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ORIGINAL ARTICLE

Determination of Energy Input-Output Analysis in Plum (*Prunus domestica* L.) Production

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Abstract The aim of this research is to compose the energy input-output analysis of plum in Nevsehir province in Turkey. This research was conducted at the plum cultivating facilities during the 2015–2016 production seasons in Nevsehir province of Central Anatolian Region in Turkey. The agricultural input energies and output energies used in plum cultivation were calculated to determine the energy input-output analysis. According to the research findings, the energy inputs in plum cultivation were calculated respectively 3920 MJ ha^{-1} (44.99%) chemical fertilizers energy, 1618.91 MJ ha^{-1} (18.58%) diesel fuel energy, 1125.85 MJ ha^{-1} (12.92%) chemicals energy, 1069.20 MJ ha^{-1} (12.27%) machinery energy, 723.24 MJ ha^{-1} (8.30%) human labour energy and 255 MJ ha^{-1} (2.93%) irrigation water energy. Production output plum yield were calculated as 12,112.50 MJ ha^{-1}. The energy output/input ratio, specific energy, energy usage efficiency and net energy calculations were calculated respectively as 1.39, 1.37 MJ kg^{-1}, 0.73 kg MJ^{-1} and 3400.30 MJ ha^{-1}.

Keywords Energy input-output analysis · Plum · Specific energy · Turkey

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Ermittlung der Energiebilanz bei der Produktion von Pflaumen (*Prunus domestica* L.)

Schlüsselwörter Energiebilanz · Pflaumen · Spezifische Energie · Türkei

Introduction

Plums (*Prunus domestica* L.) are the most taxonomically diverse of stone fruits and are adapted to a board range of climatic and edaphic factors (Ertekin et al. 2006; Tabatabaie et al. 2012). Plums constitute the most numerous and diverse group of fruit tree species. The wide variety of plums, the distribution of the fruit through a wide area, and its adaptability to varying conditions make it, not only of great importance at present, but also for future development (Blazek 2007; Tabatabaie et al. 2012). It is accepted that plum contains plenty of vitamin B, and is also rich in potassium and magnesium minerals. Experts advise consumption of plum against liver, heart and liver diseases, digestion problems, and it also benefits those on a salt-free diet or those suffering from rheumatism. 100 g fresh plum contains 66 calories, 17.8 g carbohydrates, 299 mg potassium, 17 mg phosphor, 2 mg sodium, 18 mg potassium, 0.5 mg iron, 0.4 mg fibre. It additionally contains vitamins A, B1, B2, B3, B6, C, E (Anonymous 2004a, 2004b; Tunalioglu and Keskin 2004). The leading plum producing countries in the world are China, Yugoslavia, Germany, France and Turkey. In some years Romania and Bulgaria are also among these countries (Tunalioglu and Keskin 2004). The annual production of plum was about 279,761 tons in Turkey in 2015 (Anonymous 2016).

Energy consumption in agriculture has developed in response to rising population in around the world, restricted

Table 1 Energy equivalents in agriculture production

Inputs and outputs	Unit	Energy equivalent (MJ/unit)	References
Human labour	h	1.96	Mani et al. 2007; Karaagac et al. 2011
Machinery	h	64.80	Singh 2002; Kizilaslan 2009
Chemical fertilizers			
Nitrogen	kg	60.60	Singh 2002
Phosphorous	kg	11.10	Singh 2002
Potassium	kg	6.70	Singh 2002
Chemicals	kg	101.20	Yaldiz et al. 1993
Diesel fuel	l	56.31	Singh 2002; Demircan et al. 2006
Irrigation water	m^3	1.02	Acaroglu 1998; Azizi and Heidari 2013
Outputs	Unit	Values (MJ/unit)	Sources
Plum yield	kg	1.90	Singh and Mittal 1992; Tabatabaie et al. 2012

