

ENERGY USE IN APPLE PRODUCTION IN THE ESFAHAN PROVINCE OF IRAN

M. SAMI, M.J. SHIEKHDAVOODI¹ and A. ASAKEREH²

Department of Agricultural Machinery Engineering, Shahid Chamran University of Ahvaz, Iran

¹Department of Agricultural Machinery Engineering, Shahid Chamran University of Ahvaz, Iran

²Department of Agricultural Machinery Engineering, Faculty of Agricultural Engineering and Technology,
University of Tehran, Karaj, Iran

Corresponding author: Asakereh@ut.ac.ir

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ABSTRACT

Energy is a fundamental ingredient in the process of economic development, as it provides essential services that maintain economic activity and the quality of human life. Modern agriculture has become very energy-intensive. The aim of this study was to evaluate energy use in apple production in the Esfahan Province in Iran. Data used in this study were obtained from 146 farmers using a face to face interview method. The total energy requirement under apple farming was 36,135.16 MJ ha⁻¹, whereas 46.2, 25 and 15.8% was consumed due to chemicals, fuel and manure fertiliser, respectively. Renewable energy was 23.6% of total energy input. The input-output ratio, productivities, specific and net energy gain were 1.17, 0.49 kg MJ⁻¹, 2.05 MJ kg⁻¹ and 6,143.2 MJ ha⁻¹, respectively. Apple production needs to improve the efficiency of energy consumption and to employ renewable energy.

Key Words: Energy intensive, energy ratio, renewable energy

RÉSUMÉ

L'énergie est un ingrédient fondamental dans le processus de développement économique, étant donné qu'elle fournit de services essentiels pour le maintien des activités économiques et la qualité de vie humaine. L'agriculture moderne est devenue trop exigeante en énergie. L'objet de cette étude était d'évaluer l'usage de l'énergie dans la production de la pomme dans la Province d' Esfahan en Iran. Les données utilisées dans cette étude étaient obtenues de 146 fermiers par la méthode d'interview face à face. Le total des besoins en énergie pour la production de la pomme était de 36,135.16 MJ ha⁻¹, alors que 46.2, 25 et 15.8% étaient consommés par des produits chimiques, le carburant et la fumure organique, respectivement. L'énergie renouvelable était de 23.6% du total d'énergie fournie. Le rapport de l'énergie fournie à celle consommée, la productivité, le gain net et spécifique en énergie étaient de 1.17, 0.49 kg MJ⁻¹, 2.05 MJ kg⁻¹ et 6,143.2 MJ ha⁻¹, respectivement. La production de la pomme nécessite une amélioration efficiente de la consommation énergétique et l'emploi de l'énergie renouvelable.

Mots Clés: Energie intensive, rapport énergétique, énergie renouvelable

INTRODUCTION

Energy use in agriculture has developed in response to increasing populations, limited supply of arable land and desire for an increasing standard of living. In all societies, these factors have encouraged an increase in energy inputs to maximise yields, minimise labour-intensive

practices or both (Esengun *et al.*, 2007). The agriculture sector, like other sectors, has become increasingly dependent on energy resources such as electricity, fuels, natural gas and coke. Continuous demand for increase in food production has resulted in intensive use of chemical fertilisers, pesticides, agricultural machinery and other natural resources.

However, intensive use of energy threatens public health and environment (Dalgaard *et al.*, 2001) and is partly responsible for the deterioration of world peace and development (Demirbas, 2006; Grennan, 2006).

This increase in energy use and its associated increase in capital intensive technology, can be partially attributed to low-energy prices in relation to the resource for which it was being substituted (Karkacier *et al.*, 2006). Energy is a fundamental ingredient in the process of economic development, as it provides essential services that maintain economic activity and the quality of human life. Shortages of energy are a serious constraint to the development of low-income countries. However, considering the limited natural resources and the impact of using different energy sources on environment and human health, it is imperative to investigate energy use patterns in agriculture (Hatirli *et al.*, 2005). Energy input-output analysis is usually used to evaluate the efficiency and environmental impacts of production systems (Uhlin, 1998; Yilmaz *et al.*, 2005).

Apples are one of the most common fruits consumed on a regular basis by people globally. Apples in most countries are crops with high-energy inputs, due to inputs in machinery, chemicals and human labour) required for successful commercial production of high-quality fruit (Strapatsa *et al.*, 2006). Apples in Iran are often produced in mountainous and cold areas.

Iran produces 2.66 million metric tonnes of apples in each year (Anon., 2009). Most of them are exported to neighbouring countries such as the United Arab Emirates, Turkey and Germany (Tabatabaeefar and Rajabipour, 2005).

