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ORIGINAL ARTICLE

# Energy Input-Output Analysis of Organic Grape Production: A Case Study from Adiyaman Province

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**Abstract** In this study, it was aimed to perform an energy analysis of organic grape production in Besni district of Adıyaman province of Turkey. In order to determine the energy input-output of organic grape production, the observations and surveys were performed in the 82 organic grape growers in Adıyaman province. 82 farms were selected on full count method. The data obtained from study were collected from 82 different farms (398.32 hectares) by face to face questionnaires and observations. In organic grape farms, energy input-output analysis was also determinated by observation and survey methods in production season in 2015. In organic grape production, energy input was calculated as 24,875.06 MJ $ha^{-1}$ and energy output was calculated as 163,430 MJ $ha^{-1}$. Energy use efficiency, energy productivity, specific energy and net energy in organic grape production were calculated as 6.57; 0.56 kg $MJ^{-1}$, 1.79 MJ $kg^{-1}$ and 138,554.94 MJ $ha^{-1}$, respectively.

**Keywords** Energy use efficiency · Organic grape · Specific energy · Turkey

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## Energiebilanz im ökologischen Weinanbau: Eine Fallstudie aus der Provinz Adiyaman

**Schlüsselwörter** Effiziente Energienutzung · Ökologischer Weinanbau · Spezifische Energie · Türkei

## Introduction

Organic farming is a type of farming that is practised only through cultural measures, biologic control and organic based inputs, by selecting appropriate ecologies and without using artificial chemical inputs, with the purpose of conducting herbal or animal production without harming the balance of nature. The purpose of organic farming is to protect environment, plants, human and animal health, without polluting soil, air and water resources (Kızılaslan and Olgun 2012). In the world, 37.2 million ha area is being used for organic farming. When we consider the gathering areas in nature (41.9 million ha), this figure becomes 79.1 million ha. According to 2009 data, 0.9% of the World's agricultural lands are under organic production (Anonym 2016a). According to TÜİK (Turkish Statistical Institute) data, in 2011 our total product number was 225, total number of farmers 42,460, total area of organic farming was 614,618 ha and our total production was 1,659,543 tons, including organic farming transition period. The number of farmers practising organic farming is constantly increasing in Turkey (Anonym 2016b). Many farmers and agriculturists are using organic fertilizer such as vermicompost and manure for organic farming in Turkey nowadays (Belliturk et al. 2015a).

Agriculture is a one of the main areas of development in developing countries like Turkey (Belliturk et al. 2015b). Located on the most suitable climate zone in the world for

**Table 1** Energy equivalents of inputs and outputs in organic grape production

| Inputs and outputs | Unit | Energy equivalent coefficient | Sources |
|---|---|---|---|
| *Inputs* | *Unit* | *Values (MJ/unit)* | *Sources* |
| Human labour | h | 1.96 | Mani et al. (2007); Karaağaç et al. (2011) |
| Machinery | h | 64.80 | Singh (2002); Kızılaslan (2009) |
| Organic chemicals | kg | 77.20 | Guzmán and Alonso (2008); Bilalis et al. (2013) |
| Farmyard manure | kg | 0.30 | Singh (2002) |
| Lime | kg | 1.32 | Pimentel (1980); Ekinci et al. (2005) |
| Sulphur | kg | 1.12 | Nagy (1999); Mohammadi et al. (2010) |
| Diesel fuel | l | 56.31 | Singh (2002); Demircan et al. (2006) |
| Water of irrigation | $m^3$ | 4.20 | Mrini et al. (2002); Mrini (1999) |
| *Outputs* | *Unit* | *Values (MJ/unit)* | *Sources* |
| Grape | kg | 11.80 | Singh (2002); Özkan et al. (2007) |

viniculture, Turkey is not only the gene centre of grapevine, but it has also a very old and deep rooted grapey culture. South-eastern Anatolian Region, is one of the most grape producing regions of Turkey, preceded by Aegean and Mediterranean regions, and it has a share of approximately 10% of the national production. Grape is one of the products that are being exported by our country, and it has a high nutritional value. According to the results of various researches, it contains A, B, B2 and C vitamins. Grape is not only for table consumption, but it is also used for drying, winemaking, fermentation and tinned food, therefore it can be used as a source of nutrition throughout the year (Anonym 2016c). Organic viniculture aims to re-establish the ecologic balance which has been harmed due to malpractices, by using conscious agricultural techniques and natural inputs and also to create a vivid and sustainable agro-ecosystem. Organic viniculture is not a costly luxury. In contrast to what many people think, it is not an impracticable farming type, but rather something that requires knowledge and analysis. Organic viniculture is not an alternative of conventional production, but it is an opportunity given to us by the low contamination levels and climate conditions of our geography (Ateş 2012).

