An analysis of energy use, input costs and relation between energy inputs and yield of apple orchard

R. Fadavi, A. Keyhani, S.S. Mohtasebi

Department of Agricultural Machinery Engineering, Faculty of Agricultural Engineering and Technology, University of Tehran, Karaj, Iran

Abstract

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This study examines the energy balance between the input and the output per hectare for an apple orchard in the West Azarbaijan province in Iran (2008–2009). Data were collected by using random sampling method for 80 "face to face" questioners. Results showed that the highest share of energy consumption belongs to packaging (57%) and irrigation (16%). The highest share of expenses was found to be 34% and 30% for labor and packaging, respectively. The total energy input for apple production, energy productivity, net energy and output-input energy value were estimated as 101,505 MJ/ha, 0.23 kg/MJ, –56,320 MJ/ha and 0.44, respectively. Results indicated that 71% and 96.7% of total energy input were in indirect and non-renewable form, respectively. The benefit-cost ratio was estimated as 1.77. The regression results revealed that all exogenous variables (for machinery, fertilizers, farmyard manure and packaging energies) were found statistically significant. The packaging had the highest impact (3.23). According to the benefit-cost ratio, large farms were more successful in economic performance.

Keywords: energy; economic productivity; apple; packaging

Apple is one of the most important fruits in the world. In Iran, apple (Delicious and Golden varieties) is mostly cultivated in the West Azarbaijan province. Also, the Oromieh Township is the leading apple producer in this province (Anonymous 2005). Based on the Food and Agriculture Organization (FAO) China, United States, Poland and Iran are the main apple producing countries in the world, respectively (Anonymous 2008a).

Energy use in agriculture was developed in response to increasing populations, limited supply of arable land and a desire for higher standards of living. More intensive energy use of fossil fuel, chemical fertilizers, pesticides, machinery and electricity brought some important human health and environmental problems. Thus, efficient use of energy inputs is of prompt importance in terms of sustainable farming. Energy requirements in agriculture are divided into two groups: direct and indirect. Direct energy is required to perform various tasks related to crop production processes such as land preparation, irrigation, intercultural operation, threshing, harvesting and transportation of agricultural inputs and farm production (Singh 2000). Indirect energy consists of the energy used in the manufacture, packaging and transport of fertilizers, pesticides and farm machinery (CAEEDAC 2000; Kennedy 2000).

An input-output energy analysis provides farm planners and policy makers an opportunity to evaluate economic intersection of energy use (Ozkan et al. 2004a). Considerable research studies were conducted on energy use in agriculture, however, relatively little attention was paid to apple production.

Strapatsa et al. (2006), determined the amount of energy consumption from which one kilogram of apples is produced along with energy indices in apple production in Greece. Hasanzadeh and Rahbar (2005) studied energy use for apple production in Iran. For correct utilization of inputs in an agricultural system, a solution is to determine the best production function. In agriculture, many production functions are developed from which the Cobb-Douglas production function was shown to be efficient. Hatirli et al. (2006), investigated energy inputs and crop yield relationship to develop and estimate an econometric model for greenhouse tomato production in Turkey. Furthermore, this study considered the effect of farm size on energy use and input costs. Yilmaz et al. (2005) reported that large farms are more successful in energy productivity, energy use efficiency and economic performance.

The aims of this study were to determine input-output energy use in apple production to investigate the efficiency of energy consumption and to make an economic analysis. The study also sought to analyze the effect of farm size on energy use and input costs based on apple orchards and to reveal the relationship between energy inputs and yield by developing mathematical models in the Oromieh Township in Iran.

MATERIAL AND METHODS

The West Azarbaijan province is located in the northwestern Iran. The average annual rainfall is 300–400 mm with average high and low annual temperatures of 19.4°C and 6.7°C, respectively (Anonymous 2007).

