Erwerbs-Obstbau (2017) 59:325–330
DOI 10.1007/s10341-017-0333-y

ORIGINAL ARTICLE

Energy Input-Output Analysis in Organic Mulberry (*Morus spp.*) Production in Turkey: a Case Study Adiyaman-Tut Region

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Received: 22 September 2016 / Accepted: 26 April 2017 / Published online: 17 May 2017

Abstract The goal of this study is to do the energy input-output analysis of organic mulberry. This study was conducted at the organic mulberry producing facilities during the 2015–2016 production seasons in Adiyaman-Tut region of Turkey. The agricultural input energies and output energies used in organic mulberry production were computed to determine the energy input-output analysis. According to the research findings, the energy inputs in organic mulberry production were computed respectively as 3948 MJ ha^{-1} (59.01%) drip and sprinkler irrigation energy, 1092.42 MJ ha^{-1} (16.33%) gravity irrigation energy, 449.33 MJ ha^{-1} (6.72%) diesel fuel energy, 416.52 MJ ha^{-1} (6.23%) farmyard manure energy, 335.14 MJ ha^{-1} (5.01%) human labour energy, 253.52 MJ ha^{-1} (3.79%) machinery energy, 93.12 MJ ha^{-1} (1.39%) transportation energy, 75.78 MJ ha^{-1} (1.13%) animal labour energy and 26.62 MJ ha^{-1} (0.40%) organic fertilizer energy. Total input energy was computed as 6690.46 MJ ha^{-1}. Production output organic mulberry yield were calculated as 37,627.84 MJ ha^{-1}. The energy output/input ratio, specific energy, energy productivity and net energy computations were computed respectively as 5.62, 1.51 MJ kg^{-1}, 0.66 kg MJ^{-1} and 30,937.37 MJ ha^{-1}. The consumed total energy input in organic mulberry production could be classified as 88.20% direct, 11.80% indirect, 88.10% renewable and 11.90% non-renewable.

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Keywords Energy output/input ratio · mulberry · Energy productivity · Turkey

Analyse der Energiebilanz im ökologischen Anbau der Maulbeere (*Morus spp.*) in der Türkei: Eine Fallstudie aus dem Gebiet Adiyaman-Tut

Schlüsselwörter Energiebilanz · Maulbeere · Energieproduktivität · Türkei

Introduction

Mulberry is a type of fruit that is being grown in many parts of the world as it has a great ability to adopt to different climate and soil conditions. Similar to many other fruit species, Anatolia is the homeland and one of the oldest culture zones of mulberry, hence it is being grown in almost every province of Turkey (Erdogan and Pirlak 2005). Mulberry is very common particularly in East, West and Southeast Asia, Southern Europe, southern parts of North America, north-west of South America and some parts of Africa (Datta 2002; Erdogan and Pirlak 2005). Among the cultivated fruit types, mulberry trees are the most cautious and never starts budding until the end of cold climate conditions, therefore it is deemed as symbolizing wit and patience (Grieve 2002; Erdogan and Pirlak 2005). Mulberry is an important vitamin and energy source. As well as being consumed in fresh and dried forms, mulberry fruit is also used to produce various products such as molasses, jam, dried fruit roll-up, mulberry flake, ice cream flavour, churchkhela, vinegar, fruit juice concentrate and spirit in Turkey (Erdogan and Pirlak 2005).

In other countries, the fruit is consumed in fresh and dried forms but also used for producing bread, muffin, pie, pudding, mulberry wine and ice cream. In recent years mulberry juice has become a very popular drink and it can be stored for three months under cold storage conditions, without needing any preservatives (Lale and Ozcagiran 1996; Machii et al. 2002; Martin et al. 2002; Erdogan and Pirlak 2005). Even though it has been spread to many parts of the world, there are no records of mulberry production figures in the world, as it is being mostly used for silkworm breeding rather than its fruit. As it is the case with many fruit types, Anatolia is the homeland and one of the oldest cultivation zones of mulberry (Ozbek 1977; Erdogan and Pirlak 2005). According to 2015 data, the total figure for mulberry production in Turkey was 69,334 tons for last year (Anonymous 2016a). Organic mulberry production and organic mulberry molasses production is an important source of revenue for Adıyaman-Tut region. There is no available study regarding energy input-output analysis of organic mulberry production in Turkey. In this sense, this study is highly important in terms of measuring and determining energy of organic mulberry and analysing energy input-output figures.