Comparing the total energy value of the inputs used in agricultural production by the energy value of the achieved product is a more realistic approach for evaluating production efficiency. Energy consumption through the use of tractors and agricultural tools/machines is being taken into account when defining the mechanization level, depending on the production systems and regional conditions (Erdoğan 2009). In this study was conducted in other researches. Researches were done on energy input-output analysis in agricultural products. For example, researches were made on energy usage activities of wheat (Çiçek et al. 2011), grape (Koçtürk and Engindeniz 2009), grape (Özkan et al. 2007), wheat (Marakoğlu and Çarman 2010), sunflower (Semerci 2013), black carrot (Çelik et al. 2010), barley (Baran and Gökdoğan 2014), maize (Konak et al. 2004) and sugar beet (Hacıseferoğulları et al. 2003), walnut (Banaeian and Zangeneh 2011) etc. In this study, the purpose was to determine the energy of efficiency of production, by revealing the energy inputs and outputs of organic grape production in Besni district of Adıyaman province.

## Materials and Methods

The study was performed in Besni district of Adıyaman province of Turkey. Besni is located at the western end of the Southeastern Anatolia as geographical location is located in the western part of the province (Anonym 2016d). Surveys and observations were performed face to face with 82 organic grape farms, in production season during in 2015. Main material of study was composed of data accumaleted by face to face surveys made with 82 organic grape farms (3983.257 decares) in Adıyaman province. Surveys were made in totally 82 farms were determined by using full count method (Karagölge and Peker 2002). Total energy input in unit area (ha) constitutes of each total of input's energy. Diesel fuel energy, machinery energy, organic chemicals energy, farmyard manure energy, lime energy, sulphur energy, water of irrigation energy and human labour energy were the inputs calculated. Organic grape were as output calculated.

Energy output/input ratio of the organic farms involved in organic farms agriculture in Adıyaman province was found. Energy balance calculations were made to determine the organic grape production productivity. The units shown in Table 1 was used to calculate the values of the inputs in organic grape production. Input amounts were calculated and then these inputs data were multiplied by the energy equivalent coefficient. By adding energy equivalents of all

**Table 2** Energy input-output analysis in organic grape 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* | *352.66* | *691.21* | *2.78* |
| Tillage | h | 1.96 | 28 | 54.88 | – |
| Pruning-collecting | h | 1.96 | 43.50 | 85.26 | – |
| Digging of roots | h | 1.96 | 72 | 141.12 | – |
| Arm connecting | h | 1.96 | 15 | 29.40 | – |
| Green pruning | h | 1.96 | 15 | 29.40 | – |
| Fertilizer application | h | 1.96 | 10.50 | 20.58 | – |
| Spraying and spraying of hand | h | 1.96 | 27.66 | 54.21 | – |
| Water of irrigation | h | 1.96 | 56 | 109.76 | – |
| Harvesting | h | 1.96 | 80 | 156.80 | – |
| Transporting | h | 1.96 | 5 | 9.80 | – |
| *Machinery* | *h* | *64.80* | *51* | *3304.80* | *13.29* |
| Tillage | h | 64.80 | 28 | 1814.40 | – |
| Spraying | h | 64.80 | 18 | 1166.40 | – |
| Transporting | h | 64.80 | 5 | 324 | – |
| *Organic chemicals* | *kg* | *77.20* | *17.80* | *1374.16* | *5.53* |
| *Farmyard manure* | *kg* | *0.30* | *3600* | *1080* | *4.34* |
| *Lime* | *kg* | *1.32* | *8.90* | *11.75* | *0.05* |
| *Sulphur* | *kg* | *1.12* | *10* | *11.20* | *0.04* |
| *Diesel fuel* | *l* | *56.31* | *55.30* | *3113.94* | *12.51* |
| Tillage | l | 56.31 | 36.80 | 2072.20 | – |
| Spraying | l | 56.31 | 13.50 | 760.19 | – |
| Transporting | l | 56.31 | 5 | 281.55 | – |
| *Water of irrigation* | *m*$^3$ | *4.20* | *3640* | *15,288* | *61.46* |
| *Total inputs* | – | – | – | *24,875.06* | *100* |
| **Outputs** | **Unit** | **Energy equivalent (MJ/unit)** | **Output per hectare (unit ha$^{-1}$)** | **Energy value (MJ ha$^{-1}$)** | **Rate (%)** |
| *Grape* | *kg* | *11.80* | *13,850* | *163,430* | *100* |
| *Total outputs* | – | – | – | *163,430* | *100* |

inputs in MJ unit, the total energy equivalent was found. Mohammadi et al. (2010) reported that, "The energy ratio (energy use efficiency), energy productivity, specific energy and net energy were calculated using the following formulates (Mandal et al. 2002; Mohammadi et al. 2008)".

