

# ENERGY EFFICIENCY AND ECONOMIC ANALYSIS IN TOMATO PRODUCTION: A CASE STUDY OF MERSIN PROVINCE IN THE MEDITERRANEAN REGION

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**Abstract.** This study was carried out to find the energy equivalents of inputs and outputs in tomato cultivation in the Mediterranean region of Mersin province. For this aim, the energy balance between values of the input and output energies per unit field for tomato cultivation in open-field and greenhouses was investigated. Energy efficiency, energy density, energy efficiency were compared in terms of cost-benefit ratio. Data were collected and analyzed in open-field (112) and in greenhouses (14) from producers of tomato cultivation. The results showed that the total energy requirement in open fields and greenhouses was 56127.77 and 245246.78 MJ ha<sup>-1</sup>, respectively. Energy use efficiency in the open-fields and in greenhouses was realized as 1.12 and 0.75 respectively. The cost-benefit-ratios were 2.32 in open-fields and 3.06 in greenhouses. According to the current results, the open-fields tomato production system has a higher energy efficiency than the greenhouse tomato production system, while the greenhouse system has a higher economic benefit.

**Keywords:** *tomato production, greenhouse, energy, energy consumption, cost benefit ratio*

## Introduction

Tomato (*Lycopersicon esculentum* Mill.) is a perennial plant in tropical regions which is Solanales of the family of Solanaceae Lycopersicon family, depending on the single-year in temperate climates (Kinet and Peet, 1997). In total vegetable production, which is 1.1 billion tons in the world, tomatoes have 15% ratio with 162 million tons. In Turkey, the share of total vegetable production with production reaching 12.6 million tons exceeded 40%. In the current figures of tomato production; Turkey ranks 4th in the world (FAO, 2013). High adaptability, open the predisposition to greenhouse cultivation next to agriculture, as well as one of the various forms of reasons such as the availability of the processing industry, where most heavily cultivated and most widely consumed and the Mediterranean Basin which Turkey involved in. The amount of tomato consumption per capita in Turkey is 115 kg/year around (Yanmaz et al., 2015). Regional distribution in the largest ratio, is Mediterranean region with the 31% of the total (Abak, 2018). Mersin province is one of Turkey's largest tomato growing fields (ha) (Anonymous, 2017). From 2000 to 2015; Turkey's greenhouse fields increased with the ratio of 58.41%, from 47355.5 ha to 75015.5 (Turemiş, 2015). Today agricultural production is dependent on the consumption of fossil fuels (Taskın and Vardar, 2016). The use of energy in agriculture has increased due to the increasing human population, the limited supply of arable land and the will to improve the standard of living (Banaeian et al., 2010). Agriculture is an energy user and energy supplier (Alam et al., 2005). From the sowing-

planting processes to the harvest-blending operations, direct energy is needed (Singh, 2007). Indirect energy is needed in the process from sowing to harvesting and transportation of products (Ozkan et al., 2004a). Yield, annual production, energy consumption, investments and costs are very high in greenhouses (Heidari and Omid, 2011). Inputs such as electricity, machinery, seeds, chemical fertilizers constitute a significant part of the inputs in the tomato production system (Hatirli et al., 2006). On the other hand, efficient use of energy contributes to increased production, profitability and competitiveness (Singh et al., 2002). Thus, sustainability in agriculture can be achieved in rural life (Park and Seaton, 1996). By using energy efficient in agriculture and by saving fossil fuels, air pollution can be reduced (Pervanchon et al., 2002). More efficient use of energy can be achieved so that the same level of development can be achieved with less energy use and less emissions (Ozturk et al., 2018). Using energy efficiently is very important for the terms of sustainability and the reduction of emissions of greenhouse gases (Alluvione et al., 2011). Energy used in agriculture is 17% of the world's energy (Mohammadi and Omid, 2010). The financial and technical analysis of the tomato production system is called the energy budget (Canakci and Akinci, 2006). In terms of energy input-output relations, seed bed preparation, fertilizer quantity, soil cultivation processes and productivity etc. subjects are looked at (Mandal et al., 2002). In terms of production efficiency, input-output energy analysis is used (Alluvione et al., 2011). Production efficiency can be increased by reducing energy inputs. In the energy consumption in agriculture, mechanization is important (Ozkan et al., 2004b). The efficient use of energy provides sustainability (Dalgaard et al., 2001). In the world; there are important researches had done about field crops, fruits and the use of energy for vegetables. Energy inputs and outputs of apricot cultivation were examined (Gezer et al., 2003). Many researchers; soybean, corn and wheat in Italy (Sartori et al., 2005), tomatoes and tomato paste in Turkey (Esengün et al., 2007), lettuce in Colombia, radishes and spinach (Bojaca and Schrevens, 2010), rice in Malaysia (Bockari et al., 2005), kiwi in Iran production (Mohammadi et al., 2010), apple (Rafiee et al., 2010), onion and coriander Pennsylvania in the USA (Moore, 2010), the productivity of crops such as sugar cane production in Morocco (Mrini et al., 2001) has made energy issues and economic analysis. Work efficiency and alternative energy consumption in tomato production were analyzed (Onal and Tozan, 1986). Detailed energy usability surveys were conducted (Yılmaz et al., 2005). Greenhouse energy and cost analysis were carried out in the Serik district of Antalya for the production of grapes in open-field and greenhouses (Ozkan et al., 2007). Some studies have been carried out on the use of energy in peach production in Tokat province (Goktolga et al., 2006). Economic analysis of the input energy requirements and costs are made in tomato production in Turkey (Cetin and Vardar, 2008).