Data were collected from apple orchard's holder in the Oromieh Township by using a "face to face" questionnaire and a stratified random sampling technique in 2008. For estimating the size of required sample Neyman technique (Yamane 1967) as Eq. (1) is used that statistical sample method was executed by 80 orchards:

$$n = \frac{\sum N_h S_h}{N^2 D^2 + \sum N_h S_h^2} \quad (1)$$

where:

n – required sample size

N – number of holdings in target population

N_h – number of the population in the h stratification

S_h – standard deviation in the h stratification

S_h^2 – variance of h stratification

d – precision where (x–X) or mid-confidence interval

z – reliability coefficient (1.96, which represents the 95% confidence interval)

D^2 – d^2/z^2

The permissible error in the sample size was defined to be 5% for 95% confidence, sample size was calculated as 80 orchards. Based on the energy equivalents of the inputs and outputs (Table 1), the metabolisable energy was calculated. Energy ratio (energy use efficiency) and energy productivity were calculated as Eq. (2) and Eq. (3) (Mandal et al. 2002):

$$\text{Output-input ratio (ER)} = \text{Energy output (MJ/ha)} / \text{Energy input (MJ/ha)} \quad (2)$$

$$\text{Energy productivity (EP)} = \text{Total output (kg/ha)} / \text{Energy input (MJ/ha)} \quad (3)$$

In this study, energy embodied in pesticides, fertilizers, manure, packaging, machinery and refrigerating were considered as indirect energies while human energy, diesel and electricity were taken as direct form of energies. Also, non-renewable energies were considered as all input energies (except human energy and farmyard manure) while human energy and farmyard manure were considered as renewable energies.

The output/input analysis was also applied in economic benefits analysis. The process was similar with energy balance analysis. The economic (or energy) inputs of this system include costs of human labor, chemical fertilizers, chemicals biocides, packaging, transportation, refrigerating, fixed costs and agricultural machinery. The economic (or energy) outputs of this system include main and secondary yields.

In the literature, Cobb-Douglas function was used by several authors to examine the relationship between energy inputs and production or yield (Singh et al. 1998, 2002), Cobb-Douglas function yielded better estimates in terms of statistical significance and expected signs of parameters among linear, linear logarithmic and second degree polynomial functions. All estimations were carried out using the Eviews software (SHAZAM Analytics Ltd., London, UK) and MS Excel program, Cobb-Douglas production function is expressed as Eq. (4):

$$\ln Y_i = a + \sum_{j=1}^{n} b_j \times \ln(x_{ij}) + e_i \times i = 1,2,3,.....80 \quad (4)$$

Table 1. Energy equivalents of inputs-output in agricultural production

Inputs (unit)	Energy equivalent (MJ/unit)	Reference
1. Chemical fertilizers (kg)		
(a) Nitrogen	78.1 MJ/kg	Kitani (1999)
(b) Phosphate (P_2O_5)	17.4 MJ/kg	Kitani (1999)
(c) Potassium (K_2O)	13.7 MJ/kg	Kitani (1999)
(d) Microelements	120 MJ/kg	Mandal et al. (2002)
2. Farmyard manure (kg)	0.0303 MJ/kg	Demircan et al. (2006)
3. Chemical biocides (kg)	199 MJ/kg	Ozkan et al. (2004b)
4. Diesel fuel (l)	47.8 MJ/l	Kitani (1999)
5. Electricity (kWh)	12 MJ/kWh	Kitani (1999)
6. Wood (packaging) (kg dry mass)	18 MJ/kg	Singh, Mittal (1992)
7. Transportation (t km)	2.6 MJ/t km	Kitani (1999)
8. Tractor (kg)	138 MJ/kg	Kitani (1999)
9. Sprayer (fertilizer) (kg)	129 MJ/kg	Kitani (1999)
10. Disk harrow (kg)	149 MJ/kg	Kitani (1999)
11. Human labor (h)	0.27 MJ/h	Kitani (1999)
12. Apple (kg)	1.9 MJ/kg	Singh, Mittal (1992)
13. Refrigerating (t day)	1.15 MJ/t day	Anonymous (2008b)

where:
Y_i – denotes the yield level of the i^{th} farmer
x_{ij} – vector inputs used in the production process
a – constant term
b_j – represents coefficients of inputs which are estimated from the model
e_i – the error term

