DETERMINATION OF ENERGY USAGE AND GREENHOUSE GAS EMISSIONS IN LAVENDER PRODUCTION

DETERMINACIÓN DEL USO DE ENERGÍA Y EMISIONES DE GASES DE EFECTO INVERNADERO EN LA PRODUCCIÓN DE LAVANDA

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ABSTRACT

The purpose of this study is to reveal the energy usage and greenhouse gas emission in lavender production. The study has been conducted in 2022 in Center district of Kırklareli province in Turkey and covers the 2021-2022 production seasons. Agricultural inputs and outputs were calculated to calculate the energy use and greenhouse gas emissions in lavender production. According to the research results, the inputs are 5883.39 MJ ha^{-1} (59.30%) farmyard manure energy, 2425.51 MJ ha^{-1} (24.45%) diesel fuel energy, 732.02 MJ ha^{-1} (7.38%) chemical fertilizers energy, 421.89 MJ ha^{-1} (4.25%) machinery energy, 276.70 MJ ha^{-1} (2.79%) human labour energy, 97.31 MJ ha^{-1} (0.98%) transportation energy and 84.81 MJ ha^{-1} (0.85%), vermicompost energy, respectively. Total input and output energy were calculated as 9921.63 MJ ha^{-1} and 12859.77 MJ ha^{-1}, respectively. Energy use efficiency (EUE), specific energy (SE), energy productivity (EP) and net energy (NE) were calculated as 1.30, 2.86 MJ kg^{-1}, 0.35 kg MJ^{-1} and 2938.13 MJ ha^{-1}, respectively. The total energy input can be classified as 27.24% direct, 72.76% indirect, 62.94% renewable and 37.06% non-renewable. GHG ratio value was calculated as 0.08 kg CO_{2-eq}kg^{-1} in lavender production.

Keywords: Energy use efficiency; GHG ratio; Kırklareli; Lavender; Turkey.

RESUMEN

El propósito de este estudio es revelar el uso de energía y la emisión de gases de efecto invernadero en la producción de lavanda. El estudio se realizó en 2022 en el distrito central de la provincia de Kırklareli en Turquía y cubre las temporadas de producción 2021-2022. Se calcularon insumos y productos agrícolas para calcular el uso de energía y las emisiones de gases de efecto invernadero en la producción de lavanda. Según los resultados de la investigación, los insumos son 5883,39 MJ ha^{-1} (59,30 %) energía de estiércol de corral, 2425,51 MJ ha^{-1} (24,45 %) energía de combustible diésel, 732,02 MJ ha^{-1} (7,38 %) energía de fertilizantes químicos, 421,89 MJ ha^{-1} (4,25%) energía maquinaria, 276,70 MJ ha^{-1} (2,79%) energía mano de obra humana, 97,31 MJ ha^{-1} (0,98%) energía transporte y 84,81 MJ ha^{-1} (0,85%) energía vermicompost, respectivamente. La energía total de entrada y salida se calculó como 9921,63 MJ ha^{-1} y 12859,77 MJ ha^{-1}, respectivamente. La eficiencia del uso de energía (EUE), la energía específica (SE), la productividad energética (EP) y la energía neta (NE) se calcularon como 1,30, 2,86 MJ kg^{-1}, 0,35 kg MJ^{-1} y 2938,13 MJ ha^{-1}, respectivamente. El aporte total de energía se puede clasificar en 27,24% directo, 72,76% indirecto, 62,94% renovable y 37,06% no renovable. El valor de la proporción de GEI se calculó como 0,08 kg $CO_{2-eq}kg^{-1}$ en la producción de lavanda.

Palabras clave: Eficiencia en el uso de la energía; índice de GEI; Kırklareli; Lavanda; Turquía

INTRODUCTION

Some of both spontaneously growing plants and the cultivated ones have been used in the treatment of various diseases as well as in cosmetic products, nutrition and food industry from past to present. Lavender (Lavandula Sp.), one of these products, consists of 39 species that naturally grow in the Mediterranean Region, Arabian Peninsula, South West Asia and India (Lis-Balchin, 2002; Gök et al., 2022). Lavender (Lavandula spp.) is a valuable perennial essential oil plant in the semi-shrub form from the Lamiaceae family (Guenther, 1952; Kara and Baydar, 2011). Lavender contains much higher oil (between 3.5-6.0% on average) than other aromatic plants (Anonymous, 2008; Bozkıran and Giray, 2016).

