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Condition Monitoring of Energy usage and CO_2 emission for Greenhouse Cucumber in Iran

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ABSTRACT: The aims of this study were to determine the energy consumption and survey on environmental pollution of greenhouse cucumber in Golshan region, Isfahan province of Iran. For this purpose data were collected from 30 farms using a face to face questionnaire. The results revealed that total energy input for greenhouse cucumber production was found to be 163994 MJha^{-1} that the share of non-renewable energy form (94%) was more than renewable energy form (6%). Fossil fuel has the highest share by 45% followed by total fertilizers and electricity. Energy ration, energy productivity, and net energy were 0.38, 0.45 kgMJ^{-1} and -101498MJha^{-1}, respectively. The results also showed the share of indirect and renewable energy is very low. The results of CO_2 emission analyzes showed that the diesel fuel had the highest share of total CO_2 emission for greenhouse cucumber production. The total amounts of CO_2 emission were 6.8 tonha^{-1}. This result is very clearly shows that the use of fossil fuel is very high and government should change the political action about intensive cultivation. May be we should go to modern technology to build solar greenhouse to catch most of energy requirement of solar and other renewable resources.

Keywords: Energy Use; Energy Efficiency; CO_2 emission; wheat, Cucumber

INTRODUCTION

In order to maximize the efficiency of modern agricultural technology to farms in a target region, the farming system of the region should be first characterized, especially to identify possible resource constraints and to capture the diversity of farming systems (Zangeneh *et al.*, 2010). Currently, agricultural operations have to adapt to a more competitive environment and consequently, use new intelligent technologies (Mahmoud, 2004). Hydroponics and greenhouse production are the way of obtaining profitable crops (Nelson, 2002). A sustainable crop production system requires keeping a high-quality harvest, while keeping energy and raw material consumption low.

The agricultural sector is an important energy consumer. Farmers have an option for reducing energy use by investing in intelligent systems (Kornerand Straten, 2008). The high rate of population growth and reducing the extent of fertile land due to the increasing development of urban and industrial areas induce more efficient use of existing facilities. The effective and efficient use of limited resources like water, soil and human power that are of particular importance to provide food requirements for people in developing countries, Including Iran. Successful efforts to achieve self-sufficiency and growth of gross national income like any other activity requiring deep knowledge of the practical and economic processes and applying the latest knowledge and technology around the world. Greenhouse production technology led to increase the efficiency of limited water and soil resources. And its importance is undeniable with respect to the dry climate and low rainfall in most parts of Iran. The major disadvantage of this method is high energy consumption because in most cases greenhouse production is off-season. Increase in energy efficiency in greenhouse cultures is of the most important energy studies in agriculture, and any success in increasing energy efficiency in greenhouse cultures can cause efficient use of valuable energy resources (Taki *et al*, 2012b).

In a research conducted in Spain, energy use and economic evaluation were considered for winter wheat, winter barley, spring barley and vetch production. The spring barley showed highest energy consumption since a larger number of tillage operations were required and a larger amount of herbicides for weed control (Hernanz *et al*, 1995). Khan *et al.*, (2009) studied the energy inputs in wheat, rice and barley production for reducing the environmental footprint of food production in Australia. The results showed that barley crop seems more efficient in terms of energy and water use jointly.

Heidari and Omid (2011) studied energy use patterns of major greenhouse vegetable productions in Iran and found that impact of human labor for cucumber and chemicals for tomato was significant at 1% levels. Pishgar-Komleh *et al.* (2012) determined energy consumption and CO_2 emissions of potato production in three different sizes of farms in Esfahan province, Iran.

The result of this paper revealed total energy consumption and GHG emission in potato production are 47 GJ ha^{-1} and 993 kg CO_{2eq} ha^{-1}, respectively. Soni *et al*. (2013) considered the energy use index and CO_2 emissions in rain fed agricultural production systems of Northeast Thailand. In this study, system efficiency, total energy input and corresponding CO_2 eq. emissions were estimated and compared for different crops. Soltani *et al.* (2013) analyze energy use and greenhouse gases (GHG) emissions in various wheat production scenarios in north eastern Iran. The results indicate that the seedbed preparation, sowing and applications of nitrogen fertilizer are the key factors which are related to energy use and GHG emissions.

