavender production. Input values have been calculated and then these input data have been multiplied by the energy equivalent coefficient. When determining the energy equivalent coefficients, previous energy analysis studies (sources) have been used. By adding energy equivalents of all inputs in MJ unit, the total energy equivalent has been found. In order to determine the energy usage efficiency in lavender production, Mohammadi et al.[22] reported that, "The energy ratio (energy use efficiency), energy productivity, specific energy and net energy were calculated using the following formulates [42, 43]."

$$\text{Energy use efficiency} = \frac{\text{Energy output}}{\text{Energy input}} \quad (1)$$

$$\text{Energy productivity} = \frac{\text{Lavender output}}{\text{Energy input}} \quad (2)$$

$$\text{Specific energy} = \frac{\text{Energy input}}{\text{Lavender output}} \quad (3)$$

$$\text{Net energy} = \text{Energy}_o - \text{Energy}_i \quad (4)$$

By referring to the inputs, data analysis has been conducted by using Microsoft Excel program, before the results have been tabulated. Koçtürk and Engindeniz[25] have reported: "The input energy can also be classified into direct and indirect and renewable and non-renewable forms. The indirect energy consists of pesticide and fertilizers while the direct energy includes human and animal power, diesel and electricity energy used in the production process. Furthermore, non-renewable energy includes petrol, diesel, electricity, chemicals, fertilizers, machinery and renewable energy consists of human and animal labour[42,44]". Energy input-output and energy efficiency calculations in lavender production have been given in Table 2.

Table 1 Energy equivalents of inputs and outputs in agricultural production

	Unit	Values/MJ unit^{-1}	Sources
Inputs			
Human labour	h	1.87	[36, 45]
Machinery	h	64.80	[12, 46]
Chemical fertilizers			
Nitrogen	kg	60.60	[46]
Phosphorous	kg	11.10	[46]
Potassium	kg	6.70	[46]
Sulphur	kg	1.12	[22, 47]
Chemicals	kg	101.20	[48]
Diesel	L	56.31	[15, 46]
Outputs			
Fresh stalked lavender flower	MJ/kg dry matter	20.61	Measured

3 Results and discussion

Following the studies conducted on the farms, the average amount of lavender plant produced per hectare during the 2013 production season has been calculated as 4725 kg. Regarding this study, the energy balance of lavender oil production in 2013 has been given in Table 2. Examining the values in Table 2, chemical fertilizers, chemicals, diesel, machinery and human labour are among the top in lavender inputs. If the average values are examined by referring to Table 2, it can be seen that the highest energy inputs in lavender production are chemical fertilizers energy by 52.88%, diesel energy by 33.32%, machinery energy by 9.72%, human labour energy by 2.85% and chemicals energy by 1.23%. In lavender production, it is noteworthy that chemical fertilizers and diesel energy are being used as the highest input. The reason for chemical fertilizer energy being so high is that, chemical fertilizers are used, instead of farm fertilizers; while the reason for diesel energy being high is that lavender plants are harvested by using certain motors, which run on diesel energy. In addition, diesel energy value is also increased by the use of plough, cultivator, rotary tiller and trailers. In terms of energy outputs, an average of 4725 kg of lavender has been produced per hectare.

Table 2 Energy balance in lavender production

	Unit	Energy equivalent /MJ unit^{-1}	Input used per hectare /unit hm^{-2}	Energy value /MJ hm^{-2}	Ratio /%
Inputs					
Human labour*	h	1.87	96.73	180.89	2.85
Machinery			9.50	615.60	9.72
Cultivation	h	64.80	4.93	319.46	5.04
Plant protection	h	64.80	2.91	188.57	2.98
Transportation	h	64.80	1.66	107.57	1.70
Chemical fertilizers				3350.46	52.88
Nitrogen	kg	60.60	47.90	2902.74	45.81
Phosphorous	kg	11.10	28.50	316.35	4.99
Potassium	kg	6.70	17	113.90	1.80
Sulphur	kg	1.12	15.60	17.47	0.28
Chemicals	kg	101.20	0.77	77.92	1.23
Diesel	L	56.31	37.50	2111.63	33.32
Total				6336.50	100.00
Outputs					
Fresh stalked lavender flower	kg	20.61 MJ (%18 dry matter)	4725	17 528.81	100.00
Calculations				Values	
Energy use efficiency				2.77	
Energy productivity				0.75	
Specific energy				1.34	
Net energy				11 192.31	

Note: * For harvesting lavender plant, pruning shears and wood-cutting motors have been used, which is manually operated and run on fuel-oil.

Lavender production output/input ratio has been defined as 2.77. This value indicates that lavender production is productive. The oil rose output/input ratio average of oil rose from medical and aromatic plants has been defined as 1.42 by Gökdoğan and Demir[32]. In this study, fertilizer application energy had the biggest share by 52.88%. Similarly, in previous studies, Gökdoğan and Demir[32] have concluded in their oil rose study that fertilizer application energy had the biggest share with 58.45%; Erdal et al.[49] found in their sugar beet study that fertilizer application energy had the biggest share with 42.53%; Shahin et al.[50] found in their wheat study that fertilizer application energy had the biggest share by

38.45%. Moreover, the reason for having such high values of chemical fertilizers energy (52.88%) is due to the fact that chemical fertilizers have been used instead of the farm fertilizers.