Table 2 Energy input-output in plum production

Inputs	Unit	Energy equivalent (MJ/unit)	Input used per hectare (unit ha^{-1})	Energy value (MJ ha^{-1})	Ratio (%)
Human labour	h	1.96	369	723.24	8.30
Machinery	h	64.80	16.50	1069.20	12.27
Diesel fuel	l	56.31	28.75	1618.91	18.58
Chemical fertilizers	–	–	150	3920	44.99
Nitrogen	kg	60.60	50	3030	34.78
Phosphorous	kg	11.10	50	555	6.37
Potassium	kg	6.70	50	335	3.85
Chemicals	kg	101.20	11.125	1125.85	12.92
Irrigation water	m^3	1.02	250	255	2.93
Total inputs	–	–	–	8712.20	100.00
Outputs	Unit	Energy equivalent (MJ/unit)	Output per hectare (unit ha^{-1})	Energy value (MJ ha^{-1})	Ratio (%)
Plum yield	kg	1.90	6375	12,112.50	100.00
Total output	–	–	–	12,112.50	100.00

supply of arable land and desire for an increasing life standard. These factors have encouraged a rise in energy inputs to maximize yields, minimize labour-intensive practices, or both in almost everywhere (Kennedy 2000; Ozkan et al. 2011). Energy has a key role in economic and social development but there is a general lack of rural energy development policies that focus on agriculture. Agriculture has a dual role as user and supplier of energy. This energy function of agriculture offers important rural development opportunities as well as climate change mitigation by substituting bio-energy for fossil fuels (Anonymous 2000; Ozkan et al. 2011). Nowadays, agricultural systems rely on fossil energies seriously and crop production level is characterized by the high quantity input of it (Tabatabaie et al. 2013; Beigi et al. 2016). However, some public health and environmental problems such as global warming, greenhouse gaseous emission, water source contamination and land degradation are emerged by extra use of energy sources. On the other hand, continual growth of energy prices threats the global agricultural sector. Hence, in order to promote the agriculture section as an economical system; it is necessary for efficient use of energy sources (Mohammadi et al. 2010; Beigi et al. 2016).

Different researches were performed on energy input-output analysis of agricultural products. For example, researches were performed on energy input-output analyses of plum (Tabatabaie et al. 2012), sweet cherry (Demircan et al. 2006), strawberry (Banaeian et al. 2011), grape (Ozkan et al. 2007), black carrot (Celik et al. 2010), pomegranate (Canakci 2010), cherry (Kizilaslan 2009), orange (Mohammadshirazi et al. 2015), citrus (Ozkan et al. 2004), peach (Goktolga et al. 2006), apricot (Gezer et al. 2003), kiwifruit (Mohammadi et al. 2010), apple (Gokdogan and Baran 2016) etc. Although many experimental works were performed on energy usage in agriculture, there is no study on the energy analysis of plum production in Turkey. In this research, it is aimed to perform the energy input-output analysis of plum.

Materials and Method

The research was performed for the whole Nevsehir province of Turkey (N 38º-12´-39º-20´; E 34º-11´ 35º-06´). Nevsehir is located in the Central Anatolian Region and is bordering Kayseri in the east, Aksaray in the west, Nigde in the south and Yozgat and Kirsehir in the north. The town centre at the southern hill of Kizilirmak valley has an elevation of 1150 m. The province is divided into two by Kizilirmak valley, depression increases moving west to east and the elevation rises moving towards southern and northern areas. The soil of Nevsehir is made of

Table 3 Energy input-output analyses indicators in plum production

Calculations	Unit	Values
Plum yield	kg ha^{-1}	6375
Energy input	MJ ha^{-1}	8712.20
Energy output	MJ ha^{-1}	12,112.50
Energy usage efficiency	–	1.39
Energy productivity	kg MJ^{-1}	0.73
Specific energy	MJ kg^{-1}	1.37
Net energy	MJ ha^{-1}	3400.30

Table 4 Energy inputs in the forms of energy for plum production

Plum production	Energy input (MJ ha^{-1})	Ratio (%)
Direct energy[a]	2597.15	29.81
Indirect energy[b]	6115.05	70.19
Total	8712.20	100.00
Renewable energy[c]	978.24	11.23
Non-renewable energy[d]	7733.96	88.77
Total	8712.20	100.00

[a]Includes human labour, diesel and irrigation water
[b]Includes chemical fertilizers, chemicals and machinery
[c]Includes human labour and irrigation water
[d]Includes diesel, chemicals, chemical fertilizers and machinery

volcanic tuffs. Thus it has a permeable structure. Results of various researches indicate that the Nevsehir soil structure is 85% loamy, 9% loamy-clayey, 2% clayey and 4% sandy. The annual average temperature of the province is 10 °C and the monthly average rainfall of the province 36.75 mm (Anonymous 2012). The research performed on trials and measurements area has 0.40 ha plum garden, located at Nevsehir in 2015–2016 production season. Randomized Complete-Block Design with three replicates was performed in this research.