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; since, has a double role as user and supplier of energy. This energy function of agriculture offers important rural development opportunities as well as climatic change lightening by substituting bio-energy for fossil fuels (Ozkan et al. 2011; Mohammadshirazi et al. 2015). There is a close relationship between agriculture and energy. While agriculture uses energy, it also supplies it in the form of bio-energy. At the present time, the productivity and profitability of agriculture depend upon energy consumption (Tabatabaeefar et al. 2009; Tabatabaie et al. 2012). Energy usage in agriculture has developed in response to increasing populations, limited supply of arable land and desire for an increasing standard of living. In all societies, these factors have encouraged an increase in energy inputs to maximize yields, minimize labor-intensive practices or both (Esengun et al. 2007a; Tabatabaie et al. 2012). In order to evaluate the sustainability of agriculture, the energy efficiency must be considered and the major sources of energy wastes must be identified and assessed (Pervanchon et al. 2002; Tabatabaie et al. 2012).

Different researches were done on energy balance of agricultural and animal products. For example, researches were done on energy input-output analysis of organic apricot (Gundogmus 2006), organic olive (Kaltsas et al. 2007), banana (Akcaoz 2011), apricot (Gezer et al. 2003), dry apricot (Esengun et al. 2007a), pear (Tabatabaie et al. 2013), kiwifruit (Mohammadi et al. 2010), plum (Tabatabaie et al. 2012), cherry (Kizilaslan 2009), sweet cherry (Demircan et al. 2006), strawberry (Banaeian et al. 2011), cucumber (Mohammadi and Omid 2010), black carrot (Celik et al. 2010), grape (Kocturk and Engindeniz 2009), peach (Goktolga et al. 2006), pomegranate (Canakci 2010), apple (Gokdogan and Baran 2016), citrus (Ozkan et al. 2004a), organic lentil (Mirzaee et al. 2011), organic maize, organic potato (Pimentel 1993), wheat (Cicek et al. 2011), barley (Mobtaker et al. 2010), soybean (Mandal et al. 2002), apple (Yilmaz et al. 2010), sugar beet (Haciseferogullari et al. 2003), rice (Pishgar-Komleh et al. 2011), sunflower (Uzunoz et al. 2008), stake-tomato (Esengun et al. 2007b), lamb (Koknaroglu et al. 2007), beef cattle (Demircan and Koknaroglu 2007), broiler (Atilgan and Koknaroglu 2006), Japanese quail (Gokdogan et al. 2016) etc. Although many experimental works were done on energy input-output analysis in agriculture, there is no study on the energy analysis of organic mulberry production in Turkey. In this research, it is goaled to done the energy input-output analysis of organic mulberry.

Materials and Method

Adiyaman-Tut region is located to the south of Akdag, at the foothill of South-eastern Toros Mountains, an extension of the Toros Mountains. Covering an area of 350 km², the terrain is mostly mountainous and rugged. It has an altitude of 1050 m from the sea level (Anonymous 2016b). Main material of this study was composed of data accumaleted by face to face surveys made with 57 organic mulberry producers in Adıyaman-Tut region in 2016. Surveys were made in farms were determined by using full count method (Karagolge and Peker, 2002). Surveys have been made with some of these enterprises (57 organic mulberry producers) during our survey conducted in this region. By computing the agricultural input energies and output energies used in organic mulberry production, the energy usage efficiency was determined. Total energy input in unit area (ha) constitutes the total energy inputs. Human labour energy, animal labour energy, machinery energy, farmyard manure energy, organic fertilizer energy, diesel fuel energy, gravity irrigation energy, other (drip and sprinkler) irrigation energy and transportation energy were computed as inputs. The units shown in Table 1 were used to compute the values of the inputs of organic mulberry 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. In order to determine the energy input-output in organic mulberry production, "Energy usage efficiency, energy productivity, specific energy and net energy were calculated by using the following formulates (Mandal et al. 2002; Mohammadi et al. 2008, 2010)".