Among all of the costs, energy is one that can be controlled at a larger scale. Therefore, there is a significant potential to energy the consumption levels of energy and consequently, the cost (Jekayinfa, 2006; Altuntas et al., 2020). Agricultural systems are identified and grouped based on energy consumption and this is done through the energy analyses conducted for agricultural production activities. Several studies have been conducted in recent years to assess agricultural productions. The focal points of these studies were sustainable agricultural principles, economy, energy and emission (environment). The need for energy is getting ever-higher in agricultural activities. The plans to renew tillage systems for better energy efficiency will consequently lead to lower usage of energy and better productivity (Altuntas et al., 2020).

The actions of producing, formulating, storing and distributing of agricultural inputs as well as the application of the inputs through mechanical equipment require the use of different forms of energy. These energy forms include diesel fuel, which emits GHG into atmosphere. As the main target is to reduce GHG emissions, a logical option to do this in agro ecosystems would be to take the amount of emissions from specific sources in production processes under control. Then the next step would be to reveal the most economically feasible options with reduced GHG emissions (Jones et al., 2012; Mondani et al., 2017). This requires to obtain data related to energy use in farms, and then converting them to their GHG equivalents. The achieved figures can then be used to express energy use in terms of GHG emission as kg carbon equivalent (Lal, 2004; Mondani et al., 2017).

There are a number of goals set forth in the development plans in Turkey and these goals shape the national agricultural policies. The 11th Development Plan (2019-2023) regulates that agricultural policies should be sustainable in environmental, social and economic terms; provide an adequate and balanced nutrition for the public; increase international competitiveness through a production system that addresses the supply-demand balance; overcome infrastructure problems based on an advanced technology; and be highly organized and productive (Bayav, 2022).

A number of studies have been conducted on energy usage and GHG of various agricultural productions. These include studies on lavender (Gökdoğan, 2016), field crops (Yaldız et al., 1993), dry bean (Sonmete and Demir, 2007), legume (Ertekin et al. 2010), tobacco (Moraditochaee 2012), black cumin (Yilmaz et al., 2021), mandarin (Ozkan et al., 2004), peanut (Nabavi-Pelesaraei et al., 2013), apple (Taghavifar and Mardani, 2015a), watermelon (Mohammadi-Barsari et al., 2016), guar (Gökdoğan et al., 2017) almond (Yılmaz and Bayav, 2022), avocado (Gökduman et al., 2022), vegetable (Canakci et al., 2005), wheat (Tipi et al., 2009), oat (Rajaniemi et al., 2011), broiler (Atilgan and Koknaroglu 2006), milk (Oğuz and Yener Ogur, 2019) etc. The purpose of this study is to reveal the energy usage and greenhouse gas emissions in lavender production in Kırklareli province and it is a significant study as there were no previous comprehensive studies conducted in the region on this matter in the past.

MATERIALS AND METHOD

Kırklareli is located in the Thrace Region of Turkey on the European Continent. It lies between 41°44’ - 42°00’ north latitudes and 26°53’ - 41°44’ east longitudes. It has a land area of 6555 km^2. It is surrounded by Bulgaria with a border length of 159 km from the north, the Black Sea with a coastal length of 58 km from the east, Edirne from the west, Istanbul from the southeast and Tekirdağ from the south. 48% of the land is mountainous, 35% is undulating land and 17% is plain (Anonymous, 2022a). Kırklareli has different climatic characteristics. In the center of Kırklareli, the continental climate is dominant. The Black Sea climate is seen in the north-facing parts of the Yıldız Mountains. Accordingly, summers are cool and winters are cold. Continental climate is observed in the interior parts far from the sea. Summers are hot, winters are cold and occasionally snowy (Anonymous, 2022b).

The study has been conducted in 2022 in Center district of Kırklareli province in Turkey and covers the 2021-2022 production seasons. The survey, observation and research studies have been done in agricultural farms of the Center district of Kırklareli. Farms have been determined on the basis of 2021 data provided by the Kırklareli Provincial Directorate of Agriculture and Forestry. The data provided by the study were reached from 12 lavender farms through face-to-face surveys and observations with full count method proposed by Karagölge and Peker (2002).