Human labour energy, machinery energy, diesel fuel energy, chemical fertilizers energy, chemicals energy and irrigation water were calculated as inputs. Plum yield was calculated as output. Input amounts were calculated and then these input data were multiplied by the energy equivalent coefficient. The units shown in Table 1 were used to calculate the values of the inputs of plum production. Previous energy analysis studies were used when determining the energy equivalent coefficients. The total energy equivalent was determined by adding energy equivalents of all inputs in MJ unit. By calculating the agricultural input energies and output energies used in plum cultivation, the energy input-output analyses were determined.

Following the analysis of data through Microsoft Excel program, by referring to the inputs, the results were tabulated. Plum production input-output values were determined and the calculations were given in Table 2. Energy input-output indicators in plum production were given in Table 3. Total fuel consumption of each parcel was calculated as l ha^{-1}. Full tank method was used to measure the amount of fuel used (Gokturk 1999; El Saleh 2000; Sonmete 2006). Labor yield of each parcel (ha h^{-1}) was calculated by proportion the total time calculated for in area of the trial to the area amount. Using the effective labour time (t_{ef}), while experiments in parcel was conducted (Guzel 1986; Ozcan 1986; Sonmete 2006). Measuring the time spent during agricultural operations in the parcel was performed with the aid of chronometer (Sonmete 2006). In order to determine the energy input-output in plum production, Mohammadi et al. (2010) reported that, "Energy use efficiency, energy productivity, specific energy and net energy were calculated by using the following formulates (Mandal et al. 2002; Mohammadi et al. 2008)".

$$\text{Energy efficiency} = \text{Energy output } \left(\text{MJ ha}^{-1}\right) / \text{Energy input } \left(\text{MJ ha}^{-1}\right) \quad (1)$$

$$\text{Energy productivity} = \text{Yield output } \left(\text{kg ha}^{-1}\right) / \text{Energy input } \left(\text{MJ ha}^{-1}\right) \quad (2)$$

$$\text{Specific energy} = \text{Energy input } \left(\text{MJ ha}^{-1}\right) / \text{Yield output } \left(\text{kg ha}^{-1}\right) \quad (3)$$

$$\text{Net energy} = \text{Energy output } \left(\text{MJ ha}^{-1}\right) - \text{Energy input } \left(\text{MJ ha}^{-1}\right) \quad (4)$$

Kocturk and Engindeniz (2009) reported that, "The input energy is also classified into direct and indirect, and renewable and non-renewable forms. The indirect energy consists of pesticide and fertilizer, while the direct energy includes human and animal labour, diesel and electricity used during the production process. On the other hand, non-renewable energy includes petrol, diesel, electricity, chemicals, fertilizers, machinery, while renewable energy consists of human and animal labour (Mandal et al. 2002; Singh et al. 2003)". Energy inputs of plum production, in the form of direct and indirect, as well as renewable and non-renewable energy were given in Table 4.

Results and Discussion

During the researches in the plum garden, the average amount of plum produced per hectare during the 2015–2016 production seasons was calculated as 6375 kg. As it can be seen in Table 2, energy inputs in plum cultivation production are as follows: 3920 MJ ha^{-1} (44.99%) chemical fertilizers energy, 1618.91 MJ ha^{-1} (18.58%) diesel fuel energy, 1125.85 MJ ha^{-1} (12.92%) chemicals energy, 1069.20 MJ ha^{-1} (12.27%) machine energy, 723.24 MJ ha^{-1} (8.30%) human labour energy and 255 MJ ha^{-1} (2.93%) irrigation water energy. Production output plum yield were calculated as 12,112.50 MJ ha^{-1}.