The objectives of this study are; determine the effectiveness of tomato production systems, energy utilization rates, energy output-input ratio, cost/benefit ratio, energy inputs optimization of energy use efficiency and to determine the economic analysis. Thus in Mersin, greenhouse tomatoes and open-field tomato production systems will be compared.

## Materials and methods

In this study, data were collected from 126 producers in open-fields and greenhouses in Mersin. In the Mediterranean city of Mersin, located south of Turkey. 36° 48' north

latitude and 34° 38' east longitude. The average annual temperature is approximately 19.2 °C and the total annual rainfall is 592.1 mm. Approximately 94% rainfall falls from October to May (TSMS, 2017). The total number of registered farmers in Mersin, in 2016 is 35039 (MAF, 2016). Data on the production of tomatoes collected by face-to-face survey from growers are belong to 2016 production period. in the province of Mersin, 941.232 tons of tomatoes were obtained from 91.211 decares of field. Sample farms were randomly selected from the study area by using a random sampling technique. However, it should be taken into account the factor in which variability can be observed in basic datasets. The sample size was calculated using the Neyman method (Eq. 1) (Yamane, 1967).

$$n = \frac{N \times S^2}{(N-1)S_x^2 + S^2} \quad (\text{Eq.1})$$

For this equation; n is the required sample size, N population volume, S standard deviation, Sx standard deviation of the sample average (Sx = d/z), z reliability coefficient, d is based on the allowable error equation of the sample size. For open-field and greenhouse tomato cultivation, the number of samples examined was 112 and 14 (126) respectively. The permissible error (d) was defined as 5%, and for the 95% reliability (z), 126 sampling sizes were calculated. Firstly, the most common production systems for each product were identified, and then all inputs and outputs from the systems were identified and digitized, and then converted to energy units. By adding partial energies to total energies (ha) per production unit; energy inputs include human labor, diesel fuel, machinery, farm manure, irrigation, nitrogenous, phosphorus and potassium chemical fertilizers. In order to estimate the energy in MJ/ha and to find the amount of inputs in terms of efficiency values by the energy analysis of the tomato, the equivalents in *Table 1* are used.

**Table 1.** Energy equivalents for different inputs and outputs in agricultural production

Particulars	Unit	Energy equivalent (MJ unit <sup>-1</sup> )	Reference
<b>A. Inputs</b>			
1. Human labor	h	1.96	Mohammadi et al., 2008
2. Machinery	h	64.80	Singh et al., 2002
3. Diesel fuel	l	47.80	Canakci and Akincl, 2006
4. Chemical fertilizers			
(a) Nitrogen	kg	66.14	Mohammadi et al., 2008
(b) Phosphate	kg	11.10	Mani et al., 2007
(c) Potassium	kg	11.15	Kousar et al., 2006; Sartori et al., 2005
(d) Sulfur	kg	1.12	Mohammadi et al., 2008
(e) Zinc	kg	8.40	Mohammadi et al., 2008
(f) Mixed micronutrients	kg or l	120.00	Alam et al., 2005
5. Chemicals			
(a) Herbicides		238.30	Esengun et al., 2007 Erdal et al., 2007
(c) Pesticides		101.20	Esengun et al., 2007
(d) Fungicides		216.00	Esengun et al., 2007
6. Cattle manure	kg	0.30	Mohammadi et al., 2008
7. Electricity	kWh	11.93	Mani et al., 2007
8. Water for irrigation	m <sup>3</sup>	1.02	Rafiee et al., 2010
9. Seeds	kg	1.00	Esengun et al., 2007
<b>B. Outputs</b>			
1. Fruit yield	kg	0.80	Taki et al., 2012

