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Evaluation of Tomato Production Systems in Terms of Energy Use Efficiency and Economical Analysis in Iran

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Abstract

Efficient use of energy helps to achieve improved production and productivity, and contributes to economy, profitability and competitiveness of agricultural sustainability. The aim of the present study was to compare open field and greenhouse tomato production systems in terms of energy efficiency, energy intensiveness, energy productivity, benefit to cost ratio and amount of renewable and non-renewable energy uses. Data were collected from 128 and 16 open field and greenhouse tomato growers, respectively, by using a face-to-face questionnaire in 2010. The results showed that the total energy requirement under open field and greenhouse systems were 47647.12 and 2102678.73 MJ ha^{-1}, respectively. The share of direct, indirect, renewable and non-renewable energies from total energy input which average in open field and greenhouse production systems were 74%, 26%, 17% and 83%, respectively. Energy use efficiency was achieved 1.42 and 0.18 in open field and greenhouse, respectively. The benefit to cost ratios of 2.33 in open field and 3.06 in greenhouse was recorded. Based on the present results, open field tomato production system had higher energy efficiency in comparison with greenhouse tomato production system while greenhouse system had a higher economical benefit.

Keywords: energy intensiveness, energy productivity, greenhouse, net return, open field

Introduction

Tomato (*Lycopersicon esculentum*) is one of the major vegetables products worldwide. It was cultivated on 161800 ha and the total production was 5.9 million tones in 2009, in Iran. Khorasan Razavi province with 14000 ha open filed tomato is one of the greatest tomato cultivation areas in Iran (Anonymous, 2009). In this province, tomato is a main source for fresh using and processing industries. Tomato production creates an income for many rural families and it is an important source of employment in the province.

From 2002 to 2007, greenhouse areas of Iran increased from 3380 ha to 6630 ha with an increasing rate of 96%. The shares of greenhouse crops production were as follow: vegetables 59.3%, flowers 39.81%, fruits 0.54% and mushroom 0.35% (Anonymous, 2009). Tomato greenhouse production is one of the most intensive and energy-consuming production systems. In this respect, the energy budget is very important. Energy budget is the numerical comparison of the relationship between input and output of a system in terms of energy units (Canakci and Akinci, 2006).

Nowadays, climate change and air pollution are the major environmental concerns related to the use of fossil fuel energy. Furthermore, considering that fossil fuel energy is a limited resource, it has to be conserved for future generations by efficient use in a sustainable approach (IPCC. 1997). Agriculture and energy consumption have very closed relation. Agriculture is an energy user and energy supplier (Alam *et al*., 2005). Energy use in agriculture has elevated in response to increasing human population, limited supply of arable land and desire for an improving standard of living (Banaeian *et al*., 2010). Moreover, energy use is one of the key indicators for developing more sustainable agricultural practices (Mohammadi *et al*., 2010). It has been reported that total energy used in agricultural production, processing and distribution is about 17 percent of the total energy used the world (Mohammadi and Omid, 2010). Therefore, effectiveness and efficient energy use are the main keys for enhanced sustainable agricultural production (Mohammadi and Omid, 2010). Energy requirements in agriculture come from renewable and non-renewable resources which can be divided into two groups: direct and indirect energy. Diesel fuels, biocides, chemical fertilizers and machineries are known as non-renewable energy, and human labor, water, seeds and farmyard manure are recognized as renewable energy (Mohammadi *et al*., 2010). Direct energy is required to carry out many operations related to crop production processes such as land preparation, irrigation, harvesting, threshing and transportation (Singh, 2000). The energy used in manufacturing, packaging and carrying of chemical fertilizers, biocides and farm machineries were classified as indirect energy (Ozkan *et al*., 2004b). The inputs such as different fuels, electricity, machineries, seed, chemical fertilizers and biocides get significant share of the energy supplies in the production system of modern agriculture (Hatirli *et al*., 2006). Efficient uses of inputs help to increase production and productivity, and contribute to the economy, profitability and competitiveness of agricultural sustainability of rural communities (Singh *et al*., 2002). Wider

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use of renewable energy sources in energy supply is able to make a valuable contribution to meet sustainable energy improvement targets (Streimikiene *et al*., 2007). Energy consumption in the agricultural sectors highly depends on the size of population engaged in agriculture, the amount of arable land and the level of mechanization (Ozkan *et al*., 2004a).

