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Full Length Research Paper

Comparing energy flow of greenhouse and open-field cucumber production systems in Iran

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The aim of this study was to compare the energy flow in greenhouse and open-field cucumber production systems in Iran. For this purpose, data were collected by using a face-to-face questionnaire performed with 100 cucumber farmers (50 farmers for greenhouse systems and 50 farmers for open-field cucumber systems) in summer 2010. Farmers were selected by random sampling method in Tehran and Kermanshah province of Iran. The results revealed that total energy consumption amount in greenhouse systems was 11709452.43 MJha^{-1} while in open-field systems it was 78476.33 MJha^{-1}. The highest share of total input energy in greenhouse cucumber systems was recorded for diesel fuel with 99% while the highest share of input energy in open-field cucumber systems was observed for electricity power with 38%. Energy use efficiency in greenhouse systems (0.017) was lower than open-field systems (0.33). Energy productivity and specific energy in greenhouse production systems were 0.02 KgMJ^{-1} and 46.84 MJKg^{-1}, respectively while that in open-field production systems were 0.41 KgMJ^{-1} and 2.38 MJKg^{-1}, respectively. Accordingly, net energy in open-field cucumber production systems (-52171.93 MJha^{-1}) was higher than greenhouse cucumber production systems (-11509452.43 MJha^{-1}).

Key words: Greenhouse, open-field, energy use efficiency.

INTRODUCTION

The cucumber (*Cucumis sativus*) is a widely cultivated plant in the gourd family Cucurbitaceous which include squash and the same genus as the muskmelon. It is one of the important vegetable products in Iran and the other regions of world. This crop can be produced in greenhouse and open-field systems. The cucumber production in Iran was produced in about 82896 ha with the 1603721.76 tons yield in 2010 (Anonymous, 2010). The greenhouses systems in Varamin and the open-field ones in Kermanshah are the important cucumber production systems in Iran.

There is a very close relation between agriculture production system and amount of energy consumption. Agriculture itself is an energy user and supplier in the form of bio-energy (Alam, 2005). Energy use in agricultural production has become more intensive due to the use of fossil fuel, chemical fertilizers, pesticides, machinery and electricity to provide substantial increases in food production. However, more intensive energy use has brought about some important human health and environment problems, so efficient use of inputs has become important in terms of sustainable agricultural production (Yilmaz et al., 2005). Energy auditing is one of the most common approaches to assess energy efficiency and environmental impact of the production system. It enables the researchers to calculate the output–input ratio, relevant indicators for energy and energy use patterns in an agricultural activity (Hatirli et al., 2006).

On the other hand, the energy audit provides sufficient data to established functional forms to investigate the relationship between energy inputs and outputs. Estimating these functional forms is very useful to determine elasticity of inputs on yield and production (Hatirli et al., 2006). The best way to lower the environmental hazard of energy use is to increase the energy use efficiency (Esengun et al., 2007). Energy

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Table 1. Energy equivalents of input and output in greenhouse and open-field cucumber production systems.

Equipment /input	Unit	Energy equivalents	Reference
A. Input			
1. Human labour	h	1.96	(Bojaca and Schrevens, 2010)
2. Machinery	h	62.70	(Samavatean et al., 2010)
3. Diesel fuel	L	51.33	(Samavatean et al., 2010)
4. Chemical fertilizer:	kg		
(a) Nitrogen		60.60	(Gundogmus, 2006)
(b) Phosphate (P_2O_5)		11.10	(Gundogmus, 2006)
(c) Potassium (K_2O)		6.70	(Gundogmus, 2006)
5. Farmyard manure	kg	0.30	(Bojaca and Schrevens, 2010)
6. Pesticides:	kg	238	
(a) Herbicides		199	(Gundogmus, 2006)
(b) Insecticides		92	(Gundogmus, 2006)
(c) fungicide		11.9	(Gundogmus, 2006)
7. Electricity	kWh	0.63	(Ghasemi et al., 2010)
8. water for irrigation	M^3	1.00	(Gundogmus, 2006)
9. Seed	Kg		(Mohammadi and Omid, 2010)
B. Output			
Cucumber	kg	0.80	(Mohammadi and Omid, 2010)

input–output analysis is usually used to evaluate the efficiency and environmental impacts of production systems.

It many studies were conducted on the agricultural energy flow such as dry apricot production in Turkey (Esengun et al., 2007), tomato (Hatirli et al., 2006), sugar beet (Erdal et al., 2007), greenhouse vegetable (Ozkan et al., 2004), some field crops and vegetable in Turkey (Demircan et al., 2006; Canakci et al., 2005), soybean, maize and wheat in Italy (Sartori et al., 2005), soybean production system (Mandal et al., 2002), oilseed rape in Germany (Rathke and Diepenbrock, 2006), and green-house cucumber in Iran (Mohammadi and Omid, 2010). But any one of them did not work on energy flow in greenhouse vegetable in compared to open-field vegetation production systems. The objective of the present study was compared to energy analysis of cucumber production on the greenhouse and open-field cucumber production systems in Iran in terms of energy use efficiency, energy productivity, specific energy, and net energy.