Energy use efficiency (Eq. 2), energy productivity (Eq. 3), specific energy (Eq. 4), energy intensiveness (Eq. 5) and net energy (Eq. 6) were calculated (Banaeian et al., 2010; Ghorbani et al., 2011).

$$\text{Energy use efficiency} = \frac{\text{Energy output}(MJha^{-1})}{\text{Energy input}(MJha^{-1})} \quad (\text{Eq.2})$$

$$\text{Energy productivity} = \frac{\text{Crops output}(Kgha^{-1})}{\text{Energy input}(MJha^{-1})} \quad (\text{Eq.3})$$

$$\text{Specific energy} = \frac{\text{Energy inpute}(MJha^{-1})}{\text{Crops output}(t.ha^{-1})} \quad (\text{Eq.4})$$

$$\text{Energy intensiveness} = \frac{\text{Energy inpute}(MJha^{-1})}{\text{Cost of cultivation}(\$ ha^{-1})} \quad (\text{Eq.5})$$

$$\text{Net energy} = [\text{Energy output}(MJha^{-1}) - \text{Energy input}(MJha^{-1})] \quad (\text{Eq.6})$$

The energy equivalents of the inputs are mega joule (MJ) per unit. In particularly this calculated ratio was used to express energy deficiency with input fossil fuel energy and output food ratio. The increase in the rate of crop production indicates improvement. It is possible to determine the energy efficiency trends of agricultural production by evaluating energy efficiency rates. Total value of production (Eq. 7), Gross return (Eq. 8), Net return (Eq. 9), Total cost of production (Eq. 10), Benefit to cost ratio (Eq. 11) and Productivity (Eq. 12) (Economic analysis of tomato cultivation) were investigated (Zangeneh et al., 2010):

$$\text{Total value of production} = \text{tomato yield} (\text{kg ha}^{-1}) \times \text{tomato price} (\$ \text{kg}^{-1}) \quad (\text{Eq.7})$$

$$\text{Gross return} = \text{total value of production} (\$ \text{ha}^{-1}) - \text{variable cost of production} (\$ \text{ha}^{-1}) \quad (\text{Eq.8})$$

$$\text{Net return} = \text{total value of production} (\$ \text{ha}^{-1}) - \text{total cost of production} (\$ \text{ha}^{-1}) \quad (\text{Eq.9})$$

$$\text{Total cost of production} = \text{variable cost of production} (\$ \text{ha}^{-1}) + \text{fixed cost of production} (\$ \text{ha}^{-1}) \quad (\text{Eq.10})$$

$$\text{Benefit to cost ratio} = \text{total value of production} (\$ \text{ha}^{-1}) / \text{total cost of production} (\$ \text{ha}^{-1}) \quad (\text{Eq.11})$$

$$\text{Productivity} = \text{tomato yield} (\text{kg ha}^{-1}) / \text{total cost of production} (\$ \text{ha}^{-1}) \quad (\text{Eq.12})$$

## Results

### ***Energy input-output relationship in open-field and greenhouse tomato production system***

In tomato production systems, per hectare in open-fields and greenhouses, 1088.25 and 2347.82 h of human labor respectively and showed that 32.44 and 98.65 h machine power

is required. The total energy used in production in open fields and green houses is 62862.93 and 183866.38 MJ ha<sup>-1</sup> (Table 2). It is the electricity sector which has the highest energy consumption in tomato production system in open-fields (32.89%), followed by nitrogen (22.08%), irrigation (13.55%) and diesel fuel (12.66%) (Table 2) If the highest energy consumption in the tomato production system in greenhouses is diesel fuel (60.90% of total energy input), followed by electricity (14.68%) and micro nutrients (fertilizer, 11.34%) (Table 2). For tomato production systems, the average fruit yield in open fields and greenhouses were 147854 kg ha<sup>-1</sup> with 52429.8 respectively, while the straw yield were 2789.21 and 8744.37 kg ha<sup>-1</sup>. While total energy output per hectare was 62862.93 MJ in open fields and 183866.38 MJ in greenhouses. The input-output energy ratio in open fields and greenhouse systems is 1.12 and 0.75, respectively. The energy use efficiency in the open-field was nearly 1.49 times more than the greenhouse system due to the use of more input energy than the greenhouse system.