Energy productivity is an important index for more efficient use of energy although higher energy productivity does not mean more economic possibility. However, the energy analysis shows the methods to reduce the energy inputs and consequently to enhance the energy productivity (Fluck and Baird, 1982).

Many investigations have been studied energy efficiency and economical analysis of different cropping systems, such as irrigated and rainfed wheat, potato, greenhouse strawberry and greenhouse cucumber in Iran (Banaeian *et al*., 2010; Ghorbani *et al*., 2011; Mohammadi *et al*., 2008, 2010), sugarcane in Morocco (Mrini *et al*., 2001) rice in Malaysia (Bockari-Gevao *et al*., 2005), stake-tomato and greenhouse tomato in Turkey (Esengun *et al*., 2007; Hatirli *et al*., 2006) and maize and sorghum in United States (Franzluebbers and Francis, 1995). However, no studies have been published on the energy and economical analysis of open field and greenhouse tomato production in Iran. The aims of this study were: (i) to determine the energy use efficiency and economical analysis of tomato production systems and, (ii) compare open field tomato with greenhouse tomato production systems in the case of energy intensiveness in Khorasan Razavi province, Iran.

Material and methods

This study was conducted in Khorasan Razavi province, Iran. The province is located in the Northeast of Iran, within 34°03' and 38°17' North latitude and 55°17' and 61°15' East longitude. The total surface area of the province is 12,842,000 ha and the total tomato cultivated area was 14561 ha consists of 1455 ha farm tomato and 6.1 ha greenhouse tomato in year 2009 (Anonymous, 2009). Data were collected from the growers by using a face-to-face questionnaire in 2010. In addition, to the data obtained by surveys, the results of previous studies by Food and Agricultural Organization (FAO) and Ministry of Jihad-e-Agriculture of Iran (MJA) were also used in this study. The number of operations involved in the tomato production systems, and their energy requirements influence the final energy balance. According to "MJA", there were 2600 tomato farmers in Khorasan Razavi province in 2009 (Anonymous, 2009). A random sampling method was used; the sample size was calculated using the following equation (Newbold, 1994):

$$\mathrm{n} = \frac{N \times S^2}{(N-1)S_X^2 + S^2} \tag{1}$$

where n is the required sample size, N is population volume, S is standard deviation, S_X is standard deviation of sample mean ($S_X = d/z$), d is the permissible error in the sample size was defined to be 5% of the mean for a 95% confidence interval and z is the reliability coefficient (1.96 which represents the 95% reliability). Based on the equation (1) the number of studied samples for open field and greenhouse tomato production systems were 128 and 16, respectively. The energetic efficiency of the studied systems has been evaluated by the energy ratio between output and input. The amount of seed, chemical fertilizers, cattle manure, pesticides, human labor, water, machinery, diesel oil and output yield (fruit and straw yield) values of tomato production systems have been used to estimate the energy ratio (Alam *et al*., 2005). Energy equivalents shown in Tab. 1 were used for energy ratio estimation. The source of mechanical energy used on the selected open fields and greenhouses included tractors and diesel oil. The mechanical energy was calculated based on total fuel consumption (l ha^{-1}) in different operations. Therefore, the energy consumed was calculated, using conversion factors (one l diesel = 56.31 MJ) and stated in MJ ha^{-1} (Tsatsarelis, 1991). Basic information on energy inputs and tomato yields were transferred into Excel spreadsheets, and analyzed. Based on the energy equivalents of the inputs and outputs (Tab. 1), the energy use efficiency (Eq. 2), the energy productivity (Eq. 3), the specific energy (Eq. 4), the energy intensiveness (Eq. 5) and the net energy (Eq. 6) were calculated (Banaeian *et al*., 2010; Ghorbani *et al*., 2011).

