Determination of energy use efficiency and greenhouse gas emissions in peach production

Cihan Demir[1*], Osman Gökdoğan[2]

(1. *Department of Mechanical and Metal Technologies, Vocational School of Technical Sciences, University of Kırklareli, Kırklareli, Turkey*; 2. *Department of Agricultural Machinery and Technologies Engineering, Faculty of Agriculture, Isparta University of Applied Sciences, Isparta, Turkey*)

Abstract: The purpose of this study was to determine the energy use efficiency and greenhouse gas (GHG) emissions in peach production that took place in Kırklareli province of Turkey during the 2020-2021 production season. This study included calculations of energy input, energy output, energy use efficiency, specific energy, energy productivity, net energy, energy input types, GHG emissions and GHG ratio. Survey, observation and data calculations are related to the 2020-2021 production season. The data obtained from the study were collected from 16 different farms (reachable) through face-to-face surveys with full count method. Energy input and energy output were calculated as 19 570.58 MJ/hm^2 and 19 471.94 MJ/hm^2, respectively. With regards to production inputs, 55.70% of the energy inputs consisted of chemical fertilizers energy (10 900.03 MJ/hm^2), 9.46% consisted of chemicals energy (1852.10 MJ/hm^2), 9.32% consisted of human labour energy (1823.13 MJ/hm^2), 7.65% consisted of electricity energy (1497.28 MJ/hm^2), 6.91% consisted of diesel fuel energy (1351.52 MJ/hm^2), 4.73% consisted of irrigation water energy (926.10 MJ/hm^2), 3.43% consisted of machinery energy (671.98 MJ/hm^2), 1.88% consisted of transportation energy (367.72 MJ/hm^2), 0.88% consisted of farmyard manure energy (171.80 MJ/hm^2) and 0.05% consisted of lime energy (8.94 MJ/hm^2). Energy use efficiency, specific energy, energy productivity and net energy were calculated as 0.99, 1.91 MJ/kg, 0.52 kg/MJ and –98.64 MJ/hm^2, respectively. The consumed total energy input in production was classified as 28.60% direct energy, 71.40% indirect energy, 14.93% renewable energy and 85.07% non-renewable. Total GHG emissions and GHG ratio were calculated as 1683.24 kg$CO_{2\text{-eq}}$/hm^2 and 0.16 kg $CO_{2\text{-eq}}$/kg, respectively.

Keywords: energy use efficiency, greenhouse gas emissions, greenhouse gas ratio, peach, Turkey

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1 Introduction

As of the new century, it has been confirmed by climate science that global warming is caused by carbon dioxide and other greenhouse gas (GHG) resulting from the use of fossil fuels. Climate changes occur as a result of human beings not changing their consumption habits. And as a consequence, extreme weather events occur, causing massive environmental destruction and disasters such as public health problems and mass deaths. It is predicted that such disasters will increase in number and severity[1]. Fossil fuels are non-renewable energy sources and have many harmful effects for the ecosystem. Today, problems related to the usage of fossil fuels in agricultural production are increasing[2,3]. The main harms caused by fossil fuels on environment are pollution of soil and water resources, poisoning of beneficial organisms and greenhouse gas emissions released into the atmosphere[3]. Energy balance in agriculture has been studied by many researchers since the 1970s[3-5]. Energy defines the work capacity, and it is the power source of all human activities, particularly those regarding the production of goods and services[6,7].

Comparing the energy value of the obtained product with total energy value of the inputs used in agricultural production processes is a more realistic approach to evaluate production efficiency[8]. Achieving the trait of optimum energy consumption can be realized through key factors such as intensive energy consumption and reducing the known energy resources. Ensuring optimum consumption, hence optimum use of energy, will consequently ensure higher yield and contribute to economy, profitability and competitiveness of agricultural sustainability[9,10]. Sustainable agriculture can be achieved by a principal precondition, which is the efficient use of energy. Ever increasing population, depleted supply of arable land, and a desire for higher standards of living are the main factors behind the increasing demand of energy use in agriculture. As a consequence of increasing demand for food production, there is now an intensive use of chemical fertilizers, pesticides, agricultural machinery, electricity, and other natural resources. But on the flip side of the coin, more usage of energy poses several risks to human health and environment. Effective usage of energy in agriculture will shrink environmental issues, block destruction of natural resources, and ensure that agriculture becomes an economic production system[11-13].

