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ENERGY BALANCE ANALYSIS AND MECHANIZATION INDEXFOR GREENHOUSE VEGETABLE PRODUCTION IN SOUTHERN OF ALGERIA. AN OVERVIEW OF BISKRA PROVINCE

تحليل الميزان الطاقوي ومؤشر المكننة لزراعة البيوت المحمية في الجزائر. نظرة عن ولاية بسكرة

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ABSTRACT

This work aims to determine the energy use for greenhouse vegetable production and to estimate the mechanization index in Biskra province (Algeria).The results revealed that the total energy required for vegetable protected production is 119.68 GJ per hectare where the infrastructure was the highest energy consumer followed by the electricity and fertilizers with a share of 22%, 20% and 19%, respectively. The energy use efficiency was calculated as 0.82, showing the inefficiency use of energy in the protected vegetable production. The entire farmers use least machinery labour energy in hectare compared to the human energy and the itinerary crop is similar for all greenhouses.

ملخص

يهدف هذا العمل إلى تحديد استخدام الطاقة لإنتاج الخضار للزراعات المحميةوتقدير مؤشر المكننة في محافظة بسكرة (الجزائر). وكشفت النتائج أن إجمالي الطاقة اللازمة لإنتاج الخضار المحمية هي 119.68 جيغا جول في الهكتار الواحد حيث كانت البنية التحتية المستهلك الأعلى للطاقة يليه الكهرباء والأسمدة بحصة بلغت 22٪، 20٪ و 19٪ على التوالي .تم احتساب كفاءة استخدام الطاقة وهي 0.82، والتيتبين عدم كفاءة استخدام الطاقة في إنتاج الخضار للزراعات المحمية . جل المزارعين يستخدمونطاقة ميكانيكية في الهكتار أقل مقارنة مع الطاقة البشرية والأعمال الزراعية هي متماثلة في جميع البيوت البلاستيكية.

INTRODUCTION

In the two last decades, Algeria has experienced a notable agricultural development driven by a prosperous trend in market gardening in plastic greenhouses due of the favourable climatic conditions and the government's policy. As results of this development, Biskra province becomes the first producer of early vegetables nationally *(Allache et al., 2015)* where, the surface occupied by the greenhouse has increased by 528.52% over the last 20 years *(Belhadi et al., 2016).*

Taking into account limited natural resources and the impact of using different energy sources on environment and human health; it is substantial to investigate energy use patterns in agriculture *(Samavatean, 2011).*Therefore, research efforts have emphasized energy and economic analysis of various agricultural productions for planning resources in the ecosystem *(Singh et al., 2002).* While several works across the world have been conducted to estimate the energy use in greenhouse vegetable production, such as: *Ozkan et al. (2004), Elings et al. (2005), Campiglia et al. (2007), Djevic and Dimitrijevic (2009), Ozkan et al. (2011), Pahlavan et al. (2011), Heidari and Omid (2011), Bojacá et al. (2012), Baptista et al. (2012) and Hedau at al. (2014).* However, no studies have been published on energy input–output analysis and the mechanization index analysis of greenhouse vegetable production in Algeria.

With these observations in mind, this study addresses the determining input-output energy use in greenhouse vegetable production in order to study the energy consumption efficiency. Furthermore, this study wishes to estimate the mechanization degree and the mechanization index for the greenhouse vegetable production in Biskra province, southern of Algeria.

MATERIAL AND METHODS

Study area

According to *Rekibi (2015),* Biskra province occupies over 32% of national production of protected crops which make it the first producer of early vegetable in Algeria. The vegetables produced most extensively are tomato, cucumber, eggplant and pepper. For this reason, this study has been carried out in this region. The study area is located in the south-eastern of the country, the gateway to the Sahara. The height above sea level is 112 m which makes it one of the lowest cities. The chief town of the province is located at 400 km of the capital, Algiers. It has surface area of 21,671 km², divided into 12 administrative districts (Fig. 1). Biskra has a hot desert climate, with very hot and dry summers and mild winters with annual rainfall averaging between 120 and 150 mm/year. The average annual temperature is 20.9°C.