The present study investigated the energy consumption in greenhouse cucumber production in Golshan region. Also we survey some environmental prolusions and the last part of study the relationship between energy form and yield was studied.

MATERIALS AND METHODS

The research was done in Golshan region which is located in Isfahan province of Iran. The data were collected from 30greenhouses using a face to face questionnaire.

The simple random sampling method was used to determine the survey volume as (Kizilaslan, 2009):

$$n = \frac{N(s\times t)^2}{(N-1)d^2+(s\times t)^2} \quad ...(1)$$

where *n* is the required sample size; *s*, the standard deviation; *t*, the t value at 95% confidence limit (1.96); *N*, the number of holding in target population and *d*, the acceptable error (permissible error 5%). consequently calculated sample size in this study was 30.

The inputs used in the production of wheat were specified in order to calculate the energy equivalences in the study. The input energy was also divided into direct and indirect and renewable and non-renewable forms (Esengun *et al.*, 2007). Direct energy constituted of human labour, diesel fuel and electricity, whereas, indirect energy include chemical fertilizers, biocides, seed and machinery. Renewable energy consists of human labour and seed and non-renewable energy includes machinery, diesel fuel, chemical fertilizers and biocides. Inputs in wheat production were: human labour, machinery, diesel fuel, chemical fertilizers, biocides, seed and electricity and output was cucumber. The units in Table 1 were used to calculate the energy equivalent of input. The input and output were calculated per hectare and then, these input and output data were multiplied by the coefficient of energy equivalent. Following the calculation of energy input and output values, the energy indexes of wheat were calculated (Mandal *et al.,* 2002). These indexes are showed in Table 2. The output-input energy ratio (energy use efficiency) is one of the indices that show the energy efficiency of agriculture. In particular, this ratio, which is calculated by the ratio of input fossil fuel energy and output food energy, has been used to express the ineffectiveness of crop production in developed countries.

Table 1: Energy equivalent of energy output and input in agricultural production.

Inputs	Unit	Energy equivalent (MJ per unit)	Reference
1. Human power	Hour	1.96	Mandal *et al.,* 2002
2. Fertilizers			
Potassium (K_2O)	Kg	11.15	Esengun *et al.,* 2007
Nitrogen (N)	Kg	47.1	Taki *et al.,* 2012a
Phosphate (P_2O_5)	Kg	15.8	Taki *et al.,* 2012a
3. Chemicals			
Pesticide	Kg	101.2	Taki *et al.,* 2012a
Herbicide	Kg	238	Taki *et al.,* 2012a
4. Machinery	Kg	62.7	Mandal *et al.,* 2002
5. Cucumber Seed	Kg	1	Mohammadi and Omid, 2010
6. Diesel Fuel	Lit	56.31	Omid *et al.,* 2011
7. Electricity	kWh	11.93	Omid *et al.,* 2011
8. Water for irrigation	m^3	1.02	Zangeneh *et al.,* 2010
Output (cucumber)	Kg	0.8	Omid *et al.,* 2011

Table 2. Indices of energy in Agriculture production (Taki *et al,* 2012b).

Indicator	Definition	Unit	
Energy ratio	$\frac{\text{Energy Output (MJ ha}^{-1}\text{)}}{\text{Energy Input (MJ ha}^{-1}\text{)}}$	ratio	(2)
Energy productivity	$\frac{\text{Yield (kg ha}^{-1}\text{)}}{\text{Energy Input (MJ ha}^{-1}\text{)}}$	Kg MJ^{-1}	(3)
Specific energy	$\frac{\text{Energy input (MJ ha}^{-1}\text{)}}{\text{Yield (kg ha}^{-1}\text{)}}$	MJ kg^{-1}	(4)
Net energy gain	Energy Output (MJ ha^{-1}) - Energy Input (MJ ha^{-1})	MJ ha^{-1}	(5)

An increase in the ratio indicates improvement in energy efficiency, and vice versa. Changes in efficiency can be both short and long term, and will often reflect changes in technology, government policies, weather patterns, or farm management practices. By carefully evaluating the ratios, it is possible to determine trends in the energy efficiency of agricultural production, and to explain these trends by attributing each change to various occurrences within the industry (Bahrami *et al,* 2011).

