Energy input-output analysis and mechanization status estimation for greenhouse vegetable production in Biskra province (Algeria)

Article *in* Agricultural Engineering International : The CIGR e-journal · December 2017

Ahmed Nourani
Centre de Recherche Scientifique et Technique sur les Régions Arides (CRSTRA)

Energy input-output analysis and mechanization status estimation for greenhouse vegetable production in Biskra province (Algeria)

Ahmed Nourani*, AbdelaaliBencheikh

(*Scientific and Technical Research Center on Arid Regions (CRSTRA), 07000, Biskra, Algeria*)

Abstract: Algeria has experienced a notable agricultural development driven by a prosperous in market gardening in plastic greenhouses due of the favorable climatic conditions and the government's policy. A survey has been conducted in Biskra province, southern of Algeria in order to determine input-output energy used and to estimate the mechanization status for the greenhouse vegetable production. The results revealed that the total energy required for vegetable protected production was 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 (energy ratio) was calculated as 0.82, showing the inefficiency use of energy in the protected vegetable production. The entire farmers use least machinery labor energy in hectare compared to the human energy labor as well asthe itinerary crop was similar for all greenhouses visited.

Keywords: protected vegetable,greenhouse, input-output analysis, mechanization-Biskra

Citation: Nourani, A., and A. Bencheikh. 2017. Energy input-output analysis and mechanization status estimation for greenhouse vegetable production in Biskra province (Algeria). Agricultural Engineering International: CIGR Journal, 19(4): 76–82.

1 Introduction

During the last two decades, Algeria has experienced a notable agricultural development driven by a prosperous in market gardening under greenhouses due to the favorable 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 covered by the greenhouse has increased by 528.52% over the last 20 years (Belhadi et al., 2016).

In consideration of the 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 been emphasized on energy and economic analysis of various agricultural productions for planning resources in the ecosystem (Singh et al., 2002). Several works across the world have been conducted to estimate the energy used in greenhouse vegetable production, such as: Ozkan et al. (2004), Elings et al. (2005), Campiglia et al. (2007), Djevic and Dimitrijevic (2009), Mohammadi et al. (2010), Ozkan et al. (2011), Pahlavan et al. (2011), Heidari and Omid (2011), Bojacá et al. (2012), Baptista et al. (2012), Zarini et al. (2013) and Hedauet al. (2014). However, no studies have been published on energy input – output analysis and the mechanization status estimation of greenhouse vegetable production in Algeria.

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

2 Materials and methods

2.1 Study area

According to Rekibi (2015), Biskra province provides over 32% of national production of protected crops which make it the first producer of early vegetable in Algeria.

Received date: 2016-12-15 **Accepted date:** 2017-04-06

* **Corresponding author: A. Nourani,** Scientific and Technical Research Center on Arid Regions (CRSTRA), Biskra, Algeria. Email: nourani83@ gmail.com.

For this reason, the present research has been carried out in this region. The study area is located in the southeastern of 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 and its surface area is 21671 km^2, divided to 12 administrative districts (Figure 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 every year. The average annual temperature is 20.9°C.