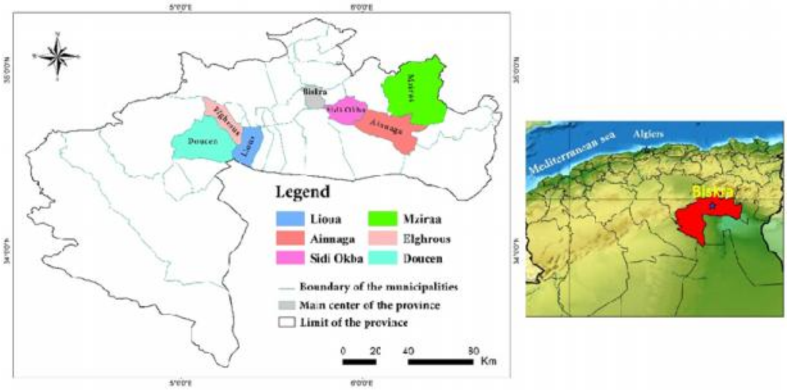

Fig. 1 - Situation of study area

Survey

An investigation was conducted in Biskra province during the season 2014-2015. The study employed face-to-face personal interviews using questionnaires which compound sections providing the economic characteristics, practices and management of the farm. The data have been collected from 65 farmers representing 5% of greenhouse vegetable growers from the six most productive municipalities, namely: M'ziraa, Ainnaga, Sidi Okba, Elaghrous, Doucen and Lioua (Fig.1). In this area, the vegetables produced most extensively are tomato, cucumber, eggplant and pepper.

Energy input-output measurement

Energy requirements in agriculture are divided into two groups, direct and indirect *(Samavatean, 2011)*. In this study, direct energy includes human labour, diesel, water for irrigation and indirect energy includes seeds, fertilizers, Farmyard manure, chemicals, machinery and infrastructure. Based on the energy equivalents of the inputs and outputs (Table 1), the metabolisable energy was calculated. Renewable energy (RE) consists of human labour, seed, manure and water for irrigation, whereas non-renewable energy (NRE) includes machinery, diesel fuel, electricity, infrastructure, fertilizers and chemicals.

To analyse the energy flow, energy ratio (energy use efficiency) (ER), energy net (EN) and energy productivity (EP) indexes were calculated as following*:*

$$Output-input\ ratio\left(ER\right)=\frac{Energy\ output\ \text{[MJ/ha]}}{Energy\ input\ \text{[MJ/ha]}} \tag{1}$$

$$Energy\ productivity\ (EP)\ \text{[kg/MJ]}=\frac{Total\ output\ \text{[kg/ha]}}{Energy\ input\ \text{[MJ/ha]}} \tag{2}$$

$$Energy\ Net\left(EN\right)\text{[MJ/ha]}=Energy\ output\,\text{[MJ/ha]}-Energy\ input\ \text{[MJ/ha]} \tag{3}$$

$$Specific\ energy\,\text{[MJ/kg]}=\frac{Energy\ input\ \text{[MJ/ha]}}{vegetable\ output\ \text{[kg/ha]}} \tag{4}$$

$$Energy\ intensiveness=\frac{Energy\ Input\ \text{[MJ/ha]}}{Cost\ of\ \ cultivation\ \text{[\$/ha]}} \tag{5}$$

Table 1

Energy equivalent factors used to transform the inputs and the outputs yield of the greenhouse tomato production system in Biskra region

Energy source	Unit	Energy equivalent [MJ/unit]	Reference
Inputs			
Human labour	h	1.96	*Singh et al. (2002)*
Machinery	h	62.70	*Singh et al. (2002)*