One of the fastest growing fruit types among the fruits produced in Turkey is peach, which is categorized in the group of stone fruits. The rapid development of peach cultivation depends on various reasons. Some of these reasons are the ability of the varieties to adapt to different ecologies, the early fruiting of this species, the fact that it is an important source of raw materials for the agricultural industry. In addition, its fruits are spectacular and

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Biographies: Osman Gökdoğan, PhD, Associate Professor, research interest: agricultural machinery management, energy usage in agricultural production. Email: osmangokdogan@gmail.com.

***Corresponding author: Cihan Demir**, PhD, Assistant professor, research interest: agricultural machinery, energy usage in agricultural production. Kırklareli University, Technical Sciences Vocational School, Kırklareli, Turkey. Tel: +90-544 442 39 22, Email: cihan.demir@klu.edu.tr.

rich in nutritional content. Peach can be consumed fresh, while fruit juice concentrate can be stored for a long time. It can also be made into jam and marmalade, and therefore provides raw materials to the industry[14]. The leading peach farms in the world are in China, Italy, USA, Spain, Greece, Turkey and France[15,16]. In 2021, 712 781 t of peach was produced in Turkey in an area of 39 160 hm^2[17].

Studies have been performed on energy use efficiency (EUE) and GHG emission in agricultural and animal production. The examples are peach[16,18,19], nectarine[20,21], plum[22,23], almond[24,25], apricot[26,27], grape[28,29], apple[30,31], olive[32,33], kiwi[34,35], chestnut[36], cotton[37,38], sunflower[39,40], tomato[41,42], onion[43,44], black cumin[45], pumpkin seed[46], legume[47], lavender[48], field crops[49], fruit crops[50], agricultural products[51], poultry[52-55], etc. The aim of this study is to determine the EUE and GHG emission in peach production phase in Kırklareli province. In addition, it is important to determine the EUE and GHG emission rate that took place in the field of research.

2 Materials and methods

Kırklareli is located in Thrace Region, comprising the European part of Turkey. It is between the 41°44'N-42°00'N and 26°53'E-41°44'E. 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 plains[56]. This study has been conducted in relation to the 2020-2021 production season in Kırklareli province of Turkey. The survey, observation and study have all been conducted in agricultural farms of the Central district of Kırklareli and they were determined on the basis of 2021 data provided by the Kırklareli Provincial Directorate of Agriculture and Forestry. The data obtained from the study were collected from 16 farms (reachable) through face-to-face surveys with full count method proposed by Karagölge and Peker[57].

Energy equivalents (EE) of inputs and outputs used in agriculture production are given in Table 1. The total energy input was obtained by multiplying the EE of the EI used per hectare, and the total EO is obtained by multiplying the output from the hectare with the energy equivalents. EUE, specific energy, energy productivity and net energy were calculated by using the following formulas[34,58,59]. EI types were classified as direct energy, indirect energy, renewable energy and non-renewable energy[58,60,61]. GHG emissions coefficients of inputs in agricultural production are given in Table 2.