Tables 1 and 2 indicate the energy equivalents of the inputs and GHG equivalents in lavender production. The total energy inputs were calculated by multiplying the energy equivalents and input used per hectare of all inputs in MJ unit. EUE, SE, EP and NE were calculated by using the following formulae (Mandal et al., 2002; Mohammadi et al., 2008; Mohammadi et al. 2010) to calculate the energy balance in lavender production.

Energy use efficiency = Energy output (MJ ha-1) / Energy input (MJ ha-1) (1)

Specific energy = Energy input (MJ ha-1) / Product output (kg ha-1) (2)

Energy productivity = Product output (kg ha-1) / Energy input (MJ ha-1) (3)

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

Table 1. Energy equivalents in lavender production

INPUTS	UNIT	ENERGY EQUIVALENT (MJ $UNIT^{-1}$)	REFERENCES
HUMAN LABOUR	h	1.96	MANI ET AL., 2007; KARAAĞAÇ ET AL., 2011
MACHINERY	h	64.80	SINGH, 2002; KIZILASLAN, 2009
N	kg	60.60	SINGH, 2002; OZALP ET AL., 2018
CA	kg	8.80	PIMENTEL, 1980; ZAFIRIOU ET AL., 2012
MICRO ELEMENTS	kg	120	MANDAL ET AL., 2002; SINGH, 2002; CANAKCI AND AKINCI, 2006; BANAEIAN ET AL., 2011
DIESEL FUEL	L	56.31	SINGH, 2002; DEMIRCAN ET AL., 2006
FARMYARD MANURE	kg	0.30	ERTEKIN ET AL., 2011; OZALP ET AL., 2018
VERMICOMPOST	kg	1.20	BABU ET AL., 2016
TRANSPORTATION	MJ (ton km)-1	4.50	FLUCK AND BAIRD, 1982; KITANI, 1999
OUTPUT	Unit	Energy equivalent (MJ uni^{-1})	REFERENCE
FRESH STALKED LAVENDER FLOWER	kg (18% dry matter)	20.61	GÖKDOĞAN, 2016

Table 2. GHG emissions coefficients in lavender production

INPUTS	UNIT	GHG EQUIVALENT (KG $CO_{2\text{-eq}}$ $UNIT^{-1}$)	REFERENCES
MACHINERY	MJ	0.071	DYER AND DESJARDINS, 2006; EKINCI ET AL., 2020
N	kg	1.300	LAL, 2004; OZALP ET AL., 2018
CA	kg	0.39	HAMMOND AND JONES, 2008; EKINCI ET AL., 2020
MICRO ELEMENTS	kg	0.66	MACEDO ET AL., 2008; SAMI AND REYHANI, 2018
DIESEL FUEL	L	2.760	DYER AND DESJARDINS, 2006; OZALP ET AL., 2018
FARMYARD MANURE	kg	0.005	MOHAMMADI ET AL., 2014; OZALP, ET AL., 2018
TRANSPORTATION	ton.km	0.150	MEISTERLING ET AL., 2009; EREN ET AL., 2019A

The GHG emissions (kgCO2-eqha–1) associated with the inputs to produce 1 ha of plant were calculated as follows, concerted by Hughes et al. (2011) (Eren et al., 2019b).

$$GHG_{ha} = \sum_{i=1}^{n} R(i) x\ EF(i) \quad (5)$$

∑ where R(i) is the application ratio of input i ($unit_{input} ha^{-1}$) and EF(i) is the GHG emission coefficient of input i (kg $CO_{2-eq} unit_{input}^{-1}$). An index is described to evaluate the amount of emitted kg CO_{2-eq} per kg yield as following adapted Houshyar et al. (2015) and Khoshnevisan et al. (2014). Where I_{GHG}GHG is GHG ratio and Y has the yield as kg per ha (Eren et al., 2019b).

$$I_{GHG} = \frac{GHG_{ha}}{Y} \quad (6)$$

The input energy is also categorized into direct, indirect, renewable and non-renewable forms. The indirect energy consists of pesticide and fertilizer while the direct energy consists of human, animal power, diesel and electricity energy used in the production process. Non-renewable energy includes petrol, diesel, electricity, chemicals, fertilizers, machinery and renewable energy consists of human and animal labour (Mandal et al., 2002; Singh et al., 2003; Koctürk and Engindeniz, 2009). Energy usage, EUE calculations, EI types, GHG emissions of inputs related to lavender production are given in Tables 3 to 6, respectively.