$$\text{Energy use efficiency} = \frac{\mathit{Energy\ output(MJ\,ha^{-1})}}{\mathit{Energy\ input(MJ\,ha^{-1})}} \tag{2}$$

$$\text{Energy productivity} = \frac{\text{crops } \mathit{output(Kg\ ha^{-1})}}{\mathit{Energy\ input(MJ\ ha^{-1})}} \tag{3}$$

$$\text{Specific energy} = \frac{\mathit{Energy}\ \text{inpute}\mathit{(MJ\ ha^{-1})}}{\text{crops } \mathit{output(t\ ha^{-1})}} \tag{4}$$

$$\text{Energy intensiveness} = \frac{\mathit{Energy\ input\ (MJ\ ha^{-1})}}{\text{cost of cultivation } (\$\ \mathit{ha^{-1}})} \tag{5}$$

$$\text{Net energy} = \text{Energy output } (MJ\,ha^{-1})\text{-En. Input } (MJ\,ha^{-1}) \tag{6}$$

Indirect energy included energy embodied in seeds, chemical fertilizers, herbicide (Treflan and Metribuzin), pesticide (Diazinon and Metasystox), fungicide (Mancozeb and Metalaxyl), cattle manure and machinery, while direct energy included human labor, diesel fuel, electricity and water for irrigation used in the tomato production. Non-renewable energy includes diesel fuel, electricity, chemical fertilizers, herbicides, pesticides, fungicides and machinery, and renewable energy comprise of human labor, cattle manure, seeds and water for irrigation.

The economic inputs of tomato production systems were consist of fixed and variable costs. The fixed costs of production were enclosed land value, water value and

Tab. 1. Energy equivalent of inputs and outputs in tomato production

Particulars	Unit	Energy equivalent (MJ unit^{-1})	Ref.
A. Inputs			
1. Human labor	h	1.95	Taylor *et al.*, 1993
2. Machinery	h	62.7	Alam *et al.*, 2005; Singh *et al.*, 2002; Ozkan *et al.*, 2004
3. Diesel fuel	l	50.23	Taylor *et al.*, 1993
4. Chemical fertilizers			
(a) Nitrogen (N)	kg	75.46	Taylor *et al.*, 1993
(b) Phosphate (P_2O_5)	kg	13.07	Taylor *et al.*, 1993
(c) Potassium (K_2O)	kg	11.15	Ozkan *et al.*, 2004; Kousar *et al.*, 2006; Sartori *et al.*, 2005
(d) Sulphur (S)	kg	1.12	Mohammadi *et al.*, 2008
(e) Zinc (Zn)	kg	8.40	Mohammadi *et al.*, 2008
(f) mixed micro nutrients	kg or l	120	Alam *et al.*, 2005
5. Chemicals	kg or l		
(a) Herbicides		238.3	Esengun *et al.*, 2007
(c) Pesticides		101.2	Esengun *et al.*, 2007
(d) Fungicides		181.9	Esengun *et al.*, 2007
6. Cattle manure	kg	0.30	Mohammadi *et al.*, 2008
7. Electricity	kWh	3.6	Singh and Mital, 1992
8. Water for irrigation	m^3	1.02	Ozkan *et al.*, 2004
9. Seeds	kg	1.0	Esengun *et al.*, 2007
B. Outputs			
1. Fruit yield	kg	0.8	Esengun *et al.*, 2007
2. Straw yield	kg	7.5	

properties. The variable costs of production were including current costs such as chemicals, fuel, human labor and electricity. The economic output of tomato production systems was includes tomato fruit. All prices of input and output were market prices (average prices of year 2009). The gross value of production, gross and net returns, total cost of production, benefit to cost ratio and productivity indices were calculated based on equations 7-12, respectively (Banaeian *et al.*, 2010; Mrini *et al.*, 2001).