The aim of this study was to assess energy use in apple production, and the efficiency of energy consumption.

MATERIALS AND METHODS

The study was carried out in 146 apple producers in the Esfahan province in Iran. The province is located in the centre of Iran, within 30° 43' and 34° 27' N latitude and 49° 36' and 55° 31' E longitude. Data were collected from the growers by using a face-to-face questionnaire in March

to April 2009. Random sampling of farms was done within whole population and the size of each sample was determined using Equation (1) derived from Neyman method (Ozkan *et al.*, 2004).

$$n = 1(\sum N_h S_h) / (N^2 D^2 + \sum N_h S_h^2) \dots\dots\dots (1)$$

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 $(\bar{x} - \bar{X})$; and

z - Reliability coefficient (1.96, which represents the 95% reliability); $D^2 = d^2 / z^2$.

Inputs in apple production in Iran are human labour, machinery, diesel fuel, inorganic fertilisers, manure, pesticides and irrigation water (Rafiee *et al.*, 2010). Outputs are apple fruits. Energy equivalents shown in Table 1 were used for estimation. Basic information on energy inputs and apple yields were analysed using the SPSS Version 16.

Based on the energy equivalents of the inputs and outputs, output-input energy ratio, energy productivity, specific energy and net energy gain were calculated (Singh, 2002; Sartori *et al.*, 2005; Demircan *et al.*, 2006).

The input energy is also classified into direct and indirect; and renewable and non-renewable forms. The indirect energy consists of pesticide, fertiliser, machine and equipment; while the direct energy includes human power and diesel used in the production process. On the other hand, non-renewable energy includes diesel, electricity, pesticide, fertilisers; while renewable energy consists of human and manure fertiliser (Demircan *et al.*, 2006).

TABLE 1. Energy equivalents for different inputs and outputs in apple production in Iran

Input	Unit	Energy equivalent (MJ unit ⁻¹)	Reference/Source
Labour	h	2.2	Pimentel and Pimentel., 1979
Machinery	hg	138	Kitani, 1999
Diesel fuel	L	56.31	Singh, 2002
Gasoline	L	46.3	Kitani, 1999
Manure	ton	303.1	Esengun <i>et al.</i> , 2007
Nitrogen fertiliser	kg	74.2	Lockeretz, 1980
Phosphorus fertiliser (P ₂ O ₅)	kg	13.7	Lockeretz, 1980
Potassium fertiliser (K ₂ O)	kg	9.7	Lockeretz, 1980
Ca and Mg fertiliser	kg	8.8	Pimentel and Pimentel, 1979
Pesticide	kg	363	Fluck and Baird, 1982
Fungicide	kg	99	Fluck and Baird, 1982
Herbicide	kg	288	Kitani, 1999
Apple	kg	2.4	Jarach, 1985

RESULTS AND DISCUSSION

Socio-economic structure of apple farms.

The farms investigated were mainly devoted to apple production. Most farms were irrigated using the flow method; while the rest use pumping irrigation (Table 2). Tillage was done based on type, mechanised or non-mechanised. In the non-mechanised form, tillage was done with human power while in the mechanised form was done with rotary tiller that gives power from power take off shaft of tractor. Scatter of manure was done before tillage operation. The spread of manure was done with human power and cart or with tractor and human power.

Operations of pest control mainly were mechanised and a few of them (e.g. fungicide) were non-mechanised. Pruning operations were done with labour power and handsaw or motor saw. Harvesting was done by labour. Inorganic fertiliser were used a bit (about 8 kg ha⁻¹) while manure consumed a lot (18,836 kg ha⁻¹). Because, a lot of manure was in the region, use of manure was substantial. Application of inorganic fertilisation was manual while manure application was done by fertilising equipment and labour. Of all inorganic fertilisers, the share of nitrogen phosphorus (P₂O₅), potassium (K₂O), and Mg plus Ca were 33.5, 8.8, 35.9, 21.8%, respectively.

Analysis of energy use. The energy inputs for each operation in apple production are illustrated

TABLE 2. Energy inputs for each operation for apple production in Iran

Operations	Sequestered energy (MJ ha ⁻¹)	%
Spring tillage	2052.48	5.68
Pruning	661.27	1.83
Practice of manure	7808.81	21.61
Inorganic fertilisation	701.02	1.94
Pest control	22252.03	61.58
Weed control	130.08	0.36
Supply water for irrigation	1261.11	3.49
Irrigation (control an scatter)	393.87	1.09
Harvest	870.86	2.42
Total	36135.16	100

in Table 3. Pest control was the most energy-consuming operation and was the premier of energy inputs required in apple production farms. These results are similar to those of Canals *et al.* (2006) and Stapatsa *et al.* (2006) in apple orchard in New Zealand and Greece respectively. However in many studies in orchards, inorganic fertilisers were also the most energy consumer in production (Gezer *et al.*, 2003; Esengun *et al.*, 2007; Canakci, 2010).

