Erwerbs-Obstbau (2020) 62:481–487
https://doi.org/10.1007/s10341-020-00528-4

ORIGINAL ARTICLE / ORIGINALBEITRAG

Energy Efficiency and Economic Analysis of Walnut Production in Turkey

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Received: 19 November 2018 / Accepted: 25 September 2020 / Published online: 15 October 2020

Abstract
Turkey is one of the countries that is the gene center and the homeland of walnuts. The purpose of the study was to determine the energy uses of walnut production in Turkey. In the study, the energy efficiency of walnut production, net energy, energy productivity, and specific energy were examined. In addition, the benefit-cost ratio, the use of direct and indirect energy, renewable and non-renewable energy were determined. Data was obtained from walnut producers in the Istanbul province of Turkey by using a survey. Surveys were performed with 48 walnut producers. Total energy input and total energy output of the surveyed orchards were calculated as 12,605 MJ ha^{-1} and 23,300 MJ ha^{-1} respectively. The energy use efficiency was calculated as 1.85 for the walnut production. While specific energy was calculated as 5.95 MJ kg^{-1} energy productivity was calculated 0.17 kg MJ^{-1} in the study. According to economic analysis, it was determined that the walnut producers had 4850 US$ ha^{-1} net return per year. The benefit-cost ratio was calculated as 1.51. As a result of the study, it was determined that the walnut production was preferable in the region.

Keywords Energy efficiency · Specific energy · Environmental effect · Walnut productivity · Renewable energy · Benefit-cost ratio

Energieeffizienz und Wirtschaftlichkeitsanalyse der Walnussproduktion in der Türkei

Schlüsselwörter Energieeffizienz · Spezifische Energie · Umwelteffekt · Produktivität von Walnüssen · Erneuerbare Energie · Kosten-Nutzen-Verhältnis

Introduction

Turkey has a high agricultural potential in the world regarding ecological features. Turkey is one of the countries that is the gene center and the homeland of walnuts. Soil and climatic requirements for the healthy development of the walnut is available on the territory of Turkey.

Healthy nutrition has recently become an important issue in the world, and nuts, one of the fastest-consuming food products, are among the investment preferences of producers in terms of economy and nutrition. Walnut farming is a type of fruit that has a wide range in the world. There is a high consumer demand for walnuts. Walnuts have intense nutrition in terms of protein and essential fatty acids. Especially, walnuts are more abundant than many hazelnuts in rich in omega-6 acids and polyunsaturated fats called linoleic acid (Anonymous 2018a). They are a rich source of vitamins containing vitamin B6, vitamin C, thiamin, niacin, riboflavin, folate and pantothenic acid. They also contain minerals such as phosphorus, magnesium, calcium, iron, potassium, zinc, and sodium.

Walnuts also contain other important substances such as lutein, beta-carotene, and zeaxanthin, as well as phytosterols. Walnuts are a good dietary fiber source. These are rich sources of antioxidants such as phytic acid, catechin, melatonin, and ellagic acid. The walnuts, which are believed to improve the body's durability of the body, are also considered "power food" (Anonymous 2018b).

According to FAO, walnut has a share of 24% with 1.2 million hectares as a production area in the world among

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the nuts. In terms of production amount, it has a share of 34% with 3.7 million tons and is in the first place. China leads world production of walnut with 1.7 million tons per year, followed by the United States (607 thousand tons), Iran (405 thousand tons) and Turkey (195 thousand tons) (FAO 2018).

Turkey's total agricultural area is about 23.7 million hectares; it is covered by 2 million hectares of orchards. Hazelnut is in the first place with 61.31% in nuts orchards area, followed by pistachios with 27.24%, walnuts with 7.55%, almonds with 2.90% and chestnuts with 1%. In Turkey, there are 8.1 million fruiting walnut trees and the average yield is 24 kg per tree (TUIK 2018).

The energy use in the cultivation and distribution phases of agricultural production is considerably high. An advanced agricultural production requires the efficient and productive use of energy. Product yield and food supply seem to be linked direct to energy. The increase in product yield is due to the increase in commercial energy inputs in addition to the improved product variety range in developed countries (Faidley 1992). One of the major criteria is energy use efficiency for sustainable agriculture. Comparing the total energy equivalent of the production inputs used in agricultural operations with the energy equivalent of the produced crop is a more realistic approach to assessing production efficiency (Unakitan and Aydin 2018).