In this study, it is assumed that if there is no input energy, the output energy is also zero. The same assumption was also made by Singh et al. (2003). Making this assumption excludes the constant term from Eq. (5), and the equation reduces to:

$$\ln Y_i = \sum_{j=1}^{n} b_j \times \ln(x_{ij}) + e_i \quad (5)$$

In addition to the influence of each variable on the yield level, the impact of direct, indirect, renewable and non-renewable energies on yield was also investigated. For this purpose, Cobb-Douglas function was specified in the following form Eq. (6) and Eq. (7):

$$\ln Y_i = c_1 \times \ln DE + c_2 \times \ln IDE + e_i \quad (6)$$

where:
Y_i – i^{th} farm's energy output
DE – direct energy used
IDE – indirect energy used for apple orchard production
c_i – coefficient of exogenous variables

$$\ln Y_i = d_1 \times \ln RE + d_2 \times \ln NRE + e_i \quad (7)$$

where:
Y_i – i^{th} farm's energy output
RE – renewable energy used
NRE – non-renewable energy used for apple production
d_i – coefficient of exogenous variables

RESULTS AND DISCUSSION

Economic analysis of apple production

The costs of each input and gross production values calculated in apple production are given in Table 2. The gross value of production (13,873 $/ha) was found by multiplying the apple yield (19,447 kg/ha, 4,335 kg/ha) to their corresponding prices (0.7 $/kg, 0.06 $/kg) and summing the results. The total mean expenditure for the production was 7,816 $/ha, where 92.2% was the share of variable costs, whereas 7.8% was fixed expenditures. Several studies reported that the ratio of variable cost was higher than that of fixed cost in cropping systems (Esengun et al. 2007; Çetin, Vardar 2008; Mohammadi et al.

Table 2. Economic analysis of apple production

Cost and return components	Value
Yield (main) (kg/ha)	19,447
Sale price (main) ($/kg)	0.7
Yield (secondary) (kg/ha)	4,335
Sale price (secondary) ($/kg)	0.06
Gross value of production ($/ha)	13,873
Variable cost of production ($/ha)	7,200
Fixed cost of production ($/ha)	616
Total cost of production ($/ha)	7,816
Total cost of production (only main) ($/kg)	0.4
Total cost of production (main and secondary) ($/kg)	0.33
Gross return ($/ha)	6,673
Net return ($/ha)	6,057
Benefit to cost ratio (–)	1.8
Productivity (only main) (kg/$)	2.5
Productivity (main and secondary) (kg/$)	3

2008). The benefit-cost ratio from apple production in the surveyed orchards was calculated to be 1.8. The research results were consistent with the findings reported by other researchers for other orchard crops, such as 2.37 for orange, 1.89 for lemon and 1.88 for mandarin (Ozkan et al. 2004b). The gross return (6,673 $/ha) was calculated by subtracting the variable cost of production per hectare (7,200 $/ha) from the gross value of production (13,873 $/ha). The productivity (2.5 kg/$) was obtained by dividing apple yield (19,447 kg/ha) by total production costs (7,816 $/ha).

Table 3 shows that of all the inputs, the human labor expenses have the biggest share of 34%. Labor expenses share for harvesting (43%), irrigation (21.7%), pruning (21.5%), fertilization (8.8%), sprayer (3%) and plotting (2%) operation were found. Almost in all surveyed orchards, most operations were performed by human labor, due to lack of machineries suitable for long-legged trees. Also, some farmers were concerned about the soil compaction resulting from machinery traffic.

Packaging (30%) and refrigerating (19%) expenses are followed by the fixed costs (7.8%). Results revealed that harvesting and postharvest operations are the most important expenses with (65.6%). Due to low mechanization level in apple orchard, human energy is accounted for 34% and that of machineries for 1% of total costs, data concerning the percentage of the costs are presented in Table 3, the results showed that the cost of material of chemical fertilizers and biocides is calculated as 74 and 152 $/ha, respectively, which is significantly lower in comparison with other conditions and crops.