MATERIALS AND METHODS

The study was carried with 100 cucumber production systems in Iran covering 50 greenhouses in Varamin province and 50 open-field cucumber production systems in Kermanshah province. Data were collected by using a face-to-face questionnaire performed with 100 cucumber farmers (50 farmers for greenhouse systems and 50 farmers for open-field cucumber systems) in summer 2010. Another data was collected from the departments of Agricultural Ministry in Iran. Total energy input and output of these systems were calculated and converted to their energy equivalent. Energy equivalents of inputs and outputs for both greenhouse and open-field cucumber production were obtained from a number of sources (Table 1). The source of mechanical energy was including direct use of tractors and consumed diesel oil. The mechanical energy was computed on the basis of total fuel consumption (Lha^{-1}) in different operations. Therefore, the energy consumed was calculated using conversion factors (1L Diesel = 56.31 MJ) and was expressed in $MJha^{-1}$ (Rafiee et al., 2010). Basic information on energy inputs and cucumber yields were entered into Excel and SPSS 18.0 spread sheets.

The energy use efficiency, energy productivity, specific energy and net energy were calculated according to the following formulas (Canakci et al., 2005; Hatirli et al., 2008):

$$\text{Energy Use Efficiency} = (\text{Output Energy(MJ/ha)})/(\text{Input Energy(MJ/ha)}) \quad (1)$$

$$\text{Energy Productivity} = (\text{Cucumber Yield(Kg/ha)})/(\text{Input Energy(MJ/ha)}) \quad (2)$$

$$\text{Specific Energy} = (\text{Input Energy(MJ/ha)})/(\text{Cucumber Yield(Kg/ha)}) \quad (3)$$

$$\text{Net Energy} = \text{Otput Energy(MJ/ha)} - \text{Input Energy(MJ/ha)} \quad (4)$$

Table 2. Energy inputs, outputs and output–input ratio in greenhouse and open-field cucumber production.

Energy Source	Quantity used per unit area (ha)		Total energy equivalent (MJ ha)		%	
	Greenhouse	Open-field	Greenhouse	Open-field	Greenhouse	Open-field
Inputs (unit)						
Human labour	22175.55	2450	43464.07	4802	0.37	6.11
Machinery	107.873	28	6763.44	1755.6	0.05	2.23
Fertilizer (kg)						
Nitrogen (kg)	441.42	276	26750.05	16725.6	0.22	21.31
Phosphorus (kg)	385.6	253	4280.16	2808.3	0.03	3.57
Potassium (kg)	364.5	54.89	2442.15	367.763	0.02	0.46
Manure (kg)	31101.66	5977	9330.50	1793.1	0.07	2.28
Insecticides (kg)	17.89	1	3560.11	199	0.03	0.25
Fungicides	71.58	0.5	6585.36	46	0.05	0.05
herbicide	0	1.38	0	328.44	0.00	0.41
Diesel oil (l)	205939.4	278.04	11596442	15656.43	99.03	19.95
Electricity (kWh)	577.78	2450	6892.91	29228.5	0.05	37.24
Irrigation water (m^3)	4669.2	7560	2941.6	4762.8	0.02	6.06
Seed (kg)	0.1	2.8	0.1	2.8	0.00	0.00
Total energy input (MJ/ha)			11709452.4	78476.33	100	100
Outputs yield (kg)	250000	32880.5	200000	26304.4	100	100

In this study, for the growth and development, energy demand in agriculture was divided into direct and indirect, renewable, and non-renewable energies (Alam et al., 2005). Indirect energy was included as the energy embodied seeds, fertilizers, manure, chemicals and machinery, while direct energy covered human labour and diesel were used for cucumber production. Non renewable energy was included diesel, chemical; fertilizers and machinery, and renewable energy consisted of human labour, seeds, and manure.

RESULTS AND DISCUSSION

Energy use in greenhouse and open-field cucumber production

Table 2 showed the inputs used in greenhouse and open-field cucumber production and their energy equivalents, percentages in the total energy input and energy use efficiency. The results showed that the total energy input in greenhouse cucumber systems was 11709452.43 $MJha^{-1}$ whereas this amount was 78476.33 $MJha^{-1}$ in open-field cucumber systems. The highest share of total energy input in greenhouse systems was calculated for diesel fuel (99.03%), human labour (0.37%) and N fertilizer (0.22%), respectively, while this amount in open-field systems was recorded as the electricity energy (37.24%), N fertilizer (21.31%), and diesel fuel (19.95%). Ozkan et al. (2007) reported that the total input energy in greenhouse and open field grape production were 24513.0 and 23640.9 $MJha^{-1}$, and highest shear of this amount was related to electricity (28%) in greenhouse cucumber production and diesel fuel (32%) in open-field systems. In the other study in Turkey, Ozkan et al. (2004) reported that the highest shear of total input energy for greenhouse tomato, cucumber and eggplant was related to diesel fuel by 32.17, 42.64, and 31.30 percent, respectively.