RESULTS AND DISCUSSION

The average amount of lavender produced per hectare during 2021-2022 production season was calculated as 3466.43 kg. The inputs in lavender production are 5883.39 MJ ha^{-1} (59.30%) farmyard manure energy, 2425.51 MJ ha^{-1} (24.45%) diesel fuel energy, 732.02 MJ ha^{-1} (7.38%) chemical fertilizers energy, 421.89 MJ ha^{-1} (4.25%) machinery energy, 276.70 MJ ha^{-1} (2.79%) human labour energy, 97.31 MJ ha^{-1} (0.98%) transportation energy and 84.81 MJ ha^{-1} (0.85%) vermicompost energy, respectively (Table 3).

In previous researches; Gökdoğan (2016) calculated that the fertilizer application energy had the biggest share by 52.88% in lavender production; Ozbek et al. (2021) calculated that fertilizer application energy had the biggest share by 60.43% in onion production; Ozalp et al. (2018) calculated that fertilizer application energy had the biggest share by 35.80% in pomegranate production. Contrary to the studies above, in this study titled energy use in lavender production conducted in Kırklareli, a large part of the inputs, 5883.39 MJ ha-1 (59.30%), consists of farm manure. This is due to the low use of chemical fertilizers in the inputs and the high use of farmyard manure.

Table 3. Energy usage in lavender production

INPUTS	UNIT	ENERGY EQUIVALENT (MJ UNIT^{-1})	INPUT USED PER HECTARE (UNIT HA^{-1})	ENERGY VALUE (MJ HA^{-1})	RATIO (%)
HUMAN LABOUR	h	1.96	141.17	276.70	2.79
MACHINERY	h	64.80	6.51	421.89	4.25
CHEMICAL FERTILIZERS	-	-	-	732.02	7.38
N	kg	60.60	10.33	626	6.31
CA	kg	8.80	7.23	63.62	0.64
MICRO ELEMENTS	kg	120	0.35	42.40	0.43
DIESEL FUEL	L	56.31	43.07	2425.51	24.45
FARMYARD MANURE	kg	0.30	19611.31	5883.39	59.30
VERMICOMPOST	kg	1.20	70.67	84.81	0.85
TRANSPORTATION*	MJ (ton km)$^{-1}$	4.50	21.63	97.31	0.98
TOTAL INPUTS	-	-	-	9921.63	100.00
OUTPUTS	Unit	Energy equivalent (MJ / unit)	Output per hectare (unit ha^{-1})	Energy value (MJ ha^{-1})	Ratio (%)
LAVENDER FLOWER	kg (18% dry matter)	20.61	3466.43	12859.77	100.00
TOTAL OUTPUT	-	-	-	12859.77	100.00

*Average trip distance (6.25 km *3.46 tons)

Fresh stalked lavender flower, EI, EO, EUE, SE, EP and NE in lavender production were calculated as 3466.43 kg ha^{-1}, 9921.63 MJ ha^{-1}, 12859.77 MJ ha^{-1}, 1.30, 2.86 MJ kg^{-1}, 0.35 kg MJ^{-1} and 2938.13 MJ ha^{-1}, respectively (Table 4). In previous researches; Gökdoğan (2016) calculated (lavender) EUE as 2.77, Haciseferogullari et al. (2003) calculated (sugar beet) EUE as 19.15, Çelik et al. (2010) calculated (conventional black carrot) EUE as 1.30, Taghavifar and Mardani (2015b) calculated (wheat) EUE as 1.74, Semerci et al. (2019) calculated (cotton) EUE as 1.11 etc.

Table 4. EUE calculations in lavender production

CALCULATIONS	UNIT	VALUES
LAVENDER FLOWER	kg ha^{-1}	3466.43
EI	MJ ha^{-1}	9921.63
EO	MJ ha^{-1}	12859.77
EUE	-	1.30
SE	MJ kg^{-1}	2.86
EP	kg MJ^{-1}	0.35
NE	MJ ha^{-1}	2938.13

Energy inputs for lavender production have been categorized and calculated as direct (DE), indirect (IDE), renewable (RE) and non-renewable (NRE) energy groups (Table 5). The total energy input in lavender production can be classified as 27.24% (2702.21 MJ ha-1) DE, 72.76% (7219.42 MJ ha-1)

IDE, 62.94% (6244.90 MJ ha-1) RE and 37.06% (3676.73 MJ ha-1) NRE. RE was higher than the ratio of NRE in energy inputs of lavender production. Achieving higher usage levels of renewable energy source is a desirable outcome. In previous studies on lavender (Gökdoğan, 2016), on cotton (Sami and Reyhani, 2018), on onion (Ozbek et al. 2021) etc., the ratio of NRE energy has been observed to be higher than the ratio of RE.