In Turkish agriculture, energy use efficiency is gradually decreasing, while energy consumption is slowly increasing for increasing the production efficiency. In addition, energy efficiency needs to be increased in order to implement sustainable agriculture, reduce environmental pollution, reduce the use of fossil fuels and achieve economic benefits in agricultural production. Energy efficiency contributes to the economy in the rural area with the competitiveness of sustainable agriculture, increased profitability, and productivity (Ozkan et al. 2007).

The purpose of the study was to determine the energy uses of walnut production in Turkey. In the study, the energy efficiency of walnut production, net energy, energy productivity, and specific energy were examined. In addition, the benefit-cost ratio, the use of direct and indirect energy, renewable and non-renewable energy were determined. There are several studies that examine the energy efficiency analysis and the environmental impact of energy efficiency. Various studies were published on energy efficiency analysis in fruit production such as walnut (Khoshroo and Mulwa 2014; Baran et al. 2017b; Gündoğmuş 2013), almond (Beigi et al. 2016), peach (Goktolga et al. 2006; Royan et al. 2012; Aydin and Akturk 2018), apple (Ekinci et al. 2015; Strapatsa et al. 2006; Gokdogan and Baran 2017), grapefruit (Baran et al. 2017a; Qasemi Kordkheili and Rabhar 2015), apricot (Esengun et al. 2007; Gezer et al. 2003; Gündoğmuş 2006), cherries (Kizilarslan 2009; Demircan et al. 2006), strawberry (Banaeian et al. 2011; Loghmanpor et al. 2013a), organic strawberry (Baran et al. 2017c), nectarine (Qasemi Kordkheili et al. 2013), pear (Liu et al. 2010; Tabatabaie et al. 2013), kiwifruit (Mohammadi et al. 2010), citrus (Ozkan et al. 2004; Namdari et al. 2011; Loghmanpor et al. 2013b), lemon (Loghmanpor et al. 2013b), orange (Mohammadshirazi et al. 2015), banana (Akcaoz 2011), pomegranate (Akcaoz et al. 2009).

Materials and Methods

Materials

Data was obtained from walnut orchards in the Silivri, Istanbul of Turkey by using surveys performed in February–March 2016. According to records of the Ministry of Agriculture and Forestry, there are 67 walnut producers in Silivri, Istanbul. Due to the left from the production of 19 producers, surveys have been performed with 48 walnut producers.

Methods

The input quantities multiplied by their energy equivalents were calculated per hectare. Energy equivalents of production inputs and output are given in Table 1, used for the analysis. Energy equivalents have been used for estimation have been adapted to the conditions of the most appropriate resources in Turkey. Among the mechanical energy sources used in selected producers are tractors and diesel fuel. The mechanical energy was calculated according to the total diesel consumption ($l\,ha^{-1}$) on various parts of production; for this reason, the energy consumption was calculated using conversion factors and expressed in MJ ha^{-1}. The energy of a tractor and its equipment reveals energy requirement for unit weights and calculates total machine weight, transport energy, repair and care energy, and average economic life. The total input energy has been obtained as the sum of the energy values of all inputs in Mega Joules (MJ). The energy use efficiency (energy ratio), net energy, energy productivity, and specific energy have been calculated following formulas (Mohammadi et al. 2010; Tabatabaeefar et al. 2009; Rafiee et al. 2010; Zangeneh et al. 2010.):

$$Energy\,Use\,Efficiency = \frac{Energy\,Output\,\left(MJ\,ha^{-1}\right)}{Energy\,Input\,\left(MJ\,ha^{-1}\right)}$$

$$Energy\,Productivity = \frac{Yield\,\left(kg\,ha^{-1}\right)}{Energy\,Input\,\left(MJ\,ha^{-1}\right)}$$

$$Specific\,Energy = \frac{Energy\,Input\,\left(MJ\,ha^{-1}\right)}{Yield\,\left(kg\,ha^{-1}\right)}$$

Table 1 Energy equivalents of inputs and outputs in walnut production

	Energy Equivalent (MJ unit^{-1})	References
Inputs		
Human labor (h)	1.96	Singh (2002); Mandal et al. (2002)
Machinery (h)	62.70	Singh (2002); Mandal et al. (2002); Unakitan et al. (2010)
Pesticides (kg)		
Herbicides	238	Khoshroo and Mulwa (2014); Rafiee et al. (2010)
Fungicide	216	Khoshroo and Mulwa (2014); Rafie et al. (2010)
Sulfur	1.12	Mohammadi et al. (2010); Singh (2002)
Fertilizer (kg)		
Nitrogen	60.60	Singh (2002); Mandal et al. (2002)
Phosphorus	11.15	Singh (2002); Mandal et al. (2002)
Potassium	11.15	Singh (2002); Mandal et al. (2002)
Diesel (l)	56.31	Singh (2002); Mandal et al. (2002); Unakitan et al. (2010)
Water (m^3)	1.02	Khoshroo and Mulwa (2014)
Output		
Walnut kernel (kg)	11.80	Khoshroo and Mulwa (2014)
Walnut shell (kg)	10.00	Baran et al. (2017b); Gündoğmuş (2013)