Looking at lavender inputs, we notice that inputs in lavender are generally low. Unlike oil rose, lavender plant is not a plant which needs to be harvested every single day. None of the lavender farms has the facility for irrigation. Mechanization applications are limited in lavender production, but no mechanization applications are used except tillage, plant protection and transportation. Farm fertilizer is not used at all. For example, Acatay [51] has found out that when 25 t of natural fertilizer is applied per hectare for rose oil, than the amount of rose flower productivity increases to over 10 t/hm^2. Based on this, farm fertilizers, instead of chemical fertilizers, can also be used in lavender production, which make up an important part of the inputs. With this application, the ratio of chemical fertilizers input can be decreased. Energy use efficiency, energy productivity, specific energy and net energy in lavender production have been calculated as 2.77 kg/MJ, 0.75 kg/MJ; 1.34 MJ/kg and 11 192.31 MJ/hm^2, respectively. The distribution of inputs used in the production of lavender according to the direct, indirect, renewable and non-renewable energy groups are given in Table 3.

Table 3 Energy input in the form of direct and direct, renewable and non-renewable energy in lavender production

Lavender production	Energy input/MJ hm^{-2}	Ratio/%
Direct energy [a]	2292.52	36.18
Indirect energy [b]	4043.98	63.82
Total	6336.50	100.00
Renewable energy [c]	180.89	2.85
Non-renewable energy [d]	6155.61	97.15
Total	6336.50	100.00

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

Table 3 showed that the total energy input consumed in lavender production could be classified as 36.18% direct, 63.82% indirect, 2.85% renewable and 97.15% non-renewable. Similarly, in sweet cherry[15], peach[52], sugar beet[49], kiwifruit[22], canola[21], banana[27], apple[53], apricot[54], potato[43], garlic[55], cotton[56] and lemon[57] productions, it has been concluded that the ratio of indirect energy is higher than the ratio of direct energy. Demircan et al.[15] reported: "Accurate fertilization management, applying the right amount and frequency of fertilization (especially nitrogen)[58] and proper tractor selection and management of machinery, to reduce direct use of diesel fuel[59] are needed to save non-renewable energy sources without impairing the yield or profitability, in order to improve the energy use efficiency of sweet cherry production." All these conclusions also apply to lavender production.

Economic analysis of lavender production has been given in Table 4. It has been calculated by diving the total cost of lavender production per hectare by the lavender yield per hectare. The net return has been calculated by subtracting the total cost of production per hectare (variable + fixed cost) from the gross value of production[15]. The total cost of production per kg of lavender has been expressed in Turkish liras (TL), which was equal to 0.53 US dollars (US$) in 2013 (average). The gross return has been found by subtracting the variable cost of production per hectare (840.26 TL/hm^2) from the gross value of production (3543.75 TL/hm^2) and has been calculated as 2703.49 TL/hm^2. According to results, the net return from lavender production on the surveyed farms has a satisfying level. It can be concluded that the net return of 3.41 TL was obtained per 1 TL of money invested and has a cost effective business based on the data of the 2013 production season.

Table 4 Net return and benefit-cost ratio of the lavender production

Cost and return components	Value
Yield/kg hm^{-2}	4725
Sale price/TL kg^{-1}	0.75
Gross value of production/TL hm^{-2}	3543.75
Variable cost of production/TL hm^{-2}	840.26
Fixed cost of production/TL hm^{-2}	192.71
Total cost of production/TL hm^{-2}	1032.97
Total cost of production/TL kg^{-1}	0.22
Gross return/TL hm^{-2}	2703.49
Net return/TL hm^{-2}	2510.78
Benefit-cost ratio	3.41

Note: 1 US$ = 1.90 TL in 2013 (average).

4 Conclusions

In this research, the energy balance of lavender production in the region has been defined. Based on the outcome of the study, energy input value has been calculated as 6336.50 MJ/hm^2 and the energy output value has been calculated as 17 528.81 MJ/hm^2. Energy inputs consist of 52.88% chemical fertilizers energy, 33.32% diesel energy, 9.72% machine energy, 2.85% human labour energy and 1.23% chemicals. Energy use efficiency, energy productivity, specific energy and net energy in lavender production have been calculated as 2.77 kg/MJ; 0.75 kg/MJ; 1.34 MJ/kg and 11 192.31 MJ/hm^2, respectively. Evaluated results indicate that lavender production is a profitable activity in terms of energy usage.

Even if it might be possible in the future to grow lavender plant in lower water conditions, irrigation increases the productivity ratio per decar. Fertilizing the lavender fields every 2-3 years with farm fertilizers would help to improve soil conditions, therefore it is highly recommendable[2]. Irrigation model to be employed in lavender agriculture must be sprinkler irrigation. The total energy input consumed in lavender production could be classified as 36.18% direct, 63.82% indirect, 2.85% renewable and 97.15% non-renewable. On average, the non-renewable form of energy input was 97.15% of the total energy input, compared to only 2.85% for the renewable form. It is clear that the use of renewable energy in lavender production is very low. The reason for chemical fertilizers energy value being so high is because chemical fertilizers have been used instead of the farm fertilizers.

Another important point is that profit-oriented Research & Development units need to be established for lavender production, which is an important source of income in the region, just like oil rose flower. According to results, the net return from lavender production by the total cost of production on the lavender farms has a satisfactory level. Lavender production is a cost effective business based on the data from the 2013 production season.

Acknowledgement

I would also like to thank Isparta Province Food, Agriculture and Animal Directorate, Dr. Tanzer Eryılmaz and Dr. Std. Murat Kadir Yeşilyurt for their help.

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