$$\text{Energy use efficiency} = \frac{\text{Energy output } \left(\frac{\text{MJ}}{\text{ha}}\right)}{\text{Energy input}\left(\frac{\text{MJ}}{\text{ha}}\right)} \quad (1)$$

$$\text{Energy productivity} = \frac{\text{Grape output } \left(\frac{\text{kg}}{\text{ha}}\right)}{\text{Energy input}\left(\frac{\text{MJ}}{\text{ha}}\right)} \quad (2)$$

$$\text{Specific energy} = \frac{\text{Energy input } \left(\frac{\text{MJ}}{\text{ha}}\right)}{\text{Grape output}\left(\frac{\text{kg}}{\text{ha}}\right)} \quad (3)$$

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

The results were tabulated after the analysis of data was done using Microsoft Excel program considering the inputs. Examining the values of organic grape input-output and calculations were given in Table 2. Koçtürk 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 power, diesel and electricity energy used in the production process. On the other hand, non-renewable energy includes petrol, diesel, electricity, chemicals, fertilizers, machinery and renewable energy consists of human and animal (Mandal et al. 2002; Singh et al. 2003)". Energy input-output and efficiency calculations in organic grape production was given in Table 3.

**Table 3** Energy input-output and efficiency calculations in organic grape production

| Calculations | Unit | Values |
|---|---|---|
| Grape | kg ha$^{-1}$ | 13,850 |
| Energy input | MJ ha$^{-1}$ | 24,875.06 |
| Energy output | MJ ha$^{-1}$ | 163,430 |
| Energy use efficiency | – | 6.57 |
| Energy productivity | kg MJ$^{-1}$ | 0.56 |
| Specific energy | MJ kg$^{-1}$ | 1.79 |
| Net energy | MJ ha$^{-1}$ | 138,554.94 |

## Results and Discussion

In the farms, the amount of organic grape growed per hectare during the 2015 production season was calculated as an average of 13,850 kg. In organic grape production, it is noteworthy that human water of irrigation energy, machinery energy and diesel fuel energy were used as the highest input. Regarding this study, practics for organic grape production and the energy input-output analysis of organic grape production in 2015 were given in Table 2. It can be seen that the first, second and third of the highest energy of inputs in organic grape production are 61.46% water of irrigation energy, 13.29% machinery energy and 12.51% diesel fuel energy were the inputs calculated.

It can be seen that the highest energy inputs in organic grape production are 15,288 MJ ha$^{-1}$ (61.46%) water of irrigation energy, 3304.80 MJ ha$^{-1}$ (13.29%) machinery energy, 3113.94 MJ ha$^{-1}$ (12.51%) diesel fuel energy, 1374.16 (5.53%) organic chemicals energy, 1080 MJ ha$^{-1}$ (4.34%) farmyard manure energy, 691.21 MJ ha$^{-1}$ (2.78%) human labour energy, 11.75 MJ ha$^{-1}$ (0.05%) lime energy and 11.20 MJ ha$^{-1}$ (0.04%) sulphur energy as were the inputs calculated. The results indicated that human labour energy input was calculated 691.21 MJ ha$^{-1}$ in organic grape production. Human labour energy was used for tractor and farm operations such as tillage, pruning-collecting, digging of roots, arm connecting, green pruning, fertilizer application, spraying- spraying of hand, water of irrigation, harvesting and transporting. Diesel energy input was calculated 3113.94 MJ ha$^{-1}$. The diesel energy was used for operating tractor to perform the farm operations such as tillage, spraying and transportation. Machinery energy input was calculated 3304.80 MJ ha$^{-1}$. Machinery energy was used for tractor and farm operations such as tillage, spraying and transporting.

Energy input, energy output, energy use efficiency, energy productivity, specific energy and net energy in organic grape production were calculated as 24,875.06 MJ ha$^{-1}$, 163,430 MJ ha$^{-1}$, 6.57; 0.56 kg MJ$^{-1}$; 1.79 MJ kg$^{-1}$ and 138,554.94 MJ ha$^{-1}$, respectively. In previous studies, Özkan et al. (2007) calculated energy use efficiency in grape study as 2.99, 5.10, Koçtürk and Engindeniz (2009) calculated energy use efficiency in grape study as 8.64 and Hamedani et al. (2011) calculated energy use efficiency in grape study as 4.95. Other studies, Erdal et al. (2007) calculated energy use efficiency in sugar beet study as 25.75, Mohammadi et al. (2010) calculated energy use efficiency in kiwifruit study as 1.54 and Demircan et al. (2006) calculated energy use efficiency in apple study as 1.23. The total energy input consumed could be classified as renewable 74.20% and non-renewable 25.80% in organic grape production. Renewable energy is higher than ratio of non-renewable energy.

## Conclusions

Efficient use of energy is one of the principal requirements of sustainable agriculture. Energy use in agriculture has been increasing in response to increasing population, limited supply of arable land, and a desire for higher standards of living. Continuous demand in increasing food production resulted in intensive use of chemical fertilizers, pesticides, agricultural machinery, and other natural resources (Erdal et al. 2007). In this study, the energy balance of organic grape production in the region was defined. According to the evaluated results, organic grape production is a economic production in terms of energy usage.

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