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)
Animal labour	h	10.10	Ozkan et al. (2004b)
Machinery	h	64.80	Singh (2002); Kizilaslan (2009)
Organic fertilizers			
Farmyard manure	kg	0.30	Singh (2002)
Organic fertilizer	kg	10.50	Guzman and Alonso (2008); Bilalis et al. (2013)
Diesel fuel	l	56.31	Singh (2002); Demircan et al. (2006)
Gravity irrigation	m^3	1.02	Acaroglu (1998); Azizi and Heidari (2013)
Other irrigation	m^3	4.20	Mrini (1999); Mrini et al. (2002)
Transportation	MJ (ton km)$^{-1}$	9.22	Acaroglu (2004)
Outputs	*Unit*	*Energy equivalent (MJ/unit)*	*References*
Yield	MJ (kg dry matter)$^{-1}$	14.896	Measured

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

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

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

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

For calorific values of organic mulberry product IKA brand C200 model bomb calorimeter device were used. For measuring purposes, the amount of fuel (~0.1 g) was combusted inside the calorimeter bomb, which was filled with oxygen for full combustion with adequate pressure (~30 bars), the filled bomb calorimeter was put in the device and enclosed by an adequate amount of ordinary water (~2000 mL at 18–25 oC ± 1 oC). The device was given a calorific value in MJ kg-1 unit. For organic mulberry samples, reading of the calorific value was measured repetitively for 3 times and then the average value was reported.

By considering the inputs, data analysis was conducted by using Microsoft Excel program; before the results were tabulated in Table 2 and related to organic mulberry production input-output values and the relevant computations were provided in Table 3. 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 organic mulberry 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 studies in the organic mulberry farms, the average amount of organic mulberry produced per hectare for 2015–2016 production seasons was computed as 10,104.14 kg. As it can be seen in Table 2, energy inputs in organic mulberry production were as follows, respectively: 3948 MJ ha^{-1} drip and sprinkler irrigation energy, 1092.42 MJ ha^{-1} gravity irrigation energy, 449.33 MJ ha^{-1} diesel fuel energy, 416.52 MJ ha^{-1} farmyard manure energy, 335.14 MJ ha^{-1} human labour energy, 253.52 MJ ha^{-1} machinery energy, 93.12 MJ ha^{-1} transportation energy, 75.78 MJ ha^{-1} animal labour energy and 26.62 MJ ha^{-1} organic fertilizer energy. Total input energy was computed as 6690.46 MJ ha^{-1}. Production output organic mulberry yield was computed as 37,627.84 MJ ha^{-1}. The results determined that 170.99 h of human labour and 7.50 h of animal labour energy and 3.91 h of machinery labour energy are required per hectare of organic mulberry production. Human labour energy and diesel fuel energy were used for machineries and farm operations.

Organic mulberry yield, energy input, energy output, energy output/input ratio, specific energy, energy productivity and net energy in organic mulberry production were computed as 10,104.14 kg ha^{-1}, 6690.46 MJ ha^{-1}, 37,627.84 MJ ha^{-1}, 5.62, 1.51 MJ kg^{-1}, 0.66 kg MJ^{-1} and 30,937.37 MJ

Table 2 Energy input-output in organic mulberry 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	170.99	335.14	5.01
Animal labour	h	10.10	7.50	75.78	1.13
Machinery	h	64.80	3.91	253.52	3.79
Organic fertilizers					
Farmyard manure	kg	0.30	1388.40	416.52	6.23
Organic fertilizer	kg	10.50	2.54	26.62	0.40
Diesel fuel	l	56.31	7.98	449.33	6.72
Gravity irrigation	m^3	1.02	1071	1092.42	16.33
Other irrigation	m^3	4.20	940	3948	59.01
Transportation	MJ (ton km)$^{-1}$	9.22	10.10	93.12	1.39
Total inputs	–	–	–	6690.46	100.00
Outputs	*Unit*	*Energy equivalent (MJ/unit)*	*Output per hectare (unit ha^{-1})*	*Energy value (MJ ha^{-1})*	*Ratio (%)*
Yield	kg	14.896 (25% dry matter)	10,104.14	37,627.84	100.00
Total output	–	–	–	37,627.84	100.00