Gross value of production = tomato yield (kg ha^{-1}) × tomato price (\$ ha^{-1}) (7)

Gross return = gross value of production (\$ ha^{-1})-variable cost of production (\$ ha^{-1}) (8)

Net return = gross value of production (\$ ha^{-1})-total cost of production (\$ ha^{-1}) (9)

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

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

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

Results

Schedules and operations of surveyed systems

Schedules and operations of tomato production systems such as soil tillage, seedbed preparations, planting and harvesting were shown in Tab. 2. Chemicals (including herbicides, pesticides and fungicides) which were sprayed during season of tomato production were 4.3 and 15.9 times in open field and greenhouse production systems, respectively. Irrigated operations were performed on average of 17.1 and 114.3 times in open field and greenhouse systems, respectively. A Massey Ferguson 285-75 hp tractor along with using moldboard plow, disc harrows, and land leveler for open field and just moldboard plow for greenhouse were generally accomplished land preparation and soil tillage. The average farm sizes were 5.6 and 0.095 ha in open field and greenhouse production systems, respectively. About 89.7% of total land in tomato production was seedling transplant and only 10.3% was cultivated as direct seeding.

Energy input in open field and greenhouse tomato production systems

Results indicated that 1102.8 and 27381.3 h of human labor and, 28.9 and 102.8 h of machinery power (tractor and transportation) per hectare were required in open field and greenhouse tomato production systems, respectively. Total energy used in different production processes for produce open field and greenhouse tomato was 47647.1 and 2102678.7 MJ ha^{-1}, respectively (Tab. 3 and 4). Among all production practices in open field system, consumed nitrogen was the most energy consuming input (30.61%), followed by water for irrigation (17.77%), diesel fuel (15.89%) and electricity (12.54) (Tab. 3). In greenhouse tomato production system, the highest energy consumption commodity was diesel fuel (by 93.68% of total energy input), followed by human labor (2.54%) and micro nutrient fertilizers (1.51%) (Tab. 4). Nitrogen fer-

Tab. 2. Management practices for open field and greenhouse tomato production systems

Practices/operations	Open field	Greenhouse
Names of tomato varieties	'Mobil', 'Gina', 'Peto early-CH'	'Nioton', 'Sinda', 'Cherry'
Land preparation tractor used: 285 MF 75 hp,	Moldboard plow, Disc harrows, Land leveler	Moldboard plow
Land preparation period	April	August
Average tilling number	2.8±0.1	1± 0.3
Planting period	May	August
Fertilization period (Before planting)	April	August
Fertilization period (Top dressing)	May-July	September-March
Average number of fertilization	3.6±1.9	17±8.2
Irrigation period	May-October	August-July
Average number of irrigation	17.1±2.3	114.3±14.3
Spraying period	June-August	September-March
Average number of spraying	4.3±1.5	15.9±8.1
Harvesting period	September-October	October –July
Average number of harvesting	2.8±1.1	44.5±3.1

tilizer and diesel fuel energies were mainly utilized for fertilization and machinery in open field, respectively, while in greenhouse system diesel fuel energy was mainly used for heating system. The share of each energy input of total inputs for tomato production systems was shown in Tab. 5.

Energy output in open field and greenhouse tomato production systems

Average fruit yield and straw yield in open field and greenhouse tomato production systems were 57643 *vs.* 318001 kg ha^{-1} and 2882 *vs.* 15900 kg ha^{-1}, respectively. Total energy output per hectare was 67729.3 MJ ha^{-1} in open field and 373650.0 MJ ha^{-1} in greenhouse. Output-input energy ratio in open field and greenhouse systems was 1.42 and 0.18, respectively. Energy use efficiency in open field was almost 7.9 times more than greenhouse system that could be due to using more input energy in greenhouse system.