Chemicals consume 46.2% of total energy inputs due to high energy sequestered in operation of pest control, which was practiced extensively. After chemical, fuel and manure are the most energy consumer inputs, contributing 25 and 15.80% of total energy use, respectively

(Table 3). Fuel (mostly diesel fuel) was mainly consumed for land preparation, pruning practices and transportation.

Inorganic fertiliser was the least demanding energy input in apple production with 325.22 MJ ha⁻¹ (only 0.44% of the total input energy) (Table 3) followed by machinery with 542.03 MJ ha⁻¹ (1.5% of the total input energy). These results are significantly differed from the result of other studies where inorganic fertilisers consumption was high (Canals *et al.*, 2006; Stapatsa *et al.*, 2006; Page, 2009). In the studied orchard inorganic fertilisers was usually replaced by manure that is a strong point from energy and environment point of view.

Because orchards are usually watered with surface water, which should mean lower energy consumption than pumping groundwater, energy of irrigation was low (Tables 3 and 4).

A total of 76.4% of total energy input resulted from non-renewable and 23.6% from renewable energy; also 32.8% from direct energy and 67.2% indirect energy (Table 5).

TABLE 3. Distribution of sequestered energy to inputs in apple production in Iran

Sequestered energy (MJha ⁻¹)	Coefficient of production	%
Labour	2818.54	7.8
Machinery	542.03	1.5
Fuel	9033.79	25.0
Chemicals	16694.44	46.2
Chemical fertiliser	325.22	0.9
Manure	5709.36	15.8
Irrigation	1011.78	2.8
Total	36135.16	100

TABLE 4. Total energy input in the form of direct, direct renewable, non-renewable and indirect energy for apple production in Iran

Item	MJ ha ⁻¹	%
Direct energy	11852.33	32.8
Indirect energy	24282.83	67.2
Nonrenewable energy	27607.26	76.4
Renewable energy	8527.9	23.6

TABLE 5. Energetic parameters in apple production in Iran

Energy input	MJ ha ⁻¹	36135.2
Energy output	MJ ha ⁻¹	42278.4
Yield	kg ha ⁻¹	17616
Input-output energy ratio	-	1.17
Energy productivity	kg MJ ⁻¹	0.49
Specific energy	MJ kg ⁻¹	2.05
Net energy gain	MJ ha ⁻¹	6143.2

Direct inputs were mainly fuel and labour for field operations; and the indirect inputs were dominated by chemicals and manure. In other words, apple production was highly dependent on both fuel and the production of indirect inputs. Proper chemicals and manure management might reduce the indirect energy requirements for pest control and manure. Furthermore, efforts to reduce the direct energy (fuel and labour), will improve overall energy efficiency of apple production in agricultural production systems. The results indicate that the current energy use pattern among farms is mainly based on non-renewable (Table 5).

Average yield of the apple fruit was found to be 17,616 kg ha⁻¹. This amount is higher than average yield in the world (14.36 t ha⁻¹) in 2008. In energy balances, the output-input energy ratio is often used as a parameter to describe the energy efficiency in agricultural production. The average output-input energy ratio was 1.17. In studies that were done on apple production systems, energy ratio was mostly reported between 1 to 2 (such as 1.57 reported by Page, 2009, 1.18 reported by Pimentel *et al.*, 1983 and 1.11, 1.13 and 1.118 reported by Reganold *et al.*, 2001). Other previous studies reported energy ratio indices of 0.06 (Pimentel *et al.*, 1983), 0.61 (Pimentel, 2006) and 2.34 (Strapatsa *et al.*, 2006). Energy productivity, specific energy and net gain energy were respectively obtained as 0.49, 2.05 and 6,143.2 MJ ha⁻¹, for the study.

CONCLUSION

Total input energy in apple production in Esfahan Province of Iran is 36,135.16 MJ ha⁻¹. Chemicals for pest control, fuel for operation and manure are the major energy inputs with 46.2, 25, and 15.8%, respectively. About seventy four

percent of total energy input in apple production is non-renewable, while 23.6% is renewable. Also 32.8% of total input energy is direct and the rest is indirect. Thus, use of renewable energy in the studied farms is low. It shows that apple needs to improve the efficiency of energy consumption in production and to employ renewable energy.

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