Energy source	Unit	Energy equivalent [MJ/unit]	Reference
Diesel oil	l	45.40	*Bojacá et al. (2012)*
Infrastructure	kg		
Steel		33.00	*Medina A, et al (2006)*
Polyethylene		9.90	*Medina A, et al (2006)*
Synthetic fibre		1.20	*Medina A, et al (2006)*
PVC		11.60	*Medina A, et al (2006)*
Fertilizers	kg		
N		60.60	*Ozkan et al. (2004)*
P_2O_5		11.10	*Ozkan et al. (2004)*
K_2O		6.70	*Ozkan et al. (2004)*
Farmyard manure	kg	0.30	*Bojacá et al. (2012)*
Pesticides	kg		
Fungicides		216	*Mohammadi and Omid (2010)*
Insecticides		101.20	*Mohammadi and Omid (2010)*
Plant materials			
Plantlets	unit	0.20	*Bojacá et al. (2012)*
Water for irrigation	m^3	0.63	*Bojacá et al. (2012)*
Electricity	kW h	3.60	*Ozkan et al. (2004)*
Output			
Tomato, cucumber, eggplant, pepper	kg	0.80	*Ozkan et al. (2004)*

Greenhouse production is more expensive than producing the same crop in the open field, the most important factors determining costs are depreciation of the structure and equipment, labour, energy and variable costs such as plant material, substrate and fertilizer (*Peet and Welles, 2005).* For this, the output/input analysis was also applied in economic benefits. The process was similar with energy balance analysis. The economic analysis of the investigated farmers was determined using the following indicators *(Fadavi et al., 2011):*

$$\textit{Gross value}\ [\$/\text{ha}] = \textit{vegetable yields}\ [\text{kg/ha}] \times \textit{price}\ [\$/\text{kg}] \tag{6}$$

$$\textit{Gross return}\ [\$/\text{ha}] = \textit{Total production value}\ [\$/\text{ha}] - \textit{Variable cost of production}\ [\$/\text{ha}] \tag{7}$$

$$\textit{Net return}\ [\$/\text{ha}] = \textit{Total production value}\ [\$/\text{ha}] - \textit{Total production costs}\ [\$/\text{ha}] \tag{8}$$

$$Benefit - Cost\ ratio = \frac{Total\ production\ value\ [\$/\text{ha}]}{Total\ production\ costs\ [\$/\text{ha}]} \tag{9}$$

$$Productivity\ [\text{kg}/\$] = \frac{Vegetable\ yield\ [\text{kg/ha}]}{Total\ production\ costs\ [\$/\text{ha}]} \tag{10}$$

Mechanization index estimation

Mechanization index (IM): Singh (2006) presented a definition for mechanization index based on using living thing and machine in input energy which is calculated from the relationship.

$$IM = \frac{CEM}{CEH + CEA + CEM}\ [\%] \tag{11}$$

where: *IM:* mechanization index, *CEM:* Cost of using machine, *CEH:* Cost of manpower, *CEA:* Cost of using animal power.

Machinery energy ratio (machine index), the machinery energy ratio is an index which represents the fraction of the total energy inputs through the various tools and implements used in different operations for cultivation of the particular crop. The machinery energy was determined using the following equation.

$$MER = \frac{Ed}{Te}\ [\%] \tag{12}$$

Where *MER* is the ratio of the machinery energy to the total energy input; *Ed* is the energy input through the various machines/implements; *Te* is the total energy input from human labour, animals, machine/hand tools, seed, and farm yard manures for the vegetable greenhouse production.

RESULTS

The data were collected from 65 vegetable protection growers in Biskra province. The average size of greenhouses is around 2.1 ha with a range from 0.25 up to 12.75 ha. All of the surveyed greenhouses were the plastic houses and metallic structures. Also the data showed that almost all surfaces covered by greenhouse were irrigated using drip irrigation and about 73% of visited farms were privately owned and 27% rented.