Energetic of producing tomato

The total energy input consumed could be classified as direct (50.72% *vs.* 97.04%), indirect (49.28% vs. 2.96%), renewable (30.76% *vs.* 3.00%) and non-renewable (69.24% *vs.* 97.00%) energy in open field and greenhouse production systems, respectively (Tab. 6). Total energy input used in open field was 97.7% lower than greenhouse produc-

Tab. 3. Energy consumption and energy input-output relationship on open field tomato production system

Energy	Quantity per unit area (ha)	Energy equivalent (MJ unit^{-1})	Total energy equivalent (MJ)	Percentage of total energy input (%)
Input				
Human labor (h)	1102.85	1.95	2150.56	4.51
Machinery (h)	28.95	62.70	1815.02	3.81
Diesel fuel (l)	150.75	50.23	7572.17	15.89
Nitrogen (kg)	193.29	75.46	14585.48	30.61
Phosphate (P_2O_5) (kg)	102.68	13.07	1342.01	2.82
Potassium (K_2O) (kg)	37.62	11.15	419.45	0.88
Cattle manure (kg)	13464.5	0.3	4039.20	8.48
Micro nutrients (kg or l)	4.70	120	558.57	1.17
Herbicides (kg or l)	1.03	238.32	244.52	0.51
Pesticides (l)	1.45	199	289.02	0.61
Fungicide (kg or l)	2.05	92.01	188.38	0.40
Electricity (kWh)	1660	3.60	5976.0	12.54
Water for irrigation (m^3)	8300	1.02	8666.0	17.77
Seeds (kg)	0.74	1.00	0.74	0.002
Total energy input (MJ)			47647.12	100.00
Outputs				
Fruit yield (kg)	57642.86	0.80	46114.29	68.09
Straw yield (kg)	2882.4	7.5	21615.20	31.91
Total energy output (MJ)			67729.29	
Energy efficiency			1.42	

Tab. 4. Energy consumption and energy input-output relationship on greenhouse tomato production

Energy	Quantity per unit area (ha)	Energy equivalent (MJ unit^{-1})	Total energy equivalent (MJ)	Percentage of total energy input (%)
Input				
Human labor (h)	27381.3	1.95	53393.54	2.54
Machinery (h)	102.80	62.70	6445.56	0.31
Diesel fuel (l)	39216.80	50.23	1969859.86	93.68
Nitrogen (kg)	117.62	75.46	8875.76	0.42
Phosphate (P_2O_5) (kg)	76.68	13.07	1002.23	0.05
Sulphur (S) (kg)	310.16	1.12	347.38	0.02
Cattle manure (kg)	12800.00	0.3	3840.00	0.18
Micro nutrients (kg or l)	264.9	120	31788.00	1.51
Herbicides (kg or l)	0.00	238.30	0.00	0.00
Pesticide (l)	4.80	199.00	8119.20	0.39
Fungicide (kg or l)	20.40	92.00	1876.80	0.09
Electricity (kWh)	3120	3.60	11232.00	0.53
Water for irrigation (m^3)	5782.50	1.02	5898.15	0.28
Seed (kg)	0.25	1.00	0.25	0.001
Total energy input (MJ)			2102678.73	100.00
Outputs				
Fruit yield (kg)	318000.5	0.80	254400.00	68.09
Straw yield (kg)	15900	7.50	119250.00	31.91
Total energy output (MJ)			373650.00	
Energy efficiency			0.18	

tion system. In other words, total input energy required in open field tomato production was 2.3% of greenhouse system. The share of indirect and non-renewable energy input was higher than direct and renewable energy in both studied systems (Tab. 6).