$$Net\ Energy = Energy\ Output(MJ\ ha^{-1}) - Energy\ Input(MJ\ ha^{-1})$$

While direct energy was calculated from diesel fuel, human labor, and irrigation water, indirect energy was calculated from fertilizer, pesticides, and machinery. In addition, renewable energy is the sum of the energy of human labor and irrigation water, while the non-renewable energy is the sum of the energies of diesel fuel, pesticides, fertilizers, and machinery.

Economic analysis was done for walnut production in the last part of the study. Fixed and variable costs, gross return, net return, the benefit-cost ratio which are economic indicators of walnut production were calculated. Variable costs are operating costs that vary according to farm size and production volume.

Variable costs were fertilizers, pesticides, machinery, human labor, irrigation water, diesel fuel, and revolving fund interest. The revolving fund interest refers to the opportunity cost of the capital used in agricultural production.

The fixed costs constitute, general management cost, land value, amortization and other fixed costs. The general management cost was considered as 3% of the total variable cost. The gross value of walnut was calculated with market prices. Land value is the interest of the treeless land value with 5%. Amortization is the annual abrasion share of establishment costs of a walnut orchard. Other fixed costs include land rent and protection costs, etc.

The economic indicators such as gross and net profit and benefit-cost ratio were used in the determination of achievement level on walnut production. The following formulas were used in the calculation of economic indicators;

$$Gross\ profit = Gross\ production\ value - Variable\ costs$$

$$Net\ profit = Gross\ production\ value - Production\ costs$$

$$Benefit - cost\ ratio = Gross\ production\ value / Production\ costs$$

(Acil and Demirci 1984; Kiral et al. 1999).

Results

In the study, energy efficiency and economic analysis were done for walnut production. The inputs and outputs quantity and their equivalents of total energy in walnut production are given in Table 2. Also, the main headings of inputs and their details were given in Table 2. For example, the total amount of human labor is 67 h per hectare and its details were given below the main heading. In the same way, the fertilizer consumption is 125.9 kg per hectare and the distribution of the active materials (N, P, K) were given below the heading.

The economic life of walnut orchards was accepted as 25 years. The first 4 years is the facility preparation and the average walnut yield was calculated as 2120 kg ha^{-1} considering varying yields of 21 years in the walnut orchards. The walnut variety is 'Chandler' in the surveyed orchards and its walnut kernel rate was 55%. Because of the walnut kernel and shell have different energy values, walnut kernel and its shell were included separately in the account of energy balance. Total energy equivalents were obtained by multiplying the quantities of physical inputs by the energy coefficients given in Table 1. Accordingly, the total energy input and total energy output of the surveyed orchards were calculated as 12,605 MJ ha^{-1} and 23,300 MJ ha^{-1} respectively.

When the distribution of the inputs was examined, according to energy equivalents, diesel fuel had the highest share at 44.67%. The total energy equivalent of the fertilizers was 5219 MJ ha^{-1} and its share in the total energy input was 41.41%. The energy equivalents of the other inputs and their shares in the total energy input are shown in Table 2.

When the distribution of energy output was examined, it was observed that 59% of the energy output obtained from the walnut kernel and 41% was obtained from the walnut shell.

Table 2 Amounts of inputs and outputs for walnut production

	Quantity	Energy equivalent MJ ha^{-1}	%
Inputs			
Human labor (h)	*67*	*131.32*	1.04
Plowing	3.5	6.86	
Hoeing	4	7.84	
Irrigating	12.5	24.50	
Sapling renewing	1	1.96	
Dilution	5	9.80	
Fertilization	2	3.92	
Spraying	4	7.84	
Harvesting	30	58.80	
Transporting	5	9.80	
Machinery (h)	*8.5*	*532.95*	4.23
Plowing	3.5	219.45	
Transporting	5	313.50	
Diesel (l)	*100*	*5631.00*	44.67
Fertilizers (kg)	*125.9*	*5219.35*	41.41
N	76.8	4654.08	
P	13.8	171.67	
K	35.3	393.60	
Pesticides (l)	*69.6*	*1072.34*	8.51
Herbicides	3.2	761.60	
Fungicides	1.1	237.60	
Sulfur	65.3	73.14	
Water (m^3)	*18.00*	*18.36*	0.15
Total Energy Input	–	*12,605.31*	*100.00*
Outputs			
Walnut kernel yield (kg ha^{-1})	1166.06	13,759.51	59.05
Walnut shell yield (kg ha^{-1})	954.05	9540.50	40.95
Walnut yield (kg ha^{-1})	*2120.11*	–	
Total Energy Output	–	*23,300.01*	*100.00*

The discussion on absolute energy input and output amounts do not enough provide to information and it is more accurate to comment on the ratios such as specific energy, energy productivity and, energy use efficiency.