**Table 2.** Energy input-output relationship in openfield and greenhouse tomato production system

Energy inputs	Quantity per unit area (ha)		Energy equivalent (MJ unit <sup>-1</sup> )		Total energy equivalent (MJ)		Percentage of total energy input (%)	
	Open field	Green house	Open field	Green house	Open field	Green house	Open field	Green house
Human labor (h)	1088.25	2347.82	1.96	1.96	2132.97	4601.73	3.80	1.88
Machinery (h)	32.44	98.65	64.80	64.80	2102.11	6392.52	3.75	2.61
Diesel fuel (l)	148.64	3124.57	47.80	47.80	7104.99	149354.45	12.66	60.90
Nitrogen (kg)	187.39	121.84	66.14	66.14	12393.97	8058.50	22.08	3.29
Phosphate (kg)	96.27	73.15	11.10	11.10	1068.60	811.97	1.90	0.33
Potassium (kg)	34.86		11.15		388.69	0.00	0.69	0.00
Sulphur (kg)		317.52		1.12	0.00	355.62	0.00	0.15
Cattle manure (kg)	11207.23	10621.46	0.30	0.30	3362.17	3186.44	5.99	1.30
Micro nutrients (kg or l)	3.89	231.71	120.00	120.00	466.80	27805.20	0.83	11.34
Herbicides (kg or l)	1.91	0	238.30	238.30	455.15	0.00	0.81	0.00
Pesticides (l)	1.63	4.43	101.20	101.20	164.96	448.32	0.29	0.18
Fungicide (kg or l)	1.94	16.25	216.00	216.00	419.04	3510.00	0.75	1.43
Electricity (kWh)	1547.36	3018	11.93	11.93	18460.00	36004.74	32.89	14.68
Water for irrigation (m <sup>3</sup> )	7458.28	4624.54	1.02	1.02	7607.45	4717.03	13.55	1.92
Seeds (kg)	0.87	0.28	1.00	1.00	0.87	0.28	0.00	0.00
Total energy input (MJ)					56127.77	245246.78	100.00	100.00
<b>Outputs</b>								
Fruit yield (kg)	52429.8	147854.5	0.80	0.80	41943.86	118283.61	66.72	68.09
Straw yield (kg)	2789.21	8744.37	7.50	7.50	20919.08	65582.78	31.91	31.91
Total energy output (MJ)					62862.93	183866.38		
Energy efficiency					1.12	0.75		

### **Efficiency and specific energy in open-field and greenhouse systems**

Energy use efficiency is 1.12 in open-field and 0.75 in greenhouse tomato production systems. The energy intensiveness was calculated as 14.61 in open-field and 3.79 MJ S<sup>-1</sup> in greenhouse systems. The average energy productivity of the open-field and greenhouse is 0.93 and 0.60 kg MJ<sup>-1</sup>, respectively. Specific energy is 1.07 and 1.66 MJ

kg<sup>-1</sup> in the open-field and in the greenhouse, respectively. Net energy is 6735.16 and -61380.40 MJ ha<sup>-1</sup> in open-field and greenhouse respectively (*Table 3*).

**Table 3.** *Tomato production energy indices in open field and greenhouse systems*

Items	Unit	Open field	Greenhouse
Energy input	MJ ha <sup>-1</sup>	56127.77	245246.78
Energy output	MJ ha <sup>-1</sup>	62862.93	183866.38
Energy use efficiency	-	1.12	0.75
Energy intensiveness	MJ \$ <sup>-1</sup>	14.61	3.79
Specific energy	MJ kg <sup>-1</sup>	1.07	1.66
Energy productivity	kg MJ <sup>-1</sup>	0.93	0.60
Net energy	MJ ha <sup>-1</sup>	6735.16	-61380.40