Productivity and specific energy in open field and greenhouse systems

Energy input and output, energy use efficiency, energy intensiveness, specific energy, energy productivity and net energy of tomato production systems were summarized in Tab. 7. The energy use efficiency was achieved as 1.42 in open field and 0.18 in greenhouse tomato production systems. The energy intensiveness was calculated as 12.40 in open field and 32.49 MJ $$^{-1}$ in greenhouse systems. Average energy productivity of open field and greenhouse were 1.21 and 0.15 kg MJ^{-1}, respectively. This means that 1.21 and 0.15 outputs were obtained per unit energy consumed in open field and greenhouse systems. The specific energy was 0.83 and 6.61 MJ kg^{-1} in open field and greenhouse systems, respectively. In other word, net energy was 20082.16 and -1729028.73 MJ ha^{-1} in open field and greenhouse tomato production systems, respectively.

Economical indices in tomato production systems

The production cost and gross product values of both studied systems are shown in Tab. 8. In the open field and greenhouse tomato production systems the gross value of production were 8940.3 and 197893.7 $ ha^{-1}, respectively. The variable and fixed costs of tomato production in open field were 2387.4 and 1455.2 $ ha^{-1} and in greenhouse sys-

Tab. 5. Input contributions (%) in tomato production in open field and greenhouse systems

Items	Open field	Greenhouse
Diesel fuel	15.89	93.68
Human labor	4.51	2.54
Fertilizers	35.48	2.00
Chemicals	1.52	0.47
Cattle manure	8.48	0.20
Electricity	12.54	0.53
Machinery	3.81	0.31
Water for irrigation	17.77	0.30

Tab. 6. Total energy input in the form of direct, indirect, renewable energy for open field and greenhouse tomato production systems

Type of energy	Open field		Greenhouse	
	(MJ ha^{-1})	% [a]	(MJ ha^{-1})	%
Direct energy [b]	24164.73	50.72	2040383.55	97.04
Indirect energy [c]	23482.39	49.28	62295.18	2.96
Renewable energy [d]	14656.50	30.76	63131.94	3.00
Non-renewable energy [e]	32990.63	69.24	2039546.79	97.00
Total energy input	47647.12		2102678.73	

a: Indicate percentage of total energy input; b: Indicates human labor, diesel fuel, electricity and water for irrigation; c: Indicates seeds, cattle manure, chemical fertilizers, herbicides, pesticides, fungicides and machinery; d: Indicates human l abor, seeds, water for irrigation and cattle manure; e: Indicates diesel, electricity, chemical fertilizers, herbicides, pesticides, fungicides and machinery

Tab. 7. Tomato production energy indices in open field and greenhouse systems

Items	Unit	Open field	Greenhouse
Energy input	MJ ha^{-1}	47647.12	2102678.73
Energy output	MJ ha^{-1}	*67729.29*	373650.00
Energy use efficiency	-	1.42	0.18
Energy intensiveness	MJ \$$^{-1}$	12.40	32.49
Specific energy	MJ kg^{-1}	0.83	6.61
Energy productivity	kg MJ^{-1}	1.21	0.15
Net energy	MJ ha^{-1}	20082.16	-1729028.73

tem were 33939.8 and 30773.4 \$ ha^{-1}, respectively. The total costs of production per hectare in open field (3842.7 \$ ha^{-1}) were lower than greenhouse system (64713.2 \$ ha^{-1}). The total costs of production in greenhouse system were 94.1% higher than the open field system. The gross return and net return per hectare in open field production system (6552.9 and 5097.6 \$ ha^{-1}, respectively) were considerably lower than greenhouse production system (163953.9 and 133180.5 \$ ha^{-1}, respectively). In other word, the gross and net return in open field system was 25 and 26 times lower than greenhouse system, respectively. Benefit to cost ratio in greenhouse (3.06) was higher than open field system (2.33). Productivity expressed by kg \$$^{-1}$ that means each US dollar expending in tomato production how much product is produced. In this study productivity was 15.00 and 4.91 kg \$$^{-1}$ for open field and greenhouse systems.