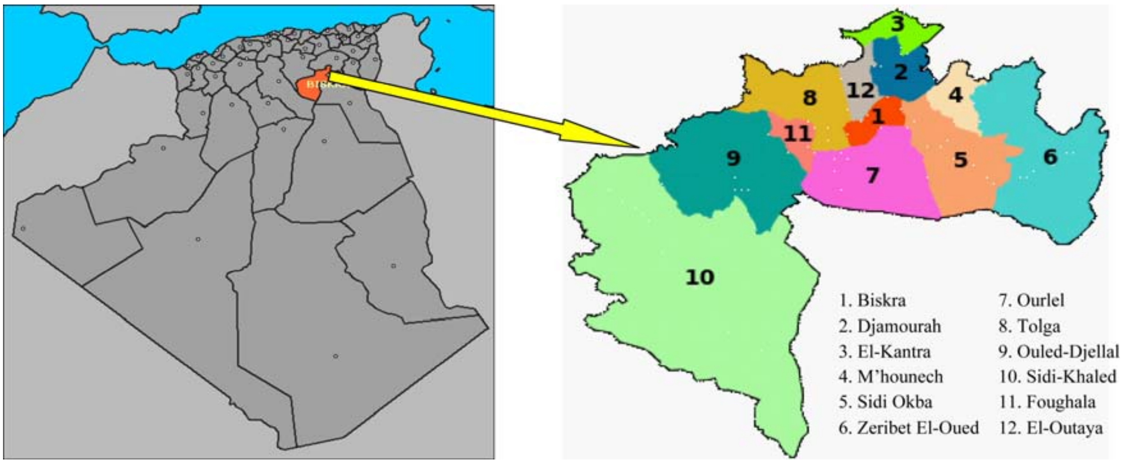

Figure 1 Situation of study area

2.2 Survey

An investigation was conducted in Biskra province during the season 2014-2015. The study employed face-to-face personal interviews using questionnaires which contained sections providing the economic characteristics, practices and management of the farm. The data have been collected from 65 farmers where randomly selected. They present 5% of greenhouse vegetable growers (DSA, 2012) from the six most productive municipalities, namely: M'ziraa, Ainnaga, SidiOkba, Elaghrous, Doucen and Lioua (Figure 1). In this area, the vegetables produced most extensively were tomato, cucumber, eggplant and pepper.

2.3 Energy input-output measurement

Energy requirements in agriculture were divided into two groups, direct and indirect (Samavatean, 2011). In this study, direct energy included human labor, 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) consisted of human labor, seed, manure and water for irrigation, whereas non-renewable energy (NRE) includes machinery, diesel fuel, electricity, infrastructure, fertilizers and chemicals.

Table 1 Energy equivalent of inputs and output in agricultural production

Energy source	Unit	Energy equivalent, Mj/unit	Reference
Inputs			
Human labor	h	1.96	Singh et al. (2002)
Machinery	h	62.7	Singh et al. (2002)
Diesel oil	l	45.4	Bojacá et al. (2012)
Infrastructure	kg		
Steel		33	Medina A et al. (2006)
Polyethylene		9.9	Medina Aet al. (2006)
Synthetic fiber		1.2	Medina Aet al. (2006)
PVC		11.6	Medina Aet al. (2006)
Fertilizers	kg		
N		60.6	Ozkan et al. (2004)
P_2O_5		11.1	Ozkan et al. (2004)
K_2O		6.7	Ozkan et al. (2004)
Farmyard manure	kg	0.3	Bojacá et al. (2012)
Pesticides	kg		
Fungicides		216	Mohammadi and Omid (2010)
Insecticides		101.2	Mohammadi and Omid (2010)
Plant materials			
Plantlets	unit	0.2	Bojacá et al. (2012)
Water for irrigation	m^3	0.63	Bojacá et al. (2012)
Electricity	(kW h)	3.6	Ozkan et al. (2004)
Output			
Tomato, cucumber, eggplant, pepper	kg	0.8	Ozkan et al. (2004)

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

$$\text{Output} - \text{input ratio (ER)} = \frac{\text{Energy output (MJ/ha)}}{\text{Energy intput (MJ/ha)}} \quad (1)$$

$$\text{Energy productivity (EP)} = \frac{\text{Total output (kg/ha)}}{\text{Energy intput (MJ/ha)}} \quad (2)$$

$$\begin{aligned}&\text{Energy net (EN)} = \\ &\text{Energy output (MJ/ha)} - \text{Energy intput (MJ/ha)}\end{aligned} \quad (3)$$

$$\text{Specific energy} = \frac{\text{Energy intput (MJ/ha)}}{\text{Vegetable output (kg/ha)}} \quad (4)$$

$$\text{Energy intensiveness} = \frac{\text{Energy intput (MJ/ha)}}{\text{Cost of cultivation (\$/ha)}} \quad (5)$$

