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# An assessment of energy modeling and input costs for greenhouse button mushroom production in Iran

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ABSTRACT

This paper studies the energy balance between the input and the output per unit area for button mushroom production in Isfahan province of Iran. Data were obtained from 22 greenhouse button mushroom growers using a face to face questionnaire method. Sensitivity analysis of energy and cost inputs was carried out using the marginal physical productivity (MPP) technique. The results revealed that the total input and output energy use was to be 901 and 25.4 MJ m$^{-2}$, respectively. The highest share of energy consumption belongs to compost (49%) followed by diesel fuel (45%). Energy use efficiency, specific energy, net energy and energy intensiveness of greenhouse button mushroom production were 0.03, 59.5 MJ kg$^{-1}$, −875 MJ m$^{-2}$ and 36.1 MJ \$$^{-1}$, respectively. Econometric model evaluation showed that the impact of compost and human labor energy inputs were significantly positive on yield. The sensitivity analysis of energy inputs indicated that among the inputs, human labor has the highest MPP value of energy inputs. Cost analysis revealed that total cost of button mushroom production was obtained as 24.9 \$ m$^{-2}$. Accordingly, the benefit–cost ratio and productivity were obtained as 1.15 and 0.62 kg \$$^{-1}$, respectively. It is suggested that new heating system with high thermal efficiency are to be used, in order to improve the greenhouse environment as well as reduction of diesel fuel consumption.



## 1. Introduction

Mushroom cultivation presents an economically important biotechnological industry that has expanded all over the world in the last few years. Its cultivation mainly depends on the agriculture crop residues (Ram and Kumar, 2010). Mushrooms have a great nutritional value since they are quite rich in protein, with an important content of essential amino acids and fiber, and poor in fat (Heleno et al., 2010). The largest portion of mushroom production is that of button mushroom with 37 percent of produced mushroom (Motevali et al., 2011). The world production of button mushrooms was about 4 billion tones in 2009 (Sonnenberg et al., 2011). In Iran from 2001 to 2012, button mushrooms production increased from 6997 tonnes to 57,932 tonnes from which about 10% is produced in Isfahan province (Anonymous, 2012).

The need to increase food production has resulted in the increased consumption of energy and natural resources because farmers have little knowledge of or few incentives to use more energy efficient methods (Esengun et al., 2007). The relation between agriculture and energy is very close. Agriculture is an energy consumer and energy supplier (Ozkan et al., 2004). It uses large quantities of locally available non-commercial inputs, such as seed, manure and animate energy, and commercial inputs directly and indirectly in the form of fuel, electricity, fertilizer, plant protection, chemicals, irrigation water and machinery. They all can be converted and stated in the form of energy units. Efficient use of energies helps to achieve increased production and productivity and contributes to the economy, profitability and competitiveness of agriculture sustainability in rural living (Royan et al., 2012).

A significant objective in agricultural production is to decrease costs and increase yield. In this respect, the energy budget is important. Energy budget is the numerical comparison of the relationship between input and output of a system or agricultural business in terms of energy units (Gezer et al., 2003). Energy input–output analysis is usually used to evaluate the efficiency and environmental impacts of production systems. It is also used to compare the different production systems (Mobtaker et al., 2010). The marginal physical productivity (MPP) technique is another way which is used to evaluate the efficiency of production systems and to determine the sensitivity of a particular energy input on production (Singh et al., 2004).

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Several researches have been conducted on energy use in different agricultural crops (Kuesters and Lammel, 1999; Canakci and Akinci, 2006; Esengun et al., 2007; Mohammadi et al., 2008; La Rosa et al., 2008; Rafiee et al., 2010; Iriarte et al., 2010; Heidari et al., 2012; Mousavi-Avval et al., 2011; Tabatabaie et al., 2012; Mohammadi et al., 2013).

Hatirli et al. (2006) investigated energy inputs and crop yield relationship to develop and estimate an econometric model for greenhouse tomato production in Antalya province of Turkey. The results showed that energy use efficiency, specific energy and energy productivity were 1.2, 12,380 MJ $t^{-1}$ and 0.09 kg $MJ^{-1}$, respectively. Mohammadi et al. (2010) examined energy use of kiwifruit in Mazandaran province of Iran and found that human power is the most important variable that influences the yield followed by water for irrigation. Mousavi-Avval et al. (2011) determined energy use pattern in canola production using the econometric model. The results showed that machinery, fertilizer, diesel fuel and water for irrigation energies significantly contributed to yield. Pahlavan et al. (2011) studied energy use pattern in greenhouse tomato production in Iran. The results indicated that total input energy and total output energy were 21,834 GJ $ha^{-1}$, 233 GJ $ha^{-1}$, respectively. In the study conducted in Iran, energy consumption for greenhouse vegetable production was determined. The results revealed that cucumber production consumed a total of 124 GJ $ha^{-1}$ followed by tomato with 117 GJ $ha^{-1}$ (Taki et al., 2012). Tabatabaie et al. (2013a) investigated the energy consumption and inputs sensitivity for prune production in Iran. Econometric model evaluation showed that electrical energy was the most significant input which affects the output level. Although many studies have conducted on energy use in agricultural crops, there is no study about energy and cost analysis for button mushroom production in Iran.