Energy use efficiency is the ratio of the total energy obtained from the outputs to the total energy obtained from the inputs. If this ratio is bigger than 1, it means that the total energy obtained from the production is higher than the energy used obtained from the inputs. The energy use efficiency was calculated to be 1.85 for the walnut production in the examined region. Energy productivity was calculated at 0.17 kg MJ^{-1}. This coefficient expresses the amount of the obtained product per energy unit. Specific energy refers to the amount of energy used per product. The specific energy was calculated as 5.95 MJ kg^{-1} in the study. The net energy, which is the difference between the produced energy and the total input energy, was calculated as 10,694 MJ ha^{-1} on walnut production. Energy usage can be examined at different approaches such as direct-indirect and renewable-non-renewable energy. The direct energy is calculated from the sum of the energy amounts of diesel and irrigation water, indirect energy is calculated from the sum of the energy amounts of the pesticides, fertilizers, and machinery. The share of direct energy was 45.86% while the share of indirect energy was 54.14% in the total energy input. Renewable energy sources are human labor and irrigation water. The share of renewable energy was estimated as 1.19% of the total energy input in walnut production. Sources of renewable energy are reusable and unexhausted sources of energy. The share of non-renewable energy was calculated at 98.81% in total energy input (Table 3).

Table 3 Energy balance of walnut production

	Unit	Quantity	%
Energy Use Efficiency	–	1.85	–
Energy Productivity	kg MJ^{-1}	0.17	–
Specific Energy	MJ kg^{-1}	5.95	–
Net Energy	MJ ha^{-1}	10,694.70	–
Direct Energy	MJ ha^{-1}	5780.68	45.86
Indirect Energy	MJ ha^{-1}	6824.63	54.14
Renewable Energy	MJ ha^{-1}	149.68	1.19
Non-Renewable	MJ ha^{-1}	12,455.63	98.81
Total Energy	MJ ha^{-1}	12,605.31	100.00

Direct Energy: human labor, diesel, water. *Indirect Energy*: fertilizers, pesticides, machinery. *Renewable Energy*: human labor, water. *Non-Renewable Energy*: diesel, pesticides, fertilizers, machinery

Table 4 gives the economic profitability of walnut production. When the producing costs are examined, it is seen that the human labor had the highest share in the variable costs with 40.41%. Human labor was followed by irrigation water costs by 26.60% and pesticides costs by 15.20%. The most important reason for the highest cost of human labor is that the mechanization in the walnut production is used only for hoeing and transportation operations. The walnut harvest is made manually by the human labor.

As shown in Table 4, although the total variable costs were 1948 US$ ha^{-1}, the fixed cost was 7574 US$ ha^{-1}, which was very high. The reason for this was the high land value that was included in the fixed costs. The study area was the Istanbul province and it had the highest land prices in Turkey. For this reason, the share of the land value was 71.46% of the total costs.

While 19.22% of the total cost was composed of variable costs, 79.53% consisted of fixed costs.

Total cost was 9523 US$ ha^{-1} for the walnut production in the surveyed region. Gross value was calculated as 14,373 US$ ha^{-1}. According to economic analysis, walnut producers earned 4850 US$ ha^{-1} net return per year. The benefit-cost ratio of walnut production was calculated as 1.51.

Table 4 Economic analysis of walnut production (US$ ha^{-1})

Cost item	US$ ha^{-1}	Total cost %	Variable cost %
Human labor	739.59	7.77	40.41
Machinery	52.88	0.56	2.89
Fertilizers	161.22	1.69	8.81
Pesticides	278.31	2.92	15.20
Diesel	111.19	1.17	6.07
Water	486.81	5.11	26.60
Variable cost	*1830.00*	*19.22*	*100.00*
Revolving interest (6.5%)	118.95	1.25	–
Total variable costs	*1948.95*	*20.47*	–
General management cost (3%)	58.47	0.61	–
Land value (5%)	6805.12	71.46	–
Amortization	515.46	5.41	–
Other fixed costs	194.98	2.05	–
Total fixed costs	*7574.03*	*79.53*	–
Total costs	*9522.98*	*100.00*	–
Yield	2120	–	–
Price	6.78	–	–
Gross value	14,373.63	–	–
Gross return	12,424.68	–	–
Net return	*4850.65*	–	–
Benefit/Cost ratio	*1.51*	–	–