Discussion

Energy requirements and input-output relationships in tomato open field and greenhouse production systems

The present results showed that total energy input used in open field production system was 47647.1 MJ ha^{-1}, which was about 44 times lower than that of greenhouse production system (2102678.7 MJ ha^{-1}). The main reason resulting in too much energy use for greenhouse tomato production was diesel fuel consumption. Also the amount of energy used in different agricultural practices such as machinery, irrigation, electricity, chemicals and fertilizers in greenhouse production system was higher than those of open field system. However, the share of energy use of total energy for fertilizers, electricity, irrigation water, chemicals, machinery and labor were higher in open field production system. Cetin and Vardar (2008) reported that open field tomato consumed total of 45530 MJ ha^{-1}, and share of diesel energy was 34.8% followed by fertilizer and machinery energy. In addition, Ozkan *et al.* (2004a) indicated that total energy input was 127320 MJ ha^{-1} for tomato greenhouse production system in Turkey, which was substantially lower than present study. It seems the differences mostly were due to higher consumption of diesel fuel for heating in the studied greenhouse tomato production systems compared with Turkey.

Tomato yield in open field was 5.5 times (57643 *vs.* 318001 kg ha^{-1}) lower than that in greenhouse system. While the energy output–input ratio was higher in open field compared with greenhouse systems (1.42 *vs.* 0.18). Cetin and Vardar (2008) stated that energy output–input ratio in open field tomato production system was 0.80 in Turkey. The energy ratio of 0.79 and 0.72 were reported by Bayramoglu and Gundogmuse (2009) on EurepGAP certified and uncertified tomato greenhouses, respectively. Mohammadi and Omid (2010) stated that the total energy input and energy use efficiency in cucumber greenhouse production were 148836.76 MJ ha^{-1} and 0.64, respectively. They added that diesel fuel (with 41.94%) and chemical fertilizers (with 19.69%) were the highest energy inputs for greenhouse cucumber production. Ghorbani *et al.* (2011) reported that the total energy requirement were 9354.2 and 45367.6 MJ ha^{-1} in low and high input wheat production systems, respectively, and energy ratios in low and high input wheat production systems were 3.38 and 1.44, respectively.

Results indicated that 24164.73 MJ ha^{-1} of the total energy input used was direct energy in open field tomato production system, which was 2019219 MJ ha^{-1} lower than that of greenhouse tomato production system. In other word, the share of direct energy used in greenhouse system was 47% higher than open field system. The share of renewable energy used in investigated systems was lower than non-renewable energy. Renewable energy in open field was higher than greenhouse systems. It is necessary to reduction the share of non-renewable energy for achieves to high energy efficiency in tomato production systems. It seems that reduction the share of diesel fuel and fertilizer (mainly nitrogen) can play a major role in enhancement of energy use efficiency. Reducing diesel fuel by changing tillage systems, harvesting methods and other field operations can help to improve energy efficiency. It seems

Tab. 8. Economic analysis of tomato production in open field and greenhouse systems

Cost and return components	Open field (value)	Greenhouse (value)
Fruit yield (kg ha^{-1})	57642.86	318000.00
Sale price (\$ kg^{-1})	0.16	0.62
Gross value of production (\$ ha^{-1})	8940.30	197893.73
Variable cost of production (\$ ha^{-1})	2387.44	33939.80
Fixed cost of production (\$ ha^{-1})	1455.24	30773.44
Total cost of production (\$ ha^{-1})	3842.68	64713.24
Total cost of production (\$ kg^{-1})	0.06	0.17
Total cost production (\$ MJ^{-1})	0.06	0.09
Gross return (\$ ha^{-1})	6552.86	163953.92
Gross return (\$ kg^{-1})	0.11	0.43
Gross return (\$ MJ^{-1})	0.10	0.22
Net return (\$ ha^{-1})	5097.62	133180.49
Net return (\$ kg^{-1})	0.08	0.35
Net return (\$ MJ^{-1})	0.08	0.18
Benefit to cost ratio	2.33	3.06
Productivity (kg \$$^{-1}$)	15.00	4.91