Table 5. Energy inputs forms of lavender production

ENERGY GROUPS	ENERGY INPUT (MJ HA^{-1})	RATIO (%)
DE	2702.21	27.24
IDE	7219.42	72.76
TOTAL	9921.63	100.00
RE	6244.90	62.94
NRE	3676.73	37.06
TOTAL	9921.63	100.00

The results of GHG emissions of lavender production are given in Table 6. The total GHG emissions were calculated as 266.62 kg$CO_{2\text{-}eq}$ha^{-1} (0.26 ton$CO_{2\text{-}eq}$ha^{-1}). According to the results of the study, the input with the highest value is diesel fuel with 118.88 kgCO2$_{\text{-}eq}$ha^{-1} (44.59%). Diesel fuel is followed by farmyard manure with 98.06 kg$CO_{2\text{-}eq}$ha^{-1} (36.78%) and machinery energy with 29.95 kg$CO_{2\text{-}eq}$ha^{-1} (11.23%). The GHG ratio (per kg) was calculated as 0.08. In previous studies, Pishgar-Komleh et al. (2012) reported GHG emission in potato production as 992.88 kg$CO_{2\text{-}eq}$ha^{-1}, Khoshnevisan et al. (2013) reported GHG emission in wheat production as 2711.58 kg$CO_{2\text{-}eq}$ha^{-1} Ozbek et al. (2021) reported the GHG emission in onion production as 2922.11 ton$CO_{2\text{-}eq}$ha^{-1}.

Table 6. GHG emissions in lavender production

INPUTS	UNIT	GHG COEFFICIENT (KG CO_{2EQ} UNIT^{-1})	INPUT USED PER AREA (UNIT HA^{-1})	GHG EMISSIONS (KG CO_{2EQ} HA^{-1})	RATIO (%)
MACHINERY	MJ	0.071	421.89	29.95	11.23
N	kg	1.300	10.33	13.43	5.04
CA	kg	0.39	7.23	2.82	1.06
MICRO ELEMENTS	kg	0.66	0.35	0.23	0.09
DIESEL FUEL	L	2.760	43.07	118.88	44.59
FARMYARD MANURE	kg	0.005	19611.31	98.06	36.78
TRANSPORTATION	ton.km	0.150	21.63	3.24	1.22
TOTAL	-	-	-	266.62	100.00
GHG RATIO (PER KG)	-	-	-	0.08	-

CONCLUSION

Energy use, GHG emissions and rate in lavender production were calculated in this study. The study results can be summarized as follows.

Production inputs consist of 5883.39 MJ ha^{-1} (59.30%) farmyard manure energy, 2425.51 MJ ha^{-1} (24.45%) diesel fuel energy, 732.02 MJ ha^{-1} (7.38%) chemical fertilizers energy, 421.89 MJ ha^{-1} (4.25%) machinery energy, 276.70 MJ ha^{-1} (2.79%) human labour energy, 97.31 MJ ha^{-1} (0.98%) transportation energy and 84.81 MJ ha^{-1} (0.85%) vermicompost energy, respectively

EUE, SE, EP and NE in lavender production were calculated as 1.30, 2.86 MJ kg^{-1}, 0.35 kg MJ^{-1} and 2938.13 MJ ha^{-1}, respectively. These results suggest that lavender production is economically viable in terms of energy usage.

The highest energy input in lavender production was calculated for farmyard manure energy by 5883.39 MJ ha^{-1} (59.30%). It is a desired result that the use of renewable energy is high in agriculture. It is desirable to reduce non-renewable energy sources and reduce the use of chemical fertilizers.

The used total energy input was classified as 62.94% renewable and 37.06% non-renewable. In terms of energy use, higher use of renewable energy is a desired result.

Total GHG emission and GHG ratio have been respectively calculated as 266.62 kgCO_{2-eq}ha^{-1} (0.26 tonCO_{2-eq}ha^{-1}) and 0.08. Based on the study results, the highest value was yielded by diesel fuel by 118.88 kgCO_{2-eq}ha^{-1} (44.59%).

Reducing diesel fuel consumption in lavender production in the region is one of the most important goals in terms of energy and GHG management.

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