

# Effect of Different Heating Systems in Cucumber Production Greenhouses in Varamin Region on Crop Yield, Volume and Cost of Gas Consumed

Majid Rashidi

*Greenhouse Cultivation Research Department, Tehran Agricultural and Natural Resources Research and Education Center, Agricultural Research, Education and Extension Organization (AREEO), Varamin, Iran*

**Abstract:** This research was conducted to study the effect of different heating systems in cucumber production greenhouses in Varamin region, Tehran province, Iran on crop yield, volume and cost of gas consumed. Three types of conventional heating systems, namely the central heating system (including boiler + hot water pipes), gas heater system (including double-walled tank + blower) and traditional furnace system (including ignition chamber + torch + pipes carrying a mixture of hot air and flammable gases) were studied during two consecutive periods of greenhouse cucumber cultivation in the cold season (from January to June), and average values of crop yield, volume and cost of gas consumed were determined separately. Results of the study indicated that the central heating system with the highest crop yield ( $295 \text{ t}\cdot\text{ha}^{-1}$ ), and the lowest volume ( $100,000 \text{ m}^3\cdot\text{ha}^{-1}$ ) and cost ( $210,000,000 \text{ Rials}\cdot\text{ha}^{-1}$ ) of gas consumed was the best and most suitable heating system for greenhouses producing cucumbers in Varamin region and other regions with the same and similar climate as well as regions with active greenhouses in the cold season.

**Key words:** Greenhouse, heating systems, greenhouse cucumber, crop yield, gas consumed, Varamin, Iran.

## 1. Introduction

Greenhouse cultivation that has grown significantly in recent years requires more energy due to the nature of off-season production. Therefore, increasing energy efficiency in greenhouse crops is one of the most important research priorities in the agricultural sector and any success in increasing energy efficiency in greenhouse crops can lead to optimal use from valuable energy sources [1].

The many advantages of controlled greenhouse cultivation conditions for the production of some vegetable crops (such as cucumber, tomato, eggplant and pepper) have made the study of optimal greenhouse management methods one of the priorities of the Fourth Iran Development Plan. Despite the

many benefits of greenhouse cultivation, high-energy consumption in greenhouses, especially in the cold season, on one hand, and the elimination of subsidies for energy carriers, on the other hand, increase the cost of energy carriers, which reduces producer (greenhouse owner) income. If appropriate methods (such as selecting the suitable heating system) are not taken to increase energy efficiency in the greenhouse, only by increasing the price of the product, greenhouse cultivation of crops can be continued, which is not a scientific and economic solution [2].

According to one of the latest reports of the Statistics Center of Iran, in 2015, out of about 2.68 million hectares of gardens in the country (both fertile and infertile), about 8,000 hectares, equivalent to 0.3%, are allocated to greenhouse crops, which is 100% fertile. Among them, the area under cultivation (of the total area of greenhouses) is 74.8% cucumbers, 7.4% tomatoes, 5.2% peppers, 1.7% eggplants, 4.3% vegetables, 3.8% strawberries, 0.5% medicinal plants

---

**Corresponding author:** Majid Rashidi, Ph.D., assistant professor, research fields: greenhouse engineering, power and machinery, post-harvest biology and technology, soil dynamic in tillage and traction, soil and machine interaction, tillage and precision farming.

and 2.3% other products. The highest cultivation area of greenhouse crops in the country belongs to Tehran province with 23.3%, southern Kerman province with 19.1% and Yazd province with 17%. These three provinces together occupy 59.4% of the country's greenhouse area [2, 3].

In addition, out of a total of 19.38 million tons of horticultural production in 2015, about 1.73 million tons, equivalent to 8.92%, are related to greenhouse products. From the production of 1.73 million tons of greenhouse products in the mentioned year, the amount of cucumber production is 84.1%, tomatoes 8.7%, peppers 3.1%, eggplant 1.1%, vegetables 1.9%, strawberries 0.8%, medicinal plants 0.2% and other crops 0.1% of the total production of greenhouse crops. The highest production of greenhouse products in the country belongs to Tehran province with 29.2%, Yazd province with 22.1% and the south of Kerman province with 17%. These three provinces together account for 68.3% of greenhouse crop production [2, 3].

According to the same statistics, Tehran province, with about 1,800 hectares of greenhouses, which have been built mainly in Pakdasht, Varamin and Pishva counties, ranks first in the country in terms of both size and development of greenhouses. The province also produces more than half a million tons of greenhouse products, ranking first in the country in terms of greenhouse production. About 85% of the total area of greenhouses in Tehran province is allocated to greenhouse cucumber, about 10% to tomatoes and about 5% to peppers, eggplants, vegetables, strawberries, medicinal plants and other products [2].

