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Almond production in Iran: An analysis of energy use efficiency (2008–2011)

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The objective of this study was to analyse input–output energy in almond production in Chahrmahal-Va-Bakhtiari province, Iran. Almond production data were collected from producers using the direct questionnaire method. The results reveal that electricity accounted for a large part of the input energy (50%), followed by chemical fertilizers. The average contributions of human labour, chemicals, farmyard manure, diesel fuel and machinery were 6.89%, 6.77%, 4.70%, 4.66% and 3.59% of the total energy input, respectively. The average values of total energy output, net energy gain and energy efficiency were 140.2 GJ ha^{-1}, 77.7 GJ ha^{-1} and 2.24, respectively. In addition, the average values for energy productivity and specific energy were 19 kg GJ^{-1} and 0.06 GJ kg^{-1}, respectively. The average values for direct, indirect, renewable and non-renewable forms of energy were 41.6 GJ ha^{-1} (66.63%), 20.9 GJ ha^{-1} (33.36%), 18.3 GJ ha^{-1} (29.21%) and 44.2 GJ ha^{-1} (70.79%), respectively.

Contents

1. Introduction

Almonds rank first among tree nuts and are very useful food products because of their content of numerous beneficial nutritive and bioactive compounds, such as total lipid (49.22 g/100 g), oleic acid (60.4%), linoleic acid (17.4%), fibre (12.2 g/100 g) and vitamin E (26.22 mg/100 g) [1,2]. Almonds nut can be peeled or unpeeled, raw or roasted and whole or ground, as ingredients in bakery and confectionery products, as well as flavouring agents in beverages and ice-cream [3,4]. Residues from almond trees (pruning and almond shell and hull) can be used as biomass for energy recovery, because of their fairly high energy content (16–18 MJ/kg) [5,6].

Energy inputs are necessary for the global food sector and it is recognized that agricultural crop yields are directly linked to energy [7]. Energy sources used in agriculture consist of two main groups: natural and auxiliary. Natural energy is essential for plant growth and includes solar energy and various forms of chemical energy stored biologically in the soil [8]. To support natural agricultural production processes, auxiliary energy inputs are used by humans so that a given area of land or water produces more than it would do otherwise [9]. This auxiliary energy can be categorized into direct, indirect, renewable and non-renewable energy uses [10]. Agriculture uses energy directly as diesel fuel or electricity to operate machinery and equipment on the farm and indirectly to produce chemical fertilizers, machinery and biocides that are produced off the farm [11]. Non-

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renewable energies include diesel fuel, chemicals, chemical fertilizers, machinery and electricity, while human labour, farmyard manure and water for irrigation are considered renewable energies [11].

Energy consumption in agriculture is increasing in response to a growing population, a limited supply of arable land and a desire for a higher standard of living. However, the intensive use of diesel fuels causes problems that threaten public health and the environment, such as greater greenhouse gas emissions, eutrophication, acidification and water and soil pollution. In addition, if energy prices continue to rise, the global food sector will face increased risks and lower profits [12,13]. Improvements in energy use efficiency are keys for sustainable energy management. To increase energy efficiency, energy input should be reduced without affecting the yield level or increase the production yield [14]. The efficient use of energy in agriculture with low-input energy, compared to the output of agricultural production, would minimize environmental problems such as greenhouse gas emissions and decrease reliance on fossil fuels, as well as improve sustainable agriculture as an economical production system [14]. To determine energy efficiency, energy input–output analyses are usually conducted. These analyses determine how efficiently energy is used [12]. Worldwide energy analysis studies have been conducted by many researchers to determine the energy efficiency in the production of different agricultural crops [15–21]. For this purpose, they have determined the contribution of each energy input, the output–input energy ratio, energy productivity, specific energy, net energy gain and contribution of different energy forms, including direct, indirect, renewable and non-renewable.