In Table 2, the amount of chemical fertilizers used for plum production was 150 kg ha^{-1} (44.99%). In terms of plum production, it is noteworthy that chemical fertilizers were the highest input. Similarly, in previous researches related to agricultural production, Demircan et al. (2006) calculated that the fertilizer application energy had the biggest share by 45.35% in sweet cherry, Celik et al. (2010) calculated that the fertilizer application energy had the biggest share by 33.19% in conventional black carrot, Canakci (2010) calculated that fertilizer application energy had the biggest share by 40.22% in pomegranate, Kizilaslan (2009) calculated that fertilizer application energy had the biggest share by 42% in cherry, Ozkan et al. (2004) calculated that fertilizer application energy had the biggest share by 36.48% in citrus, Goktolga et al. (2006) calculated that fertilizer application energy had the biggest share by 44.44% in peach, Mohammadi et al. (2010) calculated that fertilizer application energy had the biggest share by 47.23% in kiwifruit production etc.

Plum yield, energy input, energy output, energy input-output ratio, energy productivity, specific energy and net energy in plum production were calculated as 6375 kg ha^{-1}, 8712.20 MJ ha^{-1}, 12,112.50 MJ ha^{-1}, 1.39; 0.73 kg MJ^{-1}; 1.37 MJ kg^{-1} and 3400.30 MJ ha^{-1}, respectively. In previous studies related to plum production, energy output/input ratio, energy productivity and specific energy in plum production were calculated as 0.40; 0.21 kg MJ^{-1} and 4.79 MJ kg^{-1}, respectively by Tabatabaie et al. (2012). Similarly, in previous researches related to agricultural production, Demircan et al. (2006) calculated the energy input-output ratio as 1.23 in sweet cherry, Celik et al. (2010) calculated the energy input-output ratio as 1.30 in conventional black carrot, Canakci (2010) calculated the energy input-output ratio as 1.25 in pomegranate, Kizilaslan (2009) calculated the energy input-output ratio as 0.96 in cherry, Goktolga et al. (2006) calculated the energy input-output ratio as 0.93 in peach, Mohammadi et al. (2010) calculated the energy input-output ratio as 1.54 in kiwifruit production etc.

The distribution of inputs used for the production of plum, in accordance to direct, indirect, renewable, and non-renewable energy groups were given in Table 4. The consumed total energy input in plum production could be classified as 29.81% direct, 70.19% indirect, 11.23% renewable and 88.77% non-renewable. Similarly, plum (Tabatabaie et al. 2012), sweet cherry (Demircan et al. 2006), black carrot (Celik et al. 2010), apple (Gokdogan and Baran 2016), citrus (Ozkan et al. 2004), cherry (Kizilaslan 2009), orange (Mohammadshirazi et al. 2015), peach (Goktolga et al. 2006) etc. yielded results where the ratio of non-renewable energy was higher than the ratio of renewable energy. One of the reasons for the energy output/input ratio to be low in this study is that the chemical fertilizers, increasing energy input should be reduced while the usage of organic and garden manure should be increased. By reducing the use of chemical fertilizers and increasing the usage of garden and organic manure, energy output/input ratio can be increased.

In this research, the energy input-output of plum production was determined. According to the results, plum production is a profitable activity in terms of energy usage efficiency. Plum production is a cost effective business based on the trials from the 2015–2016 production season. Gundogmus (2013) reported that, “Optimization is an important tool to maximize the amount of productivity which can significantly impact the energy consumption and production costs. Optimization of energy usage in agricultural systems is achieved in two ways: an increase in productivity with the existing level of energy inputs or conserving energy without affecting the productivity. Energy management becomes more important when the energy required should be economical, sustainable and productive”.

The ratio of non-renewable energy was higher than the ratio of renewable energy. According to Goktolga et al. (2006), some of the benefits desired to be obtained through energy input/output analysis are summarized as: being able to determine whether energy has been used effectively or not. Once this is determined, then energy wastage will be prevented, as use of excessive energy will be prevented, which in turn, will lower the negative effects caused by environmental exposure of excessive energy. Demircan et al. (2006) reported that, “Accurate fertilization management, knowing the correct amount and frequency of fertilization (especially nitrogen) (Kitani 1999) need to save non-renewable energy sources without impairing the yield or profitability, in order to raise the energy output/input of sweet cherry production”. It is obvious that by abiding to these suggestions yield and energy output/input ratio will raise in plum cultivation.

Conflict of interest M.F. Baran, H.I. Oguz and O. Gokdogan declare that they have no competing interests.

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