De Cock and Van Lierde [4] analyzed energy consumption in Belgian greenhouses. They found that the amount of fuel consumed per square meter of greenhouse is more affected by the price of fuel and the temperature of the air outside the greenhouse. According to Dalgaard [5], agriculture seeks to develop methods of production that increase crop yields while reducing consumption of energy and fossil fuels. In this regard, Saye, et al. [6] conducted a

study to reduce the consumption of fossil fuels to zero. They studied a combination of greenhouses with a combination of low consumption, recycling and energy storage, and recommended the use of new building materials and the use of dehumidifiers and heat pumps.

In the principles of modern agriculture, the old principles that did not pay attention to energy consumption and only aimed to increase crop yield, are obsolete and the amount of production and crop yield is measured based on efficiency and energy consumption. In addition, the most important goal of modern agriculture is the optimal and sustainable use of energy resources in order to preserve these resources for future generations and reduce the environmental effects of improper and inappropriate energy consumption [7].

Sherafati [8] studied energy efficiency indices of cucumber production in greenhouses in Tehran province and found that the total energy consumption for the production of greenhouse cucumber in Tehran province is equal to  $6,612,592 \text{ MJ}\cdot\text{ha}^{-1}$ , and 97.7% of this amount has been spent on heating greenhouses. Also, Mohammadi and Omid [9] in economic analysis and study of energy consumption and calculation of productivity in 43 greenhouses for greenhouse cucumber production in Tehran province, estimated energy consumption of  $148,836.76 \text{ MJ}\cdot\text{ha}^{-1}$  that diesel fuel (heating) consumption with 41.94% ( $62,422.14 \text{ MJ}\cdot\text{ha}^{-1}$ ) and chemical fertilizer with 19.69% ( $29,305.96 \text{ MJ}\cdot\text{ha}^{-1}$ ) had the highest share. Moreover, Taki, et al. [10] in the analysis of energy efficiency in the production of greenhouse cucumber in Shahreza city in Isfahan province, found that fuel (heating) with 47% and water (irrigation) with 1.2% had the highest and lowest energy consumption, respectively.

Agha-Alikhani, et al. [11] in comparing the type and amount of energy inputs and determining energy efficiency in tomato production greenhouses in Hamadan province and Jiroft region showed that the total energy consumption for the production of

greenhouse tomatoes in Hamadan province and Jiroft region was equal to 133,896 and 145,957 MJ·ha<sup>-1</sup>, respectively. The highest energy consumption among tomato production inputs in the two regions was related to fossil fuels (heating) and chemical fertilizers, respectively.

Rostami, et al. [12] in their research by preparing a questionnaire and completing it through face-to-face interviews with local farmers studied energy indices for the production of non-greenhouse cucumber in Borujen city. The results of their research showed that the total amount of energy consumed in the production of non-greenhouse cucumber is 290.7 GJ·ha<sup>-1</sup>, in which irrigation operations with 83.56% of the total energy consumption had the highest energy consumption.

Ahmadbeigi, et al. [13] in another study that included 25 greenhouse production units determined the energy indices of greenhouse cucumber production in Qazvin province. The results of study showed that the highest part of energy consumption for the production of greenhouse cucumber was related to fuel energy (64,981 MJ·ha<sup>-1</sup>). After fuel energy, the highest consumption in all greenhouses was related to electricity (23,841 MJ·ha<sup>-1</sup>). Likewise, Momeni [1] in his research to evaluate the energy consumption indices of greenhouse cucumber production in the south of Kerman province, by preparing a questionnaire and completing it by referring to 30 greenhouses in six southern cities of Kerman province showed that the energy consumption for the production of greenhouse cucumber in the south of Kerman province is equal to 2,057,973 MJ·ha<sup>-1</sup>, of which 1,751,829 MJ·ha<sup>-1</sup>, i.e. 85.1% has been spent on greenhouse heating.

## **2. Materials and Methods**

### *2.1 Heating Systems*

Three types of conventional heating systems in cucumber production greenhouses in Varamin region, Tehran province, Iran, namely the central heating

system including boiler + hot water pipes (Fig. 1), gas heater system including double-walled tank + blower (Fig. 2), and traditional furnace system including ignition chamber + torch + pipes carrying a mixture of hot air and flammable gases (Fig. 3) were studied during two consecutive periods of greenhouse cucumber cultivation in the cold season (from January to June 2018 and 2019).