Energy inputs – outputs used analysis

The summarized information on energy use pattern and yield value of vegetable production is presented in Table 2 and along with Fig.1 gives the percentage distribution of energy inputs.

Table 2

Amounts of inputs and output energy used in protected vegetable production.

Energy source	Quantity per unit area [ha]	Total Energy equivalent [MJ/unit]
Input		
Human labour [h]	3457.03	6775.78
Machinery [h]	31.38	1967.25
Diesel oil [l]	129.02	5857.41
Infrastructure [kg]		
Steel	146.68	4840.31
Polyethylene	2082.54	20617.14
Synthetic fibre	105.81	126.97
PVC	130.82	1517.46
Fertilizers [kg]		
N	278.86	16899.13
P_2O_5	354.66	3936.76
K_2O	274.50	1839.16
Farmyard manure [kg]	47742.54	14322.76
Pesticides [kg]		
Fungicides	10.30	2224.12
Insecticides	96.47	9762.64
Plant materials		
Plantlets [units]	17232	3446.35
Water for irrigation [m^3]	3154.00	1987.02
Electricity [kW h]	6544.84	23561.42
Output		
Tomato, cucumber, eggplant, pepper [kg]	122095.24	97676.19

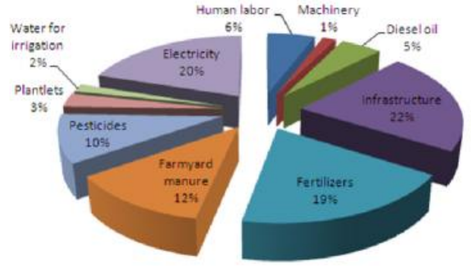

Fig. 2 - Percentage distribution of energy inputs

The results revealed that the total energy required for vegetable protected production is 119.68GJ per hectare. Compared to other study, in Turkey, the consumption of energy by cucumber, tomato, eggplants and pepper were 134.77, 127.32, 98.68 and 80.25 GJ/ha, respectively *(Ozkan et al., 2004)*. In central of Italy, the total energy requirements for producing the greenhouse vegetable crops were found in the range of 64,232–142,835 GJ/ha *(Campiglia et al., 2007).*These results indicate that the energy consumption for vegetable greenhouse production is different from one region to another with light variation. Among the different energy sources the infrastructure was the highest energy consumer followed by the electricity and fertilizers with a share of 22%, 20% and 19%, respectively. This result is in accordance with that founded by A. *Medina, et al (2006)* where the highest portion of the energy use in Colombia comes from the greenhouse construction with 41.29% of the total energy use and the major part of this energy is attributed to the steel.

The proportion of energy input of farmyard manure, pesticides, human labour, diesel oil, plantlets, water and machinery used for protected vegetable (tomato, cucumber, eggplant, pepper) growing were 12%, 10%, 6%, 5%, 3%, 2% and 1%, respectively. In similar works, in Antalya (Turkey), the results indicated that the bulk of energy consumed for greenhouse winter crop tomato production was: fertilizer (38.22%), electricity (27.09%), manure (17.33%) and diesel-oil (13.65%) *(Ozkan et al., 2011),* while, among input energy sources, diesel fuel and fertilizers contained highest energy with 54.17% - 49.02% and 21.64% - 24.01%, respectively *(Heidari and Omid, 2011).*This comparison shows that each region has specificity in terms of energy inputs sharing.

The fertilizers and manure required to fertilize the soil are48650.56 kg/ha with nearly a third of total energy consumed (31%), this observation is a common belief that increased use of fertilizer and manure will increase the yield. 3457.03 h of human power and 31.38 h of machine power are required per hectare of vegetable production in the research area. The crop itinerary is mainly similar for all the greenhouses crops moreover it is carried out generally by human labour energy (6%) compared to machinery energy (1%). The source of human labour in the investigated farms is from either family members or mainly from hired (seasonal) labours. Also, 5857,41 MJ/ha of diesel fuel was consumed generally for machinery purposes and most of the machineries are mainly provided by rent.