that alteration in heating systems lead to decrease diesel fuel consumption and increase energy use efficiency in the greenhouse system. Hatirli *et al.* (2006) reported that the shares of direct and indirect input energy were 59% and 41% and non-renewable and renewable energy were 88% and 12% in greenhouse tomato production systems, respectively. It is clear that the proportion of non-renewable energy used in studied greenhouse tomato production systems was very high. This result indicates that the greenhouse tomato production depends mainly on fossil fuels in studied area. The improvement of agricultural systems need low inputs of fossil energy while maintaining high output of food which, would help to reduce agricultural carbon dioxide emissions (Rathke and Diepenbrock, 2006). Using direct and local marketing improves profitability for farmers while leading to reduction energy required for their transport.

Net energy was 20082.2 and -172928.7 MJ ha^{-1} in open field and greenhouse systems, respectively. High negative value for net energy gain in greenhouse was due to traditional structure, low level technology of ventilation such as high consumption of diesel motors for heaters, lack of thermostat controller in suitable place of greenhouse that make this negative value, reasonable (Banaeian *et al.*, 2010). High fuel consumption partly is due to high diesel fuel subsidization by government; therefore, greenhouse holders do not care on amount of fuel which is used in their production systems. It has been reported similar patterns in term of diesel fuel consumption for cucumber and strawberry production in Iran (Banaeian *et al.,* 2010; Mohammadi and Omid, 2010).

Economical analysis in tomato production systems

The total cost of inputs in greenhouse tomato production system was higher due to high variable and fixed cost of production compared with open field tomato production systems. The share of variable cost was higher than fixed cost of production in greenhouse and open field tomato production systems. Among of variable cost of production, the labor wage paid was the highest value in both studied systems. In addition, construction cost of greenhouse is one of the main parts of fixed cost of production. Mohammadi and Omid (2010) calculated variable and fixed costs of greenhouse cucumber by 61% and 39% of the total cost of production, respectively.

The gross, net return and benefit to cost ratio based on land area (ha) in open field (6552.86 $, 5097.62 $ and 2.33, respectively) were lower than greenhouse tomato production system. This is considerably due to high price of tomato fruit in greenhouse than open field tomato production system. The higher price of greenhouse tomato is due to lack of tomato in autumn and winter seasons. Moreover, total cost of production in greenhouse was higher than open field due to intensive use of fuel energy. Banaeian *et al.* (2010) reported that the benefit to cost ratio and net return for greenhouse strawberry were as 1.74 and 151907.91 $ ha^{-1}, respectively. Agriculture section uses commercial energies directly and indirectly such as seed, manure, diesel fuel, electricity, fertilizer, chemicals, irrigation water and machinery. Optimum energy use in agriculture can be improved via an increase in productivity with the existing level of energy inputs and preserved energy without affecting the productivity. Efficient use of these inputs helps to attain improved production and productivity and contribute to economy, profitability and competitiveness of agriculture (Singh *et al*., 2002).

Conclusions

The results indicated that diesel fuel, water for irrigation, fertilizers, machinery and electricity energies contributed the major portion of the energy inputs used in tomato production systems. Total energy used in the greenhouse was higher than open field system, while, with the exception of diesel fuel, share of other inputs in the open field systems were lower than greenhouse systems. In the greenhouse, high consumption of diesel fuel was due to intensive use of diesel fuel for heating system. This was partly because of traditional greenhouse systems. In terms of energy use efficiency, open field tomato production system reflected more than 7.9 times higher than greenhouse system, resulting in a growing trend towards higher sustainability. In addition, diesel fuel and nitrogen fertilizer inputs were the most effective factors affected on energy use efficiency in greenhouse and open field systems, respectively. Therefore, decreasing of consumption of these inputs can lead to increase energy use efficiency in tomato production systems in Iran.

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