Analysis of input-output energy use in apple production

The yield in apple orchard is generally carried out by human labor energy in the research area and the number of large orchard holdings using modern technology is very limited. The average size in the surveyed orchards was found to be 1.2 ha with a range from 0.1 up to 5 ha. Machine power was used only for sprayer (in all orchards), and fertilizing and plotting (in few orchards) due to the fact that most apple orchards are designed in a conventional way in which machinery traffic is really limited. The energy consumption and its sources for apple production are presented in Table 4.

As can be seen from Table 4, the total energy used in various farm inputs is 101,505 MJ/ha. The last column in Table 4 gives the percentage share of each input from the total energy inputs. Of all the inputs, wood packaging has the largest share (57%), apples are packaged with wood because owners of apple orchards believe that wooden boxes store more power than plastics or other types of packing boxes. Packaging energy is followed by the irrigation energy (16%), based on duration of irrigation (5–24 h for one ha); irrigation methods were conventional or semi-mech-

Table 3. Input costs in apple production

Inputs	Value	%
Machinery ($/ha)	73	1
Farmyard manure ($/ha)	150	2
Chemical fertilizers ($/ha)	74	1
Chemical biocides ($/ha)	152	2
Irrigation ($/ha)	154	2
Wood packaging ($/ha)	2,335	30
Transportation ($/ha)	150	2
Refrigerating ($/ha)	1,455	19
Human labor ($/ha)	2,657	34
Fixed cost ($/ha)	616	7
Total cost of production	7,816	

Table 4. Amounts of inputs-output energy in apple production

Inputs (unit)	Total energy equivalent (MJ/ha)	Apple	%
A. Inputs			
Nitrogen (kg)	7,105		7
Phosphate (P_2O_5) (kg)	1,015		1
Potassium (K_2O) (kg)	710		0.7
Microelements (kg)	305		0.3
Water for irrigation (m^3)	16,241		16
Chemical biocides (kg)	2,030		2
Wood packaging (kg)	57,858		57
Refrigerating (t day)	2,030		2
Diesel fuel (l)	10,151		10
Human labor (h)	3,045		3
Transportation (t km) + Farmyard manure (kg) + Machinery (h)	1,015		1
Total energy input (MJ)	101,505		100
B. Outputs			
Yield (main) (kg)	19,447		
Yield (secondary) (kg)	4,335		
Yield (main and secondary) (kg)	23,782		
Output energy (main) (MJ)	36,949		
Total energy output (main and secondary) (MJ)	45,185		
C. Items			
Energy use efficiency (main)		0.36	
Energy productivity (main) (kg/MJ)		0.19	
Net energy (main) (MJ/ha)		–64,556	
Energy use efficiency (main and secondary)		0.44	
Energy productivity (main and secondary)		0.23	
Net energy (main and secondary)		–56,320	
Direct energy[a] (MJ/ha)		29,437	29
Indirect energy[b] (MJ/ha)		72,068	71
Renewable energy[c] (MJ/ha)		3,350	3.3
Non-renewable energy[d] (MJ/ha)		98,155	96.7
Total energy input (MJ/ha)			100

[a]Includes human labor, diesel, irrigation; [b]Includes fertilizers, manure, machinery, biocides, packaging and refrigerating; [c]Includes human labor, manure; [d]Includes all input energies (except human energy and farmyard manure)

anized (mostly with electric pump and conventional), an apple orchard is irrigated eight to ten times a year. The diesel energy was mainly utilized for operating tractors, [mostly Massey Ferguson (MF) and Goldoni] fuel consumption of Goldoni type is less than that of MF, in spite of being conventional, diesel energy was accounted for 10% of total energy inputs.