The present study investigated the energy consumption in greenhouse button mushroom production in Isfahan province. Also the relationship between energy inputs and yield was studied using Cobb–Douglas production function and sensitivity of energy inputs was analyzed. In the last part of the research, the costs analyses were conducted and some economical indicators were calculated for button mushroom production.

## 2. Materials and methods

### 2.1. Selection of case study region and data collection

This study was conducted in the Isfahan province. The Isfahan province is located in the central region of Iran; within 30°04′ and 34°27′ north latitude and 49°36′ and 55°31′ east longitude. The long-term average air temperature of the area is about 16 °C and the average annual precipitation is 160 mm (Anonymous, 2012). Isfahan province is ranked third in Iran in terms of mushroom production. The farmer can have 4 production periods per year in this province. The data used in the study were collected from 22 greenhouses using a face-to-face questionnaire in November–December 2012. In a face-to-face survey, an interviewer is physically present to ask the survey questions and to assist the respondent in answering them. The sample size of greenhouses was calculated using Cochran method (Snedecor and Cochran, 1989; Mobtaker et al., 2012):

$$n = \frac{Nt^2S^2}{Nd^2 + t^2S^2} \quad (1)$$

where $n$ is the required sample size; $N$ is the number of holdings in target population; $t$ is the reliability coefficient (1.96 which represents the 95% reliability); $S^2$ is the variance of studied qualification in population and $d$, the acceptable error (permissible error 5%). Based on this method of sampling, 22 greenhouses were investigated.

### 2.2. Energy analysis

The input and output in mushroom production were specified and then, these inputs and output data were multiplied by the coefficient of energy equivalent. Energy inputs in button mushroom production were: human labor, diesel fuel, machinery, electricity, chemicals, compost and water. The energy equivalents given in Table 1 were used to calculate the input amounts.

In order to calculate machinery energy the following formula was used (Ozkan et al., 2007):

$$E_m = \frac{W_m \times EI_m}{t_m} \quad (2)$$

where $E_m$ is the machinery energy (MJ $h^{-1}$), $W_m$ the weight of machinery (kg), $EI_m$ the production energy of machine (MJ $kg^{-1}$), and $t_m$ the economic life of tractor ($h$).

Button mushroom is produced on a composted substrate consisting of various raw materials including wheat straw, chicken manure, nitrogen and gypsum. Because the energy coefficient of compost wasn't reported in any references, this coefficient was calculated using energy content of inputs which were used in compost production. These inputs and their energy content are given in Table 2. According to the result of Table 2, energy coefficient of compost was obtained equal to 5.08 MJ $kg^{-1}$.

Based on the energy equivalents of the inputs and output (Table 1), the energy input and output were calculated per square meter. Following the calculation of energy input and output values, the energy use efficiency (energy ratio), energy productivity, net energy and energy intensiveness were determined as follows (Banaeian et al., 2011; Mobtaker et al., 2010):

$$\text{Energy use efficiency} = \frac{\text{Energy Output}(\text{MJ m}^{-2})}{\text{Energy Input}(\text{MJ m}^{-2})} \quad (3)$$

$$\text{Energy productivity} = \frac{\text{Button mushroom Output}(\text{kg m}^{-2})}{\text{Energy Input}(\text{MJ m}^{-2})} \quad (4)$$

$$\text{Specific energy} = \frac{\text{Energy Input}(\text{MJ m}^{-2})}{\text{Button mushroom Output}(\text{Kg m}^{-2})} \quad (5)$$

**Table 1**
Energy equivalent of inputs and output in agricultural production.

| Inputs (unit) | Unit | Energy equivalent (MJ $unit^{-1}$) | Reference |
|---|---|---|---|
| *A. Inputs* | | | |
| 1. Human labor | h | | |
| Man | | 1.96 | (Mohammadi et al., 2008) |
| Woman | | 1.57 | (Mohammadi et al., 2008) |
| 2. Diesel fuel | l | 56.3 | (Heidari and Omid, 2011) |
| 3. Compost | kg | 5.08[a] | |
| 4. Machinery: | kg | | |
| Steel | | 62.7 | (Heidari et al., 2011) |
| 5. Chemicals | kg | 120 | (Heidari and Omid, 2011) |
| 6. Electricity | kWh | 3.60 | (Kitani, 1999) |
| 7. Water | $m^3$ | 1.02 | (Erdal et al., 2007) |
| *B. Output* | | | |
| 1. Button mushrooms | kg | 1.62 | (Barros et al., 2008) |

[a] This coefficient is based on values used in Iran's compost production.

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