Table 1 Energy inputs-output in peach production and coefficients

Inputs	Unit	EE/(MJ·unit^{-1})	Reference
Human labour	h	1.96	[66, 67]
Machinery	h	64.80	[68, 69]
Chemicals	kg	101.20	[68, 70]
Nitrogen	kg	60.60	[68, 71]
Phosphorous	kg	11.10	[58, 71]
Potassium	kg	6.70	[58, 71]
Sulphur	kg	1.12	[72, 34]
Diesel fuel	L	56.31	[68, 70]
Electricity	kW·h	3.60	[73]
Lime	kg	1.32	[74, 75]
Farmyard manure	kg	0.30	[47, 71]
Irrigation water	m^3	0.63	[76, 71]
Transportation	MJ (t·km)	4.50	[77, 78]
Output (Fruit)	kg	1.90	[79, 18]

Table 2 GHG emissions in peach production and coefficients

Inputs	Unit	GHG coefficients/(kgCO$_{2\text{-eq}}$·unit^{-1})	Reference
Human labour	h	0.360	[64, 71]
Machinery	MJ	0.071	[80, 31]
Chemicals	kg	13.900	[81, 50]
Nitrogen	kg	1.300	[82, 71]
Phosphorous	kg	0.200	[82, 71]
Potassium	kg	0.200	[83, 71]
Sulphur	kg	0.370	[84, 50]
Diesel fuel	L	2.760	[80, 71]
Electricity	kW·h	0.608	[85, 71]
Lime	kg	0.110	[86, 50]
Farmyard manure	t	0.005	[87, 31]
Irrigation water	m^3	0.270	[64, 71]
Transportation	t·km	0.150	[87, 50]

$$\text{EUE} = \frac{\text{Energy output (MJ/hm}^2)}{\text{Energy input (MJ/hm}^2)} \quad (1)$$

$$\text{SE} = \frac{\text{Energy intput (MJ/hm}^2)}{\text{Product output (kg/hm}^2)} \quad (2)$$

$$\text{EP} = \frac{\text{Product output (kg/hm}^2)}{\text{Energy intput (MJ/hm}^2)} \quad (3)$$

$$\text{NE} = \text{Energyoutput (MJ/hm}^2) - \text{Energyinput (MJ/hm}^2) \quad (4)$$

GHG values are calculated by multiplying the inputs with their greenhouse gas equivalent emission values. The calculation results are given in Table 2. A greenhouse gas emission schedule was created in production and the greenhouse gas emission rate calculation was made. The following equation, adapted by Hughes et al.[63] over the suggestion of Karaağaç et al.[62], was used to determine the GHG emission.

$$\text{GHG}_{\text{ha}} = \sum_{i=1}^{n} R(i) \cdot EF(i) \quad (5)$$

where, GHG_{ha} is GHG emissions in unit area, kg $CO_{2\text{-eq}}$/hm^2; $R(i)$ is implementation amount of input i, unit$_{\text{input}}$ /hm^2; $EF(i)$ is GHG emissions equivalent of input i, kg $CO_{2\text{-eq}}$/unit$_{\text{input}}$.

The GHG ratio is the index defined as the amount of GHG emissions per unit yield. In the calculation of GHG ratio, the following equation was used, adapted by Houshyar et al.[64] and Khoshnevisan et al.[65], based on the recommendation of Karaağaç et al.[62]

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

where, I_{GHG} is GHG ratio, kg$CO_{2\text{-eq}}$ /kg; Y is yield, kg/hm^2.

3 Results and discussion

The peach orchards yielded an average of 10 248.39 kg/hm^2 during the 2020-2021 production seasons. The EB related to 2020-2021 is given in Table 3. EI was calculated as 19 570.58 MJ/hm^2, EO was calculated as 19 471.94 MJ/hm^2. With regards to the inputs in 2020-2021, 55.70% of the EI consisted of chemical fertilizers energy (10 900.03 MJ/hm^2), 9.46% consisted of chemicals energy (1852.10 MJ/hm^2), 9.32% consisted of human labour energy (1823.13 MJ/hm^2), 7.65% consisted of electricity energy (1497.28 MJ/hm^2), 6.91% consisted of diesel fuel energy (1351.52 MJ/hm^2), 4.73% consisted of irrigation water energy (926.10 MJ/hm^2), 3.43% consisted of machinery energy