RESULT AND DISCUSSION

A. Analysis of energy input and output in greenhouse cucumber production

Amount of inputs, output and their energy equivalents for greenhouse cucumber production is presented in Table 3. The total energy consumption for greenhouse cucumber production was calculated as 163994 MJ ha^{-1}; also, the percentage distribution of the energy associated with the inputs is seen in Table 3.

It is evident that, the greatest part of total energy input (45.15%) was consumed by diesel Fuel consumption. Also, fertilizers and seed was the second main energy consuming input.

Similar studies had also reported that diesel fuel and fertilizers were the most intensive energy inputs (Zangeneh *et al.,* 2010; Esengun *et al.,* 2007). In the Khuzestan province is used –however short term- of heating systems in greenhouses due to the large temperature difference between day and night and the low temperature at night. Therefore diesel fuel consumption is allocated to the share largest from other inputs. In order to improve the greenhouse environment as well as reduction of diesel fuel consumption, it is strongly suggested that the heating system efficiency is raised or replaced with alternative sources of energy such as natural gas and solar energy (Omid *et al.,* 2011).

Table 3: Energy used status for cucumber production in the Golshan region.

Input	Quantity per unit area (ha)	Equivalent energy MJ/ha	Unit	Percent
a- Input				
1. Fuel consumption	1315	74047	Lit	45.15
2. Human power	4165.2	8163	Hour	4.97
3. Machinery	51.6	3235	Kg	1.97
4. Fertilizer (sum: potassium, nitrogen, phosphate) and seed	1050.2	39907	Kg	24.33
5. Chemicals (sum: pesticide, herbicide)	120.2	9696	Kg	5.91
6. Water for irrigation	1250	1275	Lit	0.8
7. Electricity	2319.5	27671	kwh	16.87
Total energy input	-	163994	MJha^{-1}	100
b- Output				
Cucumber	78120	62496	Kg	-
Total energy output	-	62496	MJha^{-1}	-

The results also revealed that electricity was the third main energy consuming input because of rising temperatures on some days; the ventilation system is used to regulate the greenhouse temperature. The water for irrigation was the least energy demanding inputs for greenhouse cucumber production. On the other hand, the average cucumber yield obtained was found to be 78120 kg ha^{-1}; accordingly, the total energy output was calculated as 62496 MJ ha^{-1}, in the enterprises that were analyzed. In the previous study on greenhouse cucumber production in the Tehran province of Iran the yield value of greenhouse cucumber and total output energy were reported higher than that of this study (Omid *et al.,* 2011). The lower yield value and energy output of greenhouse cucumber production in the Khuzestan province were mainly due to the mismanagement of input usage.

The energy output-input ratio, energy productivity and net energy gain of greenhouse cucumber production are presented in Table 4. Energy ratio was calculated as 0.38, showing the inefficiency use of energy in greenhouse cucumber production in the Khuzestan province. It is concluded that the energy ratio can be increased by raising the crop yield and/or by decreasing energy input consumption. Similar results obtain 0.64 for the energy ratio of greenhouse cucumber production (Omid *et al.,* 2011; Mohammadi and Omid, 2010). The average energy productivity of greenhouse cucumber production was 0.47 kg MJ^{-1}. This means that 0.47 units output was obtained per unit energy. Similar results have been reported 0.39 and 0.8 kg MJ^{-1} for the energy productivity of greenhouse cucumber production (Mohammadi and Omid, 2010). The net energy gain of greenhouse cucumber production was -101498 MJ ha^{-1}. Net energy gain is negative (less than zero). Therefore, it can be concluded that in greenhouse cucumber production, energy is being lost. Similar results obtain -53027 MJ ha^{-1}.16 and -55552.83 MJ ha^{-1} for the net energy of greenhouse cucumber production (Mohammadi and Omid, 2010; Omid *et al.,* 2011).

Table 4: Energy output-input ratio and forms in greenhouse cucumber production.