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, labor, energy and variable costs such as plant material, substrate and fertilizer (Peet and Welles, 2005). For this reason, 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):

$$\text{Gross value} = \text{vegetable yields (kg/ha)} \times \text{price (\$/kg)} \quad (6)$$

$$\begin{aligned}\text{Gross return} = \text{Total production value (\$/ha)} - \\ \text{Variable cost of production (\$/h)}\end{aligned} \quad (7)$$

$$\begin{aligned}\text{Net return} = \text{Total production value (\$/ha)} - \\ \text{Total production costs (\$/h)}\end{aligned} \quad (8)$$

$$\text{Benefit} - \text{cost ratio} = \frac{\text{Total production value (\$/ha)}}{\text{Total production costs (ha)}} \quad (9)$$

$$\text{Productivity} = \frac{\text{Vegetable yield (kg/ha)}}{\text{Total production costs (ha)}} \quad (10)$$

2.4 Mechanization status estimation

Degree of mechanization, the mechanization index and machinery energy ratio are internationally accepted as indicators of mechanization status (Samavatean, 2011).

Degree of mechanization (MD) is the index which examines the quantity in mechanization problems and is defined as the mechanized performances to total needed mechanized performances or the area in which the mechanized performances are applied to the total area. Regarding specifically, we can consider the mechanization degree as a quantity index comparable with different levels of mechanization degree. This index has a wide application in the growth of mechanization in different years or in comparing the mechanization degree of different operations along with great influence on analyzing the causes.

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.

$$IM = \frac{CEM}{CEH + CEA + CEM} \quad (11)$$

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

2.5 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 (Yadav et al., 2013). The machinery energy was determined using the following equation (12).

$$MER = \frac{Ed}{Te} \quad (12)$$

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

3 Results and discussion

The data were collected from 65 greenhouse vegetable growers in Biskra province. The average size of greenhouses was 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 most of the superficies covered by greenhouses were irrigated using a drip irrigation and about 73% of visited farms were privately owned and 27% were rented.

3.1 Energy inputs – outputs used analysis

The summarized information on energy use pattern and yield value of vegetable production was presented in Table 2.

Table 2 Amounts of inputs and output energy in protected vegetable production

Energy source	Quantity per unit area, ha	Total Energy equivalent, MJ/unit	Percentage distribution
Input			
Human labor (h)	3 457.03	6 775.78	6%
Machinery (h)	31.38	1 967.25	1%
Diesel oil (l)	129.02	5 857.41	5%
Infrastructure (kg)			22%
Steel	146.68	4 840.31	
Polyethylene	2 082.54	20 617.14	
Synthetic fiber	105.81	126.97	
PVC	130.82	1 517.46	
Fertilizers (kg)			19%
N	278.86	16 899.13	
P_2O_5	354.66	3 936.76	
K_2O	274.5	1 839.16	
Farmyard manure (kg)	47 742.54	14 322.76	12%
Pesticides (kg)			10%
Fungicides	10.3	2 224.12	
Insecticides	96.47	9 762.64	
Plant materials			3%
Plantlets (units)	17232	3 446.35	
Water for irrigation (m^3)	3 154.00	1 987.02	2%
Electricity (kW h)	6 544.84	23 561.42	20%
Output			
Tomato, cucumber, eggplant, pepper(kg)	122 095.24	97 676.19	

The results revealed that the total energy required for vegetable protected production was119.68 GJ per hectare. Compared to the 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^{-1}, respectively (Ozkan et al., 2004). In central of Italy, the total energy requirements for producing the greenhouse vegetable crops were found in the range from 64.232 to 142.835 GJ ha^{-1} (Campiglia et al., 2007). These results indicated that the energy consumption for vegetable greenhouse production was different from the region to other 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 was in accordance with that the highest portion of the energy used in Colombia was the greenhouse construction (41.29% of the total energy) and the major part of this energy was attributed to the steel (Medina et al., 2006).

The proportion of energy input of farmyard manure, pesticides, human labor, 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 greenhouse winter crop tomato production was consumed in fertilizer (38.22%), electricity (27.09%), manure (17.33%) and diesel-oil (13.65%) (Ozkan et al., 2011). Moreover, 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 showed that each region had specificity in terms of energy inputs sharing.