Table 3 EB in peach production

Inputs	Unit	Energy equivalent/(MJ·unit^{-1})	Input/(unit·hm^{-2})	Energy value/(MJ·hm^{-2})	Rate/%
Human labour	h	1.96	930.17	1823.13	9.32
Machinery	h	64.80	10.37	671.98	3.43
Chemicals	kg	101.20	18.30	1852.10	9.46
Nitrogen	kg	60.60	137.46	8330.08	42.56
Phosphorous	kg	11.10	137.46	1525.81	7.80
Potassium	kg	6.70	137.46	920.98	4.71
Sulphur	kg	1.12	109.97	123.17	0.63
Diesel fuel	L	56.31	24	1351.52	6.91
Electricity	kW·h	3.60	415.91	1497.28	7.65
Lime	kg	1.32	6.77	8.94	0.05
Farmyard manure	kg	0.30	572.66	171.80	0.88
Irrigation water	m^3	0.63	1470	926.10	4.73
Transportation*	MJ (t·km)	4.50	81.72	367.72	1.88
Total				19570.58	100.00
Output	Unit	Energy equivalent/(MJ·unit^{-1})	Yield/(br·hm^{-2})	Energy value/(MJ·hm^{-2})	Rate/%
Yield	kg	1.90	10248.39	19471.94	100.00
Total	-	-	-	19471.94	100.00

(671.98 MJ/hm^2), 1.88% consisted of transportation energy (367.72 MJ/hm^2), 0.88% consisted of farmyard manure energy (171.80 MJ/hm^2) and 0.05% consisted of lime energy (8.94 MJ/hm^2).

Similar results were obtained in other studies on peach production. Göktolga et al.[18] calculated the rate of chemical fertilizers as 44.44% among the most used energy inputs, Aydın and Aktürk[16] calculated the rate of chemical fertilizers as 27.53% in energy inputs and Oğuz et al.[21] calculated 43.15% among energy inputs in nectarine production. In this study, EUE, SE, EP and NE were calculated as 0.99, 1.91 MJ/kg, 0.52 kg/MJ and –98.64 MJ/hm^2, respectively (Table 4). In other studies related to peach production, Göktolga et al.[18] calculated EUE and EP as 0.93, 0.49 kg/MJ; Aydın and Aktürk[16] calculated EUE, SE, EP and NE as 0.66, 3.64 MJ/kg, 0.27 kg/MJ and –13636.94 MJ/hm^2, Yildiz et al.[19] calculated EUE, SE, EP and NE as 1.13, 1.67 MJ/kg, 0.60 kg/MJ and 2429.96 MJ/hm^2, respectively and Oğuz et al.[21] calculated EUE, SE, EP and NE as 1.86, 1.02 MJ/kg, 0.98 kg/MJ and 25 837.74 MJ/hm^2 in nectarine production, Kızılaslan[88] calculated EUE and EP as 1.10, 0.53 kg/MJ in apple production.

Table 4 Calculations of EUE in peach production

Calculations*	Unit	Values
Fruit	kg/hm^2	10 248.39
EI	MJ/hm^2	19 570.58
EO	MJ/hm^2	19 471.94
EUE	-	0.99
SE	MJ/kg	1.91
EP	kg/MJ	0.52
NE	MJ/hm^2	–98.64

The consumed total energy input was classified as 28.60% DE, 71.40% IE, 14.93% RE and 85.07% N-RE (Table 5). In other studies related to peach production, Göktolga et al.[18], Aydın and Aktürk[16] and Yildiz et al.[19] calculated DE ratio to be higher than IE, and N-RE energy ratio to be higher than RE. In other studies, DE ratio was calculated to be higher than IE energy, and N-RE energy ratio was calculated to be higher than RE by Oğuz et al.[23] in plum cultivation, Yılmaz et al.[89] in apple cultivation, Akcaoz et al.[90] in pomegranate cultivation.