Items	Unit	cucumber	Percent of
Crop yield	kg ha^{-1}	78120	
Energy ratio	-	0.38	
Energy productivity	kg MJ^{-1}	0.47	
Net energy gain	MJ ha^{-1}	−101498	
Energy forms [1]			
Direct energy [2]	MJ ha^{-1}	109881	67.52
Indirect energy [3]	MJ ha^{-1}	52838	32.47
Renewable energy [4]	MJ ha^{-1}	8163.13	5.01
Non Renewable energy [5]	MJ ha^{-1}	154555.87	94.98
Total energy input	MJ ha^{-1}	163994	100

1. Energy equivalent of water for irrigation is not included. 2. Includes human power, diesel and electricity. 3. Includes seeds, fertilizers, chemicals and machinery. 4. Includes human power and seeds. 5. Includes diesel, fertilizers, chemicals, electricity and machinery

The distribution of inputs used for greenhouse cucumber production in groups of direct, indirect, renewable, and non-renewable sources is shown in Table 4. The ratio of direct and indirect energy sources are 67.52% and 32.47%, respectively. Also, there is a significant difference between renewable and non-renewable energy sources. Renewable energy sources are clean sources of energy that have a much lower impact on the environment than do conventional energy technologies. In the studied greenhouses, 94.98% of the input energy comes from non-renewable energy sources, which are finite and will someday be depleted. Also, many of these energy sources are harmful to the environment (Unakitan *et al.,* 2010). Several researchers showed that the ratio of direct energy is higher than that of indirect energy, and the rate of non-renewable was much greater than that of renewable consumption in cropping systems (Mohammadi *et al.,* 2008; Hatirli *et al.,* 2006).

B. Greenhouse gas emission for cucumber production

In this research GHG emissions were the scope of this analysis and the corresponding amount was calculated. The diesel fuel combustion can be expressed as fossil CO_2 emissions with equivalent of 2764.2 g L^{-1} (Abdi *et al.,* 2013). Also, the machinery and fertilizer supply terms can be expressed in terms of the fossil energy required to manufacture and transport them to the farm with CO_2 equivalents of 0.071 $TgPJ^{-1}$ and 0.058 $TgPJ^{-1}$ for machinery and chemical fertilizers, respectively (Abdi *et al.,* 2013).

Table 5 shows the CO_2 emission for cucumber production in actual energy use. Results of this table indicated that vegetable productions are mostly depending on diesel fuel sources. Diesel fuel had the highest share (63%) followed by chemical fertilizer and machinery. As it can be seen in Table 4, the total amount of CO_2 emission was 6.8 $tonha^{-1}$ for cucumber production. Using ethanol and biodiesel as biofuel is essential in the 21st century to reduce the high GHG emissions. Field operations with minimum machinery use (especially tillage operation) and machinery production are needed to be considered to reduce the amount of CO_2. Eady *et al.,* 2011, applied the Life cycle assessment modeling of complex agricultural systems with multiple food and fibre co-products. They reported that amongst the crops, estimates of emissions for the cereal grains averaged 202 kg CO_2-*e*/tonne grain, canola 222 kg CO_2-*e*/tonne and lupins 510 kg CO_2-*e*/tonne, when modeled to include the benefits of the mixed farming system. Gunady *et al.,* 2011 used the Life Cycle Assessment for evaluating the global warming potential of the fresh produce supply chain for strawberries, romaine/cos lettuces and button mushrooms in Western Australia. Results showed that the life cycle GHG emissions of strawberries and lettuces were higher than mushrooms due to intensive agricultural machinery operations during the on-farm stage. Mushrooms, however have significantly higher GHG emissions during pre-farm stage due to transport of peat, spawn, and compost.

Table 5: Amount of greenhouse gas emission for cucumber production.

Input	Equivalent ($Tg (CO_2) PJ^{-1}$)	Amount of energy usage (MJ/ha)	Quantity of CO_2 emission (kg/ha)
Diesel fuel	0.0578	74047	4279 (63%)
Machinery	0.071	3235	230 (3.3%)
Chemical fertilizer	0.058	39800	2300 (33.7%)
Total	-	117082	6809

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