Table 3 presents the energy use efficiency, energy productivity, specific energy, net energy and energy intensiveness of protected vegetable production.

Table 3

Energy input–output ratio in greenhouse vegetable production

Items	**Unit**	**Protected vegetable production**
Energy input	MJ/ ha	119681,69
Energy output	MJ/ha	97676,19
Yield	Kg/ha	122095,24
Energy use efficiency	---	0.82
Specific energy	MJ/kg	0.98
Energy productivity	Kg/MJ	1,02
Net energy	MJ/ha	-22005,50
Energy intensiveness	MJ/$	2.09

Energy use efficiency (energy ratio) was calculated as 0.82, showing the inefficiency use of energy in the protected vegetable production. Other results founded for protected vegetable, such as 0.66 for tomato *(Pahlavan et al., 2011)*, 0.76 for cucumber, 0.61 for eggplant, 0.99 for pepper *(Ozkan et al., 2004),* 0.32 for tomato, 0.31 for cucumber, 0.23 for eggplant, 0.19 for pepper *(Canakci and Akinci, 2006)* have been reported for different crops, showing the inefficient use of energy, thus it is concluded that the energy ratio can be increased by raising the crop yield and/or by decreasing energy input consumption. Similar results such as 0.68 for tomato *(Bojacá et al.,2012)*, 0.69 and 1.48 for cucumber and tomato respectively *(Heidari and Omid, 2011)* 0.8 for winter crop tomato *(Ozkan et al., 2011)* were calculated*.*

The average energy productivity of protected vegetable was 1.02 kg/MJ. This means that 1.02kg of tomato, cucumber, pepper or eggplant output was obtained per unit energy. The specific energy, net energy and energy intensiveness of protected vegetable production were 0.98 MJ/kg, -22005.50 MJ/ha and 2.09 MJ/$, respectively. Net energy is negative (less than zero). Therefore, it can be concluded that in protected vegetable production, energy is being lost and this result similar to that was obtained by other researchers such as: *Ozkan et al. (2004), Canakci and Akinci (2006)* and *Pahlavan et al. (2011).* Parallel studies obtain 0.31 MJ/kg *(Ozkan et al., 2004),* 12380.3 MJ/t *(Hatirli et al., 2006)* and 0.94 kg/MJ *(Ozkan et al., 2011)* for the specific energy of corn production.

Total mean energy input as direct, indirect, renewable and non-renewable forms are given in Table 4.

Table 4

Total energy input in the form of direct, indirect, renewable and non-renewable for vegetable production

Form of energy	**[MJ/ha]**	**[%]**
Direct energy	38181.63	31.90
Indirect energy	81500.06	68.10

Renewable energy	26531.92	22.17
Non-renewable energy	93149.77	77.83

The total energy input consumed could be classified as direct energy (31.90%), indirect energy (68.10%) and renewable energy (22.17%) and non-renewable energy (77.83%). A number of resultants, in same cultivation system, revealed that for tomato in Turkey indirect energy (41.54%) is less than that of direct energy (58.18%), and renewable energy (81.60 %) is greater than that of non-renewable energy (18.12 %) *(Ozkan et al., 2011)*while for the same crop and region, the results show that the share of direct input energy was 59% in the total energy input compared to 41% for the indirect energy. On the other hand, non-renewable and renewable energy contributed to 88 and 12% of the total energy input, respectively *(Hatirli et al., 2006).*

Economic analysis

In this section, the majority of studies worked on energy balance of protected vegetable and didn't take into account the economic feature. From our perspective, the costs of each input used and calculated gross production values for protected vegetable production are shown in Table 5.