The fertilizers and manure required to fertilize the soil was 48650.56 kg ha^{-1} with nearly a third of total energy consumed (31%). This observation was 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 were required per hectare of vegetable production in the research area. The crop itinerary was mainly similar for all the greenhouses crops. Moreover, it carried out generally by human labor energy (6%) compared to machinery energy (1%). The source of human labor in the investigated farms was from either family members or mainly from hired (seasonal) labors. Also, 5857.41 MJ ha^{-1} of diesel fuel was consumed generally for machinery purposes and most of the machineries were mainly provided by rent.

The table 3 presented the energy use efficiency, energy productivity, specific energy, energy net and energy intensiveness of vegetable protected production.

Table 3 Energy input–output ratio in greenhouse vegetable production

Items	Unit	Protected vegetable production
Energy input	MJ ha^{-1}	119681.69
Energy output	MJ ha^{-1}	97676.19
Yield	Kg ha^{-1}	122095.24
Energy use efficiency	---	0.82
Specific energy	MJ kg^{-1}	0.98
Energy productivity	Kg MJ^{-1}	1.02
Energy net	MJ ha^{-1}	–22005.50
Energy intensiveness	MJ \$$^{-1}$	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 found 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 could be concluded that the energy ratio could 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), for cucumber and tomato were calculated as 0.69 and 1.48, (Heidari and Omid, 2011) and 0.8 for winter crop tomato (Ozkan et al., 2011).

The average energy productivity of protected vegetable was 1.02 kg MJ^{-1}. This meant that 1.02 kg of tomato, cucumber and 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^{-1}, –22005.50 MJ ha^{-1} and 2.09 MJ \$$^{-1}$, respectively. Energy net was negative (less than zero). Therefore, it could be concluded that in vegetable protected production, energy was being lost and this result was similar to that obtained by other researchers such as Ozkan et al. (2004), Canakci and Akinci (2006) and Pahlavan et al. (2011). Parallel studies obtained 0.31 MJ kg^{-1} (Ozkan et al., 2004), 12380.3 MJ t^{-1} (Hatirli et al., 2006) and 0.94 kg MJ^{-1} (Ozkan et al., 2011) for the specific energy of corn production.

Total mean energy input as direct, indirect, renewable and nonrenewable forms were 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^{-1}	%
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, raveled that for tomato in Turkey indirect energy (41.54%) was less than that of direct energy (58.18%), and renewable energy (81.60%) was greater than non-renewable of energy (18.12%) (Ozkan et al., 2011) while for the same crop and region, the results showed 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).

3.2 Economic analysis

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

Table 5 Economic analysis of greenhouse vegetable production

Economic index	Unit	Value
Yield	Kg ha^{-1}	122095.24
Sale price	\$ kg^{-1}	0.47
Gross value	\$ ha^{-1}	57384.76
Variable cost	\$ ha^{-1}	24842.28
Fixed cost	\$ ha^{-1}	3907.09
Total cost	\$ ha^{-1}	28749.37
Cost of production	\$ kg^{-1}	0.24
Gross return	\$ ha^{-1}	32542.47
Net return	\$ ha^{-1}	28635.39
Benefit to cost ratio		1.99
Productivity	kg \$$^{-1}$	4.25

The result revealed that, the gross value of production was 57384.76 \$ ha^{-1} where the total mean costs for the production was 28749.37 \$ ha^{-1}. 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 were consistent with the findings reported by Canakci and Akinci (2006) that 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. In other side, benefit/cost ratio was calculated for other crops 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 given the number 32542.47 \$ ha^{-1} while for the productivity, it is 4.25 kg \$$^{-1}$.

3.3 Mechanization status analysis

Different clusters of farm were determined basing on greenhouse area. Table 6 presented the rate of MD in percent for each machinery operations during the vegetable cultivation in different clusters, separately.