The total energy equivalent of chemical fertilizers consumption placed fourth among the energy inputs and constituted (9%) of the total energy

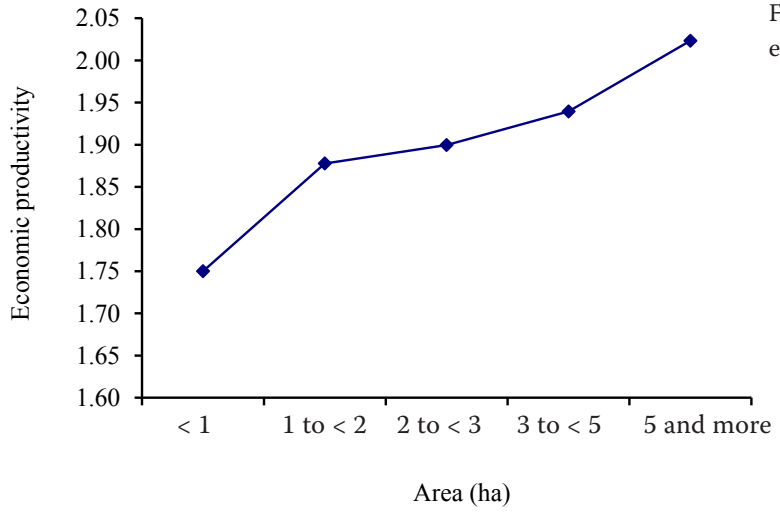

Fig. 1. The relationship between farm size and economic productivity

input, and nitrogen (7%) was in the first place followed by phosphate (1%), potassium (0.7%) and microelements (0.3%). The most frequently used fertilizer is farmyard manure and in some orchards chemical fertilizers are not even used because of soil structure and soil nutrients preservation. The contribution of transportation, farmyard manure and machinery energy remained at low level of 1% (in total) as indirect energy inputs. Hasanzadeh and Rahbar (2005), reported that the most energy consuming input for apple production in the West Azarbaijan province was that for irrigation, nitrogen chemical fertilizing and chemical biocides, respectively. Fadavi et al. (2010), reported that by increasing mechanization index only, energy consumption will not decrease necessarily, and suggested that management of inputs consumption is more important.

Strapatsa et al. (2006), calculated that the most energy inputs for orchard apple production in Greece were fuel (33%), machinery (25%) and fertilizers (15%) (mainly N) (where orchards were irrigated one or two times a year); in all studies sites, postharvest operations were not included.

The energy use efficiency, energy productivity and net energy of apple production in the Oromieh Township are tabulated in Table 4. Energy use efficiency (energy ratio) was calculated as 0.36 and varied from 0.23–0.52 in the sampled orchard holdings, showing the inefficient use of energy in the orchard apple production. It is noteworthy that the ratio can be increased by increasing the crop yield (energy equivalent of apple is relatively low) and/or by decreasing energy inputs consumption (input management). Similar results were reported for different orchard plants such as 0.96 for cherry (Kizilaslan 2009) and 0.97 for apple (Hasanzadeh, Rahbar 2005), some higher energy ratios were reported such as 1.00 for apple (Strapatsa et al. 2006) and 3.37 for apricot (Gezer et al. 2003) in the literature.

The results indicate that energy productivity and net energy were 0.19 kg/MJ and –64,556 MJ/ha, respectively. This means that 0.19 units output was obtained per unit energy. Calculation of energy productivity is well documented in the literature for different crops such as soybean (0.18) (De et al. 2001), potato (0.35) (Mohammadi et al. 2008) and cherry (0.51) (Kizilaslan 2009). The calculated net energy is negative (less than zero) implying that in apple production, energy was lost. Results showed that economic productivity is better than energy productivity, which means that only economic issue is more important for farmers in the region. This is something that governments should take into consideration, and take some steps such as managing for agricultural inputs, training farmers, introducing newer technologies, etc., to make the task beneficial both from economical and energetic points of view.