Table 5

Economic analysis of greenhouse vegetable production

Economic index	Unit	Value
Yield	Kg/ ha	122095.24
Sale price	$ /kg	0.47
Gross value	$/ ha	57384.76
Variable cost	$ /ha	24842.28
Fixed cost	$ /ha	3907.09
Total cost	$/ ha	28749.37
Cost of production	$/ kg	0.24
Gross return	$/ ha	32542.47
Net return	$ /ha	28635.39
Benefit to cost ratio		1.99
Productivity	kg /$	4.25

The result reveal that, the gross value of production is 57384.76 $/ha where the total mean costs for the production was 28749.37 $/ha. About 86.40% of the total expenditure was variable costs, while13.59 % was fixed expenditure. Several studies reported that the ratio of variable cost was higher than that of fixed cost in cropping systems *(Samavatean et al., 2011).*Starting from these results, the benefit-cost ratio from protected vegetable production in the farms was calculated to be 1.99. These results are consistent with the findings reported by *Canakci and Akinci (2006)* where the benefit/cost ratio for the tomato, pepper, cucumber and eggplant production were calculated at 1.57, 1.15, 1.29 and 1.10, respectively. On the other side, benefit/cost ratio was calculated for others crop such as 1.36 for Garlic production *(Samavatean et al., 2011),* 1.83 and 2.21 for greenhouse and open-field grape *(Ozkan et al., 2007).*Concerning the gross return, the calculation gave the result 32542.47 $/ha while for the productivity, it is 4.25 kg/$.

Mechanization index analysis

Different clusters of farm were determined basing on greenhouse area. Table 6 illustrate that Mechanization index (MI) of 0.119 is obtained for protected vegetable production in the visited region.

Table 6

Mechanization Index and Machinery energy ratio for different land size

	<1	1-<3	3-<5	>5	total
Mechanization index (MI)	0.119	0.124	0.111	0.112	0.119
Machinery energy ratio (MER)	0.008	0.012	0.007	0.017	0.010
Number of farmers	41	12	4	8	65

It seems that, the MI calculated for all clusters are almost equal with a small difference. All farmers use least machinery labour energy per hectare than the human energy labour, thus we could say that the itinerary crop is similar for all the greenhouses visited. These results could be explained by unavailability of the machine destined to greenhouse cultivation in the local market especially the planter machine, also due the finical situation of the farmer. Previous work has showed that the MI at all-India level was only 14.5% and it varied from 8.2% in sorghum and paddy to a highest value of 29.00% in wheat *(Singh, 2006).*

CONCLUSIONS

This work aimed to analyse the energy balance for the protected vegetable in Biskra province (Southern of Algeria), also to make economic analysis and determination of the mechanization index for this sector. For this reason, a survey has been conducted with 65 farmers.

The results revealed from this study could be presented as follows:

- The total energy required for vegetable protected production is 119.68 GJ per hectare which is close to that reported in previous researches *(Ozkan et al., 2004).*
- Among the different energy sources the infrastructure was the highest energy consumer followed by the electricity and fertilizers with a share of 22%, 20% and 19%, respectively.
- Each region has specificity in terms of energy inputs sharing.
- Energy use efficiency (energy ratio) was calculated as 0.82, showing the inefficiency use of energy in the protected vegetable production.
- The gross value of production is 57384.76 $/ha where the total mean costs for the production was 28749.37 $/ha. About 86.40 % of the total expenditure was variable costs, while 13.59 % was fixed expenditure.
- All farmers use least machinery labour energy per hectare compared to the human energy labour, thus we could say that the itinerary crop is similar for all the greenhouses visited.

As recommendations, the below propositions could enhance the control of energy flow in protected vegetable production and also allow the farmer to improve their financial situation, namely:

- Providing a formation, by a qualified employer, to farmers for changing their wrong behaviours and the controlled input;
- Improving the pest management using an integrated fighting method (IPM);
- Elaboration of a strategy to introduce the machine for carrying out the farm operation and to promote the farm machinery.

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