Table 3 Energy input-output analysis indicators in organic mulberry production

Computations	Unit	Values
Organic mulberry yield	kg ha^{-1}	10,104.14
Energy input	MJ ha^{-1}	6690.46
Energy output	MJ ha^{-1}	37,627.84
Energy usage efficiency	–	5.62
Energy productivity	kg MJ^{-1}	0.66
Specific energy	MJ kg^{-1}	1.51
Net energy	MJ ha^{-1}	30,937.37

Table 4 Energy inputs in the forms of energy for organic mulberry production

Energy groups	Energy input (MJ ha^{-1})	Ratio (%)
Direct energy[a]	5900.68	88.20
Indirect energy[b]	789.79	11.80
Total	6690.46	100.00
Renewable energy[c]	5894.49	88.10
Non-renewable energy[d]	795.97	11.90
Total	6690.46	100.00

[a] Includes human labour, animal labour, diesel and irrigation
[b] Includes machinery, farmyard manure, organic fertilizer and transportation
[c] Includes human labour, animal labour, farmyard manure, organic fertilizer and irrigation
[d] Includes machinery, diesel and transportation

ha^{-1}, respectively (Table 3). Additionally, 5.62 kg of organic mulberry was obtained per unit of energy. 1.51 MJ of energy was obtained of 1 kg organic mulberry. In previous agricultural studies, Gundogmus (2006) determined (organic apricot) energy output/input ratio as 1.45, Mirzaee et al. (2011) determined (organic lentil) energy output/input ratio as 0.15, Pimentel (1993) determined (organic maize) energy output/input ratio as 5.90, Pimentel (1993) determined (organic potato) energy output/input ratio as 1.08 and Kaltsas et al. (2007) determined (organic olive) energy output/input ratio as 3.31.

The distribution of inputs was used for the production of organic mulberry, in accordance to direct, indirect, renewable and non-renewable energy groups were given in Table 4. The consumed total energy input in organic mulberry production could be classified as 88.20% direct, 11.80% indirect, 88.10% renewable and 11.90% non-renewable. Similarly, organic apricot (Gundogmus 2006), organic lentil (Mirzaee et al. 2011), greenhouse grape (Ozkan et al. 2007), grape (Ozkan et al. 2007), conventional black carrot (Celik et al. 2010), cherry (Kizilaslan 2009), cucumber (Mohammadi and Omid 2010), citrus (Ozkan et al. 2004a) etc. In this study, renewable energy sources composed 88.10% (5894.49 MJ ha^{-1}) of the total energy input, which was higher than that of the non-renewable resources 11.90% (795.97 MJ ha^{-1}). Energy output/input ratio were increased, because usage of farmyard manure and organic fertilizer were used instead of chemical fertilizers.

As a result, in this study, the energy input-output of organic mulberry production was determined. According to the results, organic mulberry production is a profitable activity in terms of energy output/input ratio (5.62). The ratio of renewable energy was higher than the ratio of non-renewable energy in organic mulberry production. Guzman and Alonso (2008) reported that, "The use of biofuel could increase the energy usage efficiency of agricultural systems in general, although it would involve more extensive land use, which would need to be taken into consideration (Fredriksson et al. 2006)". Optimization is an important tool to maximize the amount of productivity which can significantly affect the energy consumption and production costs. Optimization of energy usage in agricultural systems is realized 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 (Gundogmus 2013). The agricultural sector is a key sector, which has to be performed by new, consummated approaches, completely based on renewable resources, which can free farmers from depending on fossil resources. Combining renewable energies and organic agriculture offers tremendous synergies for sustainable development. Thus, the agricultural sector can recuperate its role as an economic core sector, offering attractive living conditions in rural areas (Gundogmus 2006).

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

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