Table 6 Share of MD to total operations in greenhouse vegetable production

Implement	<1 (ha)	1-<3 (ha)	3-<5 (ha)	5< (ha)	Total
Moldboard plow	100	100	100	100	100
Disc harrow	93	100	100	100	95.38
Rotary hoe	2	25	0	62.5	14
Ridgerplough	73	67	25	50	66
Planter machine	0	0	0	0	0
Pesticides sprayer	100	100	100	100	100

As shown in Table 6, the heights mechanization degree was related to moldboard plow and pesticides sprayer. The entire plowing and pest treatment operations were100% in the area investigated. This result showed that the 100% of operations were carried out by machinery for protected vegetable production for 130.05 hectares. Then, the operations of harrowing, rotary hoe and making ridges were done. The greatest mechanization degree has been recorded in the farm with land area over five hectares which was due to frequently using machinery and farms with land area below one hectare had lowest M.D with the exception of fertilization because of using of drip irrigation (Table 6). Moreover, the majority of the farmers used the ridgerplough. This operation required a considerable energy and time, as an advice, the making ridges was not necessary when they set up a drip irrigation system.

Table 7 illustrated that MI was obtained 0.119 for protected vegetable production in visited region. It seemed that the MI calculated for all clusters were almost equal with a small difference. The entire farmers used less machinery labor energy in hectare than the human energy labor. Thus, it could be concluded that the itinerary crop was 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 to the finical situation of the farmer. Previous work showed that the MI at an 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).

Table 7 Mechanization Index and Machinery energy ratio for different land size

	<1 (ha)	1-<3 (ha)	3-<5 (ha)	>5 (ha)	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

4 Conclusion and recommendation

This work aimed to analysis the energy input-output for the vegetable under greenhouse in Biskra province (Southern of Algeria), also to make economic analysis and determination the mechanization status for this sector. A survey has been conducted with 65 farmers. The results from this study could be presented as follows:

- The total energy required for vegetable protected production was119.68 GJ per hectare which was close to that reported in previous study (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 was 57384.76 \$ ha^{-1} where the total mean costs for the production was 28749.37 \$ ha^{-1}. About 86.40% of the total expenditure was variable costs, while 13.59% was fixed expenditure.
- The entire farmers used less machinery labor energy in hectare compared to the human energy labor, thus we could say that the itinerary crop was 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 behaviors and the controlled input. Improving the pest management used an integrated fighting method (IPM). Elaborated a strategy to introduce the machine for carrying out the farm operation and promote the farm machinery.

Acknowledgement

This research was financially supported by the Scientific and Technical Research Centre for Arid Areas (CRSTRA), Biskra, Algeria. Gratitude is expressed to the agricultural specialist for their help in this work. Special thanks are extended to the farmers contributed in this survey.

References

Allache, F., Y. Boutaand, and F. Demnati. 2015. Population development of the tomato moth *Tutaabsoluta* (Lepidoptera: Gelechiidae) in greenhouse tomato in Biskra, Algeria. *Journal of Crop Protection.* 4(4): 509–517.

Baptista, F. J., A. T. Silva, L. M. Navas, A. C. Guimarães, and J. F. Meneses. 2012. Greenhouse energy consumption for tomato production in the Iberian Peninsula countries. In *Proc. International Symposium on Advanced Technologies and Management towards Sustainable Greenhouse Ecosystems: Greensys 2011 952*, 409–416. Athens, Greece, 5-10 June.

Belhadi, A., M. Mehenni, L. Reguieg, and, and H. Yekhlef. 2016. Plasticulture contribution to agricultural dynamism in the ziban region (biskra). *Revue Agriculture,* Numéro special, (1): 93–99.

Bojacá, C. R., H. A. Casilimas, R. Gil, and E. Schrevens. 2012. Extending the input/output energy balance methodology in agriculture through cluster analysis. *Energy*, 47(1): 465–470.

Campiglia, E., G. Colla, R. Mancinelli, Y. Rouphael, and A. Marucci. 2007. Energy balance of intensive vegetable cropping systems in central Italy. In *Proc. VIIIth IS on Protected Cultivation in Mild Winter Climates,* 185–191. Agadir, Morocco, 19 February.

Canakci, M., and I. Akinci. 2006. Energy use pattern analyses of greenhouse vegetable production. *Energy,* 31(8): 1243–1256.

DSA. 2012. *Direction des services agricoles*. Biskra province.

Djevic, M., and A. Dimitrijevic. 2009. Energy consumption for different greenhouse constructions. *Energy*, 34(9): 1325–1331.