The results revealed that the share of human energy and human expenses were 3% of total energy and 34% of total expenses, respectively (human energy is valuable energy). Strapatsa et al. (2006), estimated human energy as 2.7% of total input energy. Postharvesting (41%), fertilization (35%), plotting (13%), irrigating (9%) and spraying (2%) operations also accounted for most of energy inputs. Table 4 showed that the share of direct input energy (29%) was much lower compared to that of indirect energy (71%). Also, non-renewable and renewable energies contributed to 96.7% and 3.3% of the total energy input, respectively (this is a serious threat for environment). Several researchers found that the ratio of direct energy was higher (low-

Table 5. Econometric estimation results of energy inputs

Endogenous variable: yield	Coefficient	*t*-ratio
Exogenous variables		
Model 1: $\ln Y_i = b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + b_7 \ln X_7 + b_8 \ln X_8 + b_9 \ln X_9 + b_{10} \ln X_{10}$		
1. Labor energy	0.053	0.75
2. Machinery energy	0.61	4.68**
3. Chemical fertilizers energy	0.11	2.59*
4. Farmyard manure energy	0.59	3.61**
5. Chemical biocides energy	–0.29	–0.231
6. Irrigation energy	0.22	0.494
7. Packaging energy	3.23	7.82**
8. Transportation energy	0.03	0.3
9. Refrigerating energy	0.044	0.6
10. Diesel fuel energy	–0.076	–1.56
Durbin-Watson	1.83	
R^2	0.80	

* and ** indicate significance at 5% and 1% probability level, respectively

er) than that of indirect energy, and the rate of non-renewable energy was greater than that of renewable energy consumption in cropping systems (Esengun et al. 2007; Ozkan et al. 2007; Kizilaslan 2009). Results revealed that operations are carried out mostly by human energy and their share is insignificant in energy consumption compared to other inputs.

It is also useful to investigate the relationship between farm size and economic productivity and energy ratio in order to determine the efficiency of holdings (Fig. 1) as energy ratio is calculated as less than one in all apple orchards, effect of area on energy ratio was not considered. From Fig. 1, it can be concluded that large size orchard holdings have a high economic productivity than smaller size holdings. As indicated previously, the average orchard size is 1.2 ha in the research area. Therefore, the larger holdings might have their advantages of using sufficient, better management, quality inputs and output and higher level of technology due to their more favourable economical outcome. Furthermore, secondary tonnage of small orchards is more than that in larger orchards due to poorer management of inputs. According to Çetin and Vardar (2008), the benefit-cost ratio in larger farms was more successful from energy use and economic performance points of views.

Econometric model estimation of apple production

Relation between the energy inputs and yield was estimated using Cobb-Douglas production function for apple orchards. Apple yield was assumed to be a function of human labor, machinery, chemical fertilizers, farmyard manure, chemical biocides, irrigation, packaging, transportation, refrigerating and diesel fuel energies. Prior to model estimation, autocorrelation was tested using the Durbin-Watson test (Hatirli et al. 2005) for the data used in this study. This test result revealed that Durbin-Watson value was determined as 1.83 for Eq. (5), 2.06 for Eq. (6), and 1.86 for Eq (7). Hence, there was no autocorrelation at the 5% significance level in the estimated models. The coefficient of determination (R^2) was found to be 0.80 (all energy inputs), 0.78 (direct and indirect energies) and 0.76 (renewable and non-renewable energies) for these models. Regression results for this equation are shown in Table 5. The elasticity estimates are particularly useful for determining the relationship between input energy and yield. Since Cobb-Douglas function was used in the estimation, the coefficient of variables in log form also represents elasticity. Packaging energy was found as the most important variable that influences yield. The elasticity for packaging energy is 3.23, implying that a given 1% change in packaging energy will result in 3.23% increase in

Table 6. Econometric estimation results of direct, indirect, renewable and non-renewable energies

Endogenous variable: yield	Coefficient	*t*-ratio
Exogenous variables: inputs		
Model 2: $\ln Y_i = c_1 \ln DE + c_2 \ln IDE + e_i$		
Direct energy	0.038	0.36
Indirect energy	2.33	5.3**
Durbin-Watson	2.06	
R^2	0.78	
Model 3: $\ln Y_i = d_1 \ln RE + d_2 \ln NRE + e_i$		
Renewable energy	–0.102	–0.85
Non-renewable energy	1.573	4.74**
Durbin-Watson	1.86	
R^2	0.76	