In this study, the average annual yield for greenhouse and open-field cucumber production systems were found to be 250000 and 32880.5 $kgha^{-1}$, respectively, that their total energy equivalent was 200000 and 26304.4 $MJha^{-1}$, respectively

Energy indicators in different production systems of cucumber

Energy use efficiency, energy productivity, specific energy, and net energy were calculated for greenhouse and open-field cucumber production systems (Table 3). The mounts of energy use efficiency in greenhouse and open-field cucumber systems were 0.017 and 0.33, respectively.

Accordingly, energy use efficiency in open-field systems was about 20 equal to greenhouse systems. Due to high energy consumption in greenhouse systems the energy use efficiency was very lower than open-field systems. Energy use efficiency in open-field systems was reported 2.80 for maize in Turkey (Canakci et al, 2005), 1.04 for chickpea in Iran (Salami and Ahmadi, 2010), 2.12 and 2.05 for organic and non organic lentil (Asakereh et al., 2010), 1.58 for kiwifruit in Iran (Mohammad et al., 2010) whereas this amount was 0.64 for greenhouse cucumber production in Iran (Mohammadi

Table 3. The indicators of energy use in different cucumber production systems.

Indicators	Unit	Quantity for greenhouse	Quantity for open-field
Inputs energy	$MJha^{-1}$	11709452.43	78476.38
Output energy	$MJha^{-1}$	200000	26304.4
Cucumber yield	$Kgha^{-1}$	250000	32880.5
Energy use efficiency		0.017	0.33
Energy productivity	$KgMJ^{-1}$	0.02	0.41
Specific energy	$MJkg^{-1}$	46.84	2.38
Net energy	$MJha^{-1}$	-11509452.43	-52171.93

Table 4. Total energy input in the form of direct, indirect, renewable and non-renewable energy for greenhouse cucumber production.

Energy form	Energy quantity ($MJha^{-1}$)		%	
	Greenhouse	Open-field	Greenhouse	Open-field
Direct energy	11646798.96	54449.73	99.46	69.38
Indirect energy	62653.47	24026.6	0.53	30.62
Renewable energy	52794.67	11360.71	0.45	14.48
Non-renewable energy	11656657.76	67115.63	99.54	85.52

and Omid, 2010), 0.32, 0.19, 0.31, and 0.23 for greenhouse tomato, pepper, cucumber and eggplant, respectively (Canakci and Akinci, 2006). Energy use efficiency can be increased by improving crop biomass production or reducing energy application. Energy productivity in open-field systems (0.41 $kgMJ^{-1}$) was more than greenhouse systems (0.02 $kgMJ^{-1}$). In the other hands, was used the 46.84 MJ energy per kg of cucumber in greenhouse systems while this amount was 2.38 $MJKg^{-1}$ for open-field cucumber system. Amount of energy productivity was 0.65 $MJkg^{-1}$ for sugar beet (Erdal et al., 2007), 10.43 $MJkg^{-1}$ for irrigated wheat (Ghiyasi et al., 2008), and 5.87 $MJkg^{-1}$ for rain fed wheat in Turkey (Adnan et al., 2009). Net energy (total output energy minus total input energy) in greenhouse cucumber systems was -11509452.43 $MJha^{-1}$. This means that amount of input energy is lower than output energy. While this amount (-52171.93) was higher in open-field cucumber production systems.

Energy forms in different cucumber systems

Also direct, indirect, renewable, and non-renewable energy forms used in greenhouse and open-field cucumber production systems were showed in Table 4. The results showed that shares of direct and indirect input energy in greenhouse cucumber systems were 99.46 and 0.54%, respectively, while these amounts were 69.38 and 30.62%, respectively, for open-field cucumber systems. On the other hand, in greenhouse systems non-renewable and renewable energy contributed to 99.54 and 0.45% of the total energy input, respectively, while these amounts were 85.52 and 14.48% for open-field systems, respectively. Similarly, the total energy input consumed for both cucumber production systems could be classified as non-renewable, direct, indirect and renewable energy. Intensity of non-renewable energy consumption resulted from fertilizer, diesel fuel and machinery use in production (Mohammadi et al., 2010). It was understood that the proportion of non-renewable energy use in surveyed greenhouse farms was higher than open field systems. The results show that greenhouse cucumber production depends on mainly fossil fuels.

Conclusion

In this study, the inputs and output energy requirements for greenhouse and open-field cucumber production systems were assessed for Kermanshah and Varamin provinces in Iran by using a face to face questionnaire performed with farmers and Ministry of Jihad-e-Agriculture. The results revealed that the total energy input use on greenhouse cucumber production was about 11709452.43 MJ/ha, which was more than that of input energy in open-field cucumber production systems (78476.33 MJ/ha). The main factor resulting in excessive energy use on greenhouse cucumber production was diesel oil use. On the other hand, the energy use at different stages of production, such as machinery,

irrigation and fertilizer was also higher than those of open-field cucumber production. Accordingly, the energy use efficiency in open-field systems was higher than greenhouse systems. The main reason for this condition was ineffective use of energy input.

Finally, the results derived from this study can be used for effective and more efficient use of energy by farmers that can lead to increased sustainability in agricultural systems.

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