***Relationship between economic indices and analysis in tomato production system in open-field and greenhouse***

The production cost of our two works and our gross product can be seen at *Table 4*. In open-field and greenhouse tomato production systems, the gross production value is 14680.35 and 93148.34 \$ ha<sup>-1</sup>. The tomato production and stability in the open-field was 3925.23 and 2390.94 \$ ha<sup>-1</sup>, greenhouse facilities 15977.42 and 14486.52 \$ ha<sup>-1</sup>. The production amount per hectare (6316.16 \$ ha<sup>-1</sup>) in the open-field is lower than the greenhouse system (30463.94 \$ ha<sup>-1</sup>). Total production amount in the greenhouse system is 79.27% higher than the open-field system. The gross return and net return (10755.12 and 8364.19 \$ ha<sup>-1</sup>) available in open-field production is very low from the greenhouse production system (77170.92 and 62684.40 \$ ha<sup>-1</sup>). The gross and net return in the open field system is 7.2 and 7.5 times lower. In greenhouses (3.06), the benefit cost ratio is higher than the open-field system (2.32). Productivity is expressed in 1 US\$, this means how much product we can produce with 1 US dollar. This study efficiency is 8.30 and 4.85 kg<sup>-1</sup> for open-field and greenhouse systems.

**Table 4.** *Economic indices of tomato production in open space and greenhouse systems and relationship between analysis*

Cost and return components	Open field (value)	Greenhouse (value)
Fruit yield (kg ha <sup>-1</sup> )	52429.82	147854.51
Sale price (\$ kg <sup>-1</sup> )	0.28	0.63
Gross value of production (\$ ha <sup>-1</sup> )	14680.35	93148.34
Variable cost of production (\$ ha <sup>-1</sup> )	3925.23	15977.42
Fixed cost of production (\$ ha <sup>-1</sup> )	2390.94	14486.52
Total cost of production (\$ ha <sup>-1</sup> )	6316.16	30463.94
Total cost of production (\$ kg <sup>-1</sup> )	0.12	0.21
Total cost production (\$ MJ <sup>-1</sup> )	0.06	0.09
Gross return (\$ ha <sup>-1</sup> )	10755.12	77170.92
Gross return (\$ kg <sup>-1</sup> )	0.21	0.52
Gross return (\$ MJ <sup>-1</sup> )	0.10	0.22
Net return (\$ ha <sup>-1</sup> )	8364.19	62684.40
Net return (\$ kg <sup>-1</sup> )	0.16	0.42
Net return (\$ MJ <sup>-1</sup> )	0.08	0.18
Benefit to cost ratio	2.32	3.06
Productivity (kg \$ <sup>-1</sup> )	8.30	4.85

## Discussion

In tomato production systems, the total energy input (56127.77 MJ ha<sup>-1</sup>) used in the open-field has shown that it is approximately 4.37 times lower than the greenhouse production system (245246.78 MJ ha<sup>-1</sup>). Diesel fuel consumption in the production of tomatoes in greenhouses is very high. In addition, energy consumption in greenhouse production systems is higher than the open-field production system. But, the energy use rate is lower (Cetin and Vardar, 2008). In addition, tomato yield in the open field (52429.82 kg ha<sup>-1</sup>) is 2.82 times lower than the greenhouse system (147854.51 kg ha<sup>-1</sup>) (Özkan et al., 2004b). Energy output-input ratio is higher in open-field (1.12) than in greenhouse systems (0.75).

## Conclusions

Reducing the share of fertilizers and diesel fuel may increase energy efficiency. Net energy is -61380.40 and 6735.16 MJ ha<sup>-1</sup> in greenhouse systems and outdoor field. A negative value of the energy gain in the greenhouse is due to the heating technology used for heating diesel engines at high temperatures, such as low heating technology (Banaeian et al., 2010). In the open field, respectively, 10755.12 \$, 8364.19 \$ and 2.32; The gross, net return and benefit cost ratio is lower than the greenhouse tomato production system. Total production cost of greenhouse is higher than open-field due to heavy fuel usage. The high price of greenhouse tomatoes is owing to the lack of tomatoes in autumn and winter. Effective use of inputs contributes to economic profitability and competitiveness, while increasing productivity (Singh et al., 2002). The results show that water for diesel fuel, irrigation, fertilization, machinery and electrical energies is the major part of the energy inputs used in tomato production systems. In terms of energy efficiency, the tomato production system in the open-field is 1.49 times higher than the greenhouse system. This leads to an increase towards higher sustainability. In addition, the most effective factors affecting the efficiency of energy use in greenhouse and open-field systems are diesel fuel and nitrogen fertilizer inputs. Therefore, reducing the consumption of these inputs may increase the efficiency of energy use in tomato production systems in Mersin province.

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