Elings, A., F. L. K. Kempkes, R. C. Kaarsemaker, M. N. A. Ruijs, N. J. van de Braak, and T. A. Dueck. 2005. The energy balance and energy-saving measures in greenhouse tomato cultivation. In *Proc. IC on Greensys.* 67–74. Leuven, Belgium, 12 September 2004.

Fadavi, R., A. Keyhani, and S. S. Mohtasebi. 2011. An analysis of energy use, input costs and relation between energy inputs and yield of apple orchard. *Research in Agricultural Engineering*, 57(3): 88–96.

Hatirli, S. A., B. Ozkan, and C. Fert. 2006. Energy inputs and crop yield relationship in greenhouse tomato production. *Renewable Energy,* 31(4): 427–438.

Hedau, N. K., M. D. Tuti, J. Stanley, B. L. Mina, P. K. Agrawal, J. K. Bisht, and J. C. Bhatt. 2014. Energy-use efficiency and economic analysis of vegetable cropping sequences under greenhouse condition. *Energy Efficiency,* 7(3): 507–516.

Heidari, M. D., and M. Omid. 2011. Energy use patterns and econometric models of major greenhouse vegetable productions in Iran. *Energy,* 36(1): 220–225.

Medina, A., A. Cooman, C. A. Parrado, and E. Schrevens. 2006. Evaluation of energy use and some environmental impacts for greenhouse tomato production in the high altitude tropics. In *Proc. IIIrd IS on HORTIMODEL2006,* 415–422. Wageningen, Netherlands, 29 October.

Mohammadi, A., and M. Omid. 2010. Economical analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran, *Applied Energy,* 87(1): 191–196.

Ozkan, B., A. Kurklu, and H. Akcaoz. 2004. An input--output energy analysis in greenhouse vegetable production:a case study for Antalya region of Turkey. *Biomass Bioenergy,* 26(1): 189–195.

Ozkan, B., R. F. Ceylan, and H. Kizilay. 2011. Comparison of energy inputs in glasshouse double crop (fall and summer crops) tomato production. *Renewable Energy,* 36(5): 1639–1644.

Pahlavan, R., M. Omid, and A. Akram. 2011. Energy use efficiency in greenhouse tomato production in Iran. *Energy,* 36(12): 6714–6719.

Peet, M. M., and G. Welles. 2005. Greenhouse tomato production. In *Tomatoes*, ed. E. Heuvelink, ch. 9, 275-304. Wageningen University, The Netherlands: CABI publishing.

Rafiee, S., S. H. Mousavi avval, and A. Mohammadi. 2010. Modeling and sensitivity analysis of energy inputs forapple production in Iran. *Energy*, 35(8): 3301–3306.

Rekibi, F. 2015. Analyse compétitive de la filière tomate sous serre. Cas de la Wilaya de Biskra. M.S. thesis. Biskra: Mohamed Kheider University.

Samavatean, N., S. Rafiee, and H. Mobli. 2011. An analysis of energy use and estimation of a mechanization index of garlic production in Iran. *Journal of Agricultural Science,* 3(2): 198–205.

Singh, H., D. Mishra, and N. M. Nahar. 2002. Energy use pattern in production agriculture of a typical village in arid zone India-Part I. *Energy Conversion Manage*, 43(16): 2275–2286.

Singh, G. 2006. Estimation of a mechanization index and its impact on production and economic factors a case study in India. *Biosystems Engineering,* 93(1): 99–106.

Yadav, S. N., R. Chandra, T. K. Khura, and N. S. Chauhan. 2013. Energy input–output analysis and mechanization status for cultivation of rice and maize crops in Sikkim. *CIGR Journal,* 15(3): 108–116.

Zarini, R. L., A. Ghasempour, and S. M. Mostafavi. 2013. A comparative study on energy use of greenhouse and open-field cucumber production systems in Iran. *International Journal of Agriculture and Crop Sciences,* 5(13): 1437–1441.

Zella, L., and D. Smadhi. 2009. Micro irrigation of tomato under greenhouse. *Courrier du Savoir,* 09(Marsh 2009): 119–126.