Conclusion

In the study, the energy balance of walnut production was determined and economic analysis was done in Silivri province of Istanbul. The average energy use efficiency of the producers was calculated as 1.85 that was higher than the coefficients calculated by Baran et al. (2017b) (0.61), Khoshroo and Mulwa (2014) (0.93) and Gündoğmuş (2013) (1.74). It is expected that the energy use efficiency coefficient will be higher than 1. As a result of the study, energy output was 85% higher than energy input.

The energy productivity of the walnut production was calculated as 0.17 kg MJ^{-1} and this value was calculated as 0.03 kg MJ^{-1} by Baran et al. (2017b), 0.08 kg MJ^{-1} by Khoshroo and Mulwa (2014) and 0.11 kg MJ^{-1} by Gündoğmuş (2013). Energy productivity refers to the amount of product obtained per unit of energy usage. Higher energy productivity value means higher product availability compared to unit energy usage.

The specific energy was calculated as 5.95 MJ kg^{-1} in the study. In previous studies, it was calculated as 30.20 MJ kg^{-1} by Baran et al. (2017b), 12.75 MJ kg^{-1} by Khoshroo and Mulwa (2014), and 9.25 MJ kg^{-1} by Gündoğmuş (2013). Specific energy refers to the amount of energy used per unit of product and it is expected to be low. The specific energy was obtained as lower than the results of the others studies.

The net energy was calculated as 10,694.70 MJ ha^{-1} and it means that the energy output was higher than the energy input. Also, net energy was calculated by Baran et al. (2017b), Khoshroo and Mulwa (2014) and Gündoğmuş (2013) as –93,136.20 MJ ha^{-1}, –1560.48 MJ ha^{-1}, 31,069.04 MJ ha^{-1} respectively.

When compared direct and indirect energy use in walnut production, direct energy was 45.86% and indirect energy was 54.14% of the total energy input. In previous studies, shares of the direct and indirect energy use was calculated as 31.92 and 68.08% by Gündoğmuş (2013), 16.88 and 83.12% by Baran et al. (2017b), 81.35 and 16.35% by Koshoro and Mulwa (2014) respectively.

When the shares of renewable and non-renewable energy were examined, it was seen that the renewable energy was 1.19% while the non-renewable energy was 98.81%. In previous studies, renewable and non-renewable energy were calculated as 35.61% and 64.39% by Khoshroo and Mulwa (2014), 7.77% and 92.23% by Baran et al. (2017b), 6.08 and 93.92% by Gündoğmuş (2013). As a result of the study, renewable energy sources were determined to be used very low in walnut production in Istanbul province. The most important reason for this there is very low irrigation in the region.

According to the economic analysis results, net profit was obtained 4850.68 US$ ha^{-1} for walnut production per hectare. Baran et al. (2017b) calculated the net profit as 3553 US$ ha^{-1}. While the benefit-cost ratio was calculated as 1.51, Baran et al. (2017b) calculated as 1.88. Benefit-cost ratio is the ratio of gross value to total costs. There is a contradictory situation on this point. If an enterprise has a high profit, it is expected to has a high benefit-cost ratio. However, in our study, the total cost was calculated as 9522.98 US$ ha^{-1} and Baran et al. (2017b) calculated as 4039 US$ ha^{-1}. As the study was carried out in the Istanbul province, due to the high value of the land, the interest of the land value will be high and therefore the total costs will be increased. Therefore, our benefit-cost ratio was lower than the other studies'.

As a result of the study, walnut production in the region, analysis gave satisfactory results in terms of both energy use and economically. It can be said that walnut production is a profitable initiative in the region. When the fertilizer is used less, the energy use efficiency will be increased and the production costs will be reduced. In order to provide this, fertilizer should be used by soil analysis. Another highest cost element is the interest of the land value. If walnut orchards are located far away from settlements and will be located on land that will not earn settlement availability in the near future, the lower-priced land will be used and rent will decrease.

When approaching from the environmental perspective, the use of pesticides and fertilizers should be reduced as much as possible in order to reduce the energy input. If this is provided, the share of non-renewable energy usage will decrease and the share of renewable energy usage will increase. Today, farmers should not only consider profitability but also take production activities into consideration for sustainable agriculture.

Conflict of interest G. Unakitan and O. Inan declare that they have no competing interests.

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