* and ** indicate significance at 5% level and 1% level, respectively

yield. The second important input was found as machinery with 0.61 elasticity. Other important variables that influence apple yield are farmyard manure and chemical fertilizer with elasticities of 0.59 and 0.107, respectively. The regression coefficients of direct and indirect (Model 2) as well as renewable and non-renewable (Model 3) energies on yield were investigated through Eq. (6) and Eq. (7), respectively. The results are given in Table 6; the regression coefficients of indirect and non-renewable energies were all statistically significant at 1% level, (share of non-renewable and indirect energies were calculated more than renewable and direct energy). A 1% increase in indirect or non-renewable energies increases the yield by 2.33% or 1.57%, respectively; whereas direct or renewable energies increase the yield by only 0.36% or 0.85%, respectively. Hatirli et al. (2006), reported that the impact of indirect energy was shown to be more effective than that of direct energy on yield, Hatirli et al. (2005), investigated that the impact of non-renewable energy was found to be more profound than that of renewable energy on yield.

CONCLUSIONS

Data used in this study were collected from 80 farmers located in the Oromieh Township of the West Azarbaijan province in Iran. Orchard production consumed a total of 101,505 MJ/ha energy and energy output was calculated as 45,185 MJ/ha. The results revealed that wooden packaging (57%), irrigation (16%), fuel (10%) and chemical fertilizer (9%) were the major contributors of total energy use in apple orchards. Energy productivity, net energy gain and output-input energy were calculated as 0.23 kg/MJ, –56,320 MJ/ha and 0.44, respectively. It was concluded that the direct and indirect energy inputs were 29% and 71% of the total energy inputs, respectively. Renewable energy sources among the inputs had a share of 3.3% of the total energy input, which was smaller than that of non-renewable energy sources (packaging is considered as non-renewable and indirect energy). In this study, energy management is important; therefore, policies should emphasize on development of new technologies (application of new technologies such as packaging and irrigation are encouraged) and provide with alternative energy resources aiming at efficient use of energy (use of Goldoni tractors instead of other common tractors can save in fuel consumption and also prevent soil compaction). The results derived from this study can be used by policy makers and other relevant agencies for recommendations to farmers in order to use energy more efficiently.

The benefit-cost ratio was found to be 1.77. The mean net return from apple production was obtained as 6,057 $/ha. Human labor (34%) and packaging (30%) expenses are followed by the refrigerating (19%). Due to low mechanization level in apple orchards, human expense accounted for 34% and machine 1% of total costs. Postharvesting (41%), fertilization (35%), plotting (13%), irrigating (9%) and spraying (2%) operations also accounted for most energy consumptions.

These results indicate that energy use in apple production is not efficient, leading to many environmental problems, detrimental to the natural resources by excess use of inputs. All these inputs would be useful not only for reducing negative effects to environment, human health, maintaining sustainability and decreasing production costs, but also for providing higher energy use efficiency. Benefit-cost and economic productivity showed that large farms were more successful implying that large size orchard holdings have a higher economic productivity as compared with the smaller ones due to relatively better management and financial ability. The elasticity estimates of packaging energy was found as 3.23, which has a major impact on apple orchard production, followed by machinery (0.61), farmyard manure (0.59) and chemical fertilizers (0.107). The impacts of direct, indirect and renewable and non-renewable energies on yield were estimated as 0.038, 2.33, 2.06 and 0.78, respectively.

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Corresponding author:

M.Sc. Raheleh Fadavi, University of Tehran, Faculty of Agricultural Engineering and Technology, Department of Agricultural Machinery Engineering, Karaj, Iran
phone: + 98 261 280 1011, fax: + 98 261 280 8138, e-mail: fadavi.raheleh@gmail.com