To date, there are no published data or information on energy input and output patterns in almond production. Moreover, in previous studies, only the target products' quantity and energy equivalent have been considered as outputs and product residues, which are an important part of agricultural output, have been neglected. Therefore, the main aim of this study was to determine the input–output energy patterns in almond production, in order to reveal the distribution of different energies used during management practices and evaluate the efficiency of input energy consumption. In this study, almond residues were considered as practical and usable energy output resources, therefore their energy contents have been included in the total energy output.

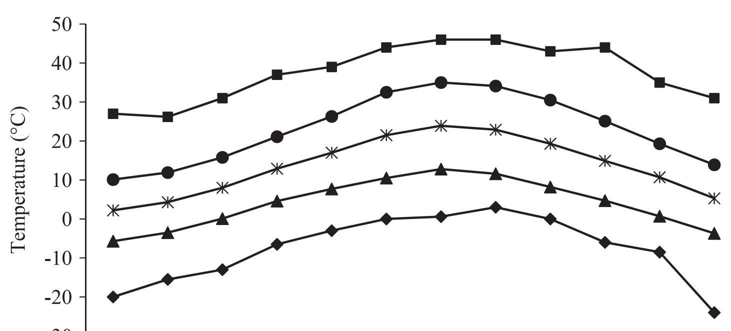
2. Materials and methods

This case study was conducted in Chaharmahal-Va-Bakhtiari province, Iran, because of its major contribution to almond production in Iran, with 18.24% of the total production. This region comprises approximately 1% of the total area of Iran and is located on the central Iranian plateau (31°14′, 33°47′N and 49°49′, 51334′E). Climatic indices from 2008 to 2011 were obtained from meteorological stations in the surveyed region and are presented in Fig. 1 and Table 1.

Almond production data were collected from farmers using a face-to-face questionnaire, over three consecutive years (2008–2011), for Sefied, Mamaei, Shahrodi 12 and Rabei cultivars in orchards classified into three age groups: 6–10, 11–15 and 15–20-years-old. A description of the cultivars is provided in Table 2. The

Table 2
Description of almond cultivars investigated in this study [22].

Cultivar	Origin	Shell hardness	Flowering data
Sefied	Iran	Soft	Early
Mamaei	Iran	Hard	Medium
Rabei	Iran	Hard	Medium
Shahrodi 12	Unknown	Hard	Late



	Jan	Feb	Mar	April	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Asolute minimum temperature	-20	-15.5	-13	-6.5	-3	0	0.6	3	0	-6	-8.5	-24
Absolute maximum temperature	27	26.2	31	37	39	44	46	46	43	44	35	31
Minimum average monthly temperature	-5.7	-3.5	0.1	4.6	7.7	10.5	12.8	11.6	8.2	4.7	0.7	-3.7
Maximum average monthly temperature	10.1	11.9	15.8	21.1	26.3	32.5	35	34.1	30.5	25.1	19.3	13.9
Average monthly temperature	2.2	4.3	8	12.9	17	21.5	23.9	22.9	19.3	14.9	10.7	5.3

Fig. 1. Principle temperature factors of surveyed region.

Table 1
Average amount of some principle climate indices of the surveyed region.

	Jan	Feb	Mar	April	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Sunny hours (h)	213.0	220.5	243.5	235.4	313.0	354.8	353.5	347.7	316.1	275.8	218.7	186.0
Light ratio	0.66	0.67	0.64	0.59	0.72	0.84	0.81	0.83	0.83	0.76	0.68	0.60
Wind speed (m s^{-1})	6.43	5.92	4.8	4.3	3.95	4.15	4.6	5.5	5.4	6.7	7.4	7.9
Windless percentage (%)	12	14.8	20	27.4	30	25.1	20.3	16.5	18.7	13	6.6	6.9
Frozen days number	28	23	15	2	0	0	0	0	0	2	13	24
Precipitation (mm)	58.2	50.2	57.4	39.8	17.1	0.6	2.3	0.18	0.3	8.1	35.3	56.9
Relative humidity (%)	64	62	58	51	44	38	38	37	40	47	57	61