The results of GHG emissions are given in Table 6. Total GHG emissions were calculated as 1686.11 kg $CO_{2\text{-}eq}$/hm^2 for peach production. GHG emissions took place due to irrigation water usage 23.58%, human labour usage 19.89%, chemicals usage 15.11%, electricity 15.02%, nitrogen 10.62%, diesel fuel usage 3.94%, transportation 3.28%, machinery usage 2.83%, sulphur usage 2.42%, phosphorous & potassium usage 1.63%, lime usage 0.04% and farmyard manure 0.01%, respectively. In previous studies, Ozalp et al.[71] calculated the total GHG emission of pomegranate production as 1734.6 kg $CO_{2\text{-}eq}$/hm^2, Gökdoğan et al.[91] calculated the total GHG emission of pistachio production as 1123.72 kg $CO_{2\text{-}eq}$/hm^2, Baran et al.[92] calculated the total GHG emission of persimmon production as 4440 kg $CO_{2\text{-}eq}$/hm^2, and Gökduman et al.[93] calculated the total GHG emission of avocado production as 6145.31 kg $CO_{2\text{-}eq}$/hm^2.

Table 5 Energy input types in peach production

Energy types*	Energy input/MJ·hm^{-2}	Rate%
DE	5598.02	28.60
IE	13 972.56	71.40
Total	19 570.58	100.00
RE	2921.02	14.93
N-RE	16 649.56	85.07
Total	19 570.58	100.00

Efficient use of energy source is crucial to reduce operating cost and reduce emissions of air pollutants and greenhouse gases[94-97]. Taking the recommendations proposed by this study into consideration can contribute to better energy use efficiency in the future.

4 Conclusions

This study has revealed the EUE, GHG emission and the obtained results along with suggestions are summarised below.

EI and EO were calculated as 19 570.58 MJ/hm^2 and 19 471.94 MJ/hm^2, respectively. The highest EI is chemical fertiliser input by a ratio of 55.70%. Using farm fertiliser can be helpful in reducing the ratio of chemical fertiliser used in agricultural activities.

EUE, SE, EP and NE were calculated as 0.99, 1.91 MJ/kg, 0.52 kg/MJ and –98.64 MJ/hm^2, respectively. According to these, this production is not a profitable activity in terms of EUE (0.99).

RE and N-RE energy inputs comprised 14.93% and 85.07% of the total energy input, respectively. In order to increase the ratio of

Table 6 GHG emissions in peach production

Inputs	Unit	GHG coefficient ($kgCO_{2\text{-eq}}\cdot unit^{-1}$)	Input/($unit\cdot hm^{-2}$)	GHG emissions ($kg\ CO_2.eq\cdot hm^{-2}$)	Ratio/%
Human labour	h	0.360	930.17	334.86	19.89
Machinery	MJ	0.071	671.98	47.71	2.83
Chemicals	kg	13.900	18.30	254.39	15.11
Nitrogen	kg	1.300	137.46	178.70	10.62
Phosphorous	kg	0.200	137.46	27.49	1.63
Potassium	kg	0.200	137.46	27.49	1.63
Sulphur	kg	0.370	109.97	40.69	2.42
Diesel fuel	L	2.760	24	66.24	3.94
Electricity	kW·h	0.608	415.91	252.87	15.02
Lime	kg	0.110	6.77	0.74	0.04
Farmyard manure	t	0.005	0.57	0.002	0.01
Irrigation water	m^3	0.270	1470	396.90	23.58
Transportation	t·km	0.150	367.72	55.16	3.28
Total	-	-	-	1683.24	100
GHG ratio (per kg)	-	-	-	0.16	-

RE, it is important to increase the use of farm manure and to use organic fertilizers.

Total GHG emissions and GHG ratio were calculated as 1683.24 kg $CO_{2\text{-eq}}/hm^2$ and 0.16 kg $CO_{2\text{-eq}}$/kg, respectively.

Reducing chemical fertiliser consumption, human labour, irrigation water and diesel fuel are the most burning issues in terms of the cultivation of various fruits in the study areas in Turkey. For this end, soil analysis is proposed to define soil fertiliser needs (reduction of high chemical fertilizers causing GHG emissions), human labor productivity (decrease of human labor used), irrigation water usage efficiency and fuel efficiency.

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