### *2.2 Research Method*

Three metal greenhouse units produce greenhouse cucumber in Varamin region, Tehran province, Iran, which were approximately the same in terms of location, hall design, area, volume of greenhouse space and other parameters affecting heating energy consumption, but have three different types of conventional heating systems in the region were selected. Average values of crop yield, volume and cost of gas consumed corresponding to each of these three heating systems during two consecutive periods of greenhouse cucumber cultivation in the cold season (from January to June) were separately determined, and by comparing the obtained results, the most efficient heating system was introduced.

### *2.3 Greenhouses*

It is worth mentioning that all three greenhouse units used in this research, in addition to location, hall design, area, volume of greenhouse space and other parameters affecting energy consumption, in terms of structural parts, type of cover, length, width of span, column height, the height of greenhouse and other specifications were the same and only different in terms of the heating systems used. The specifications of all three greenhouse units used in this research are shown in Table 1.

### *2.4 Measuring Crop Yield*

To determine the yield of product (greenhouse cucumber), the necessary information was directly measured and the crop yield was determined.



**Fig. 1** Greenhouse with central heating system.



**Fig. 2** Greenhouse with gas heater system.



**Fig. 3** Greenhouse with traditional furnace system.

**Table 1** The specifications of all three greenhouse units used in this research.

Specifications	Description/amount
Type of greenhouses	Metal units
Structure material	Galvanized steel
Type of cover	Plastic film
Length (m)	45.5
Width (m)	22.0
Height of columns (m)	3.0
Height of greenhouse (m)	4.7

### 2.5 Measuring Gas Consumed

Given that the fuel consumed in all three types of heating systems is urban natural gas, the necessary information for measuring gas consumed by each heating system is collected from an independent and separate gas meter related to that greenhouse unit. It is worth mentioning that due to the considerable amount of gas consumed in the greenhouses of the region in the cold season, all gas meters, in addition to having a special seal, are located in the gas station of the complex, in such a way that only the reading officer of the National Gas Company has the opportunity to access the gas meters and record the relevant numbers and data. This issue, in addition to reassuring the National Gas Company of accurate calculation of the cost of gas consumed by customers (greenhouse owners), creates an important advantage that the recorded data related to the gas consumed of each heating systems have the necessary accuracy and sufficient reliability to conduct this research.

### 2.6 Statistical Analysis

Due to the fact that the research project was similar to the mechanization index determination projects in terms of structure and did not have any treatment, it did not need a statistical design, analysis of variance, and comparison of means, and finally after determining the average values of crop yield, volume and cost of gas consumed corresponding to each of three heating systems, they had been compared and evaluated, and the most suitable heating system for greenhouses producing greenhouse cucumber and

similar products (tomato, eggplant and pepper) in Varamin region and other regions with the same or similar climate, and also regions with active greenhouses in the cold season were introduced.

## 3. Results and Discussion

### 3.1 Crop Yield

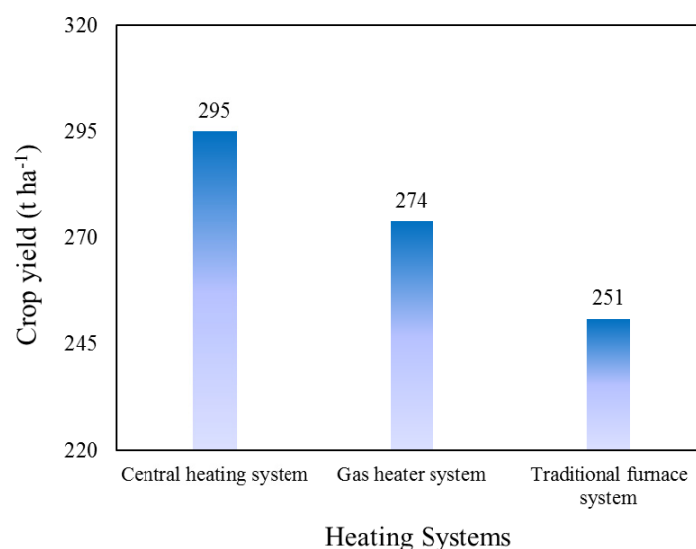
Average crop yields in two consecutive periods of greenhouse cucumber cultivation in the cold season (from January to June 2018 and 2019) under the influence of three conventional heating systems in greenhouses producing greenhouse cucumber in Varamin region, namely central heating system, gas heater system and traditional furnace system are shown in Table 2 and Fig. 4.

The results show that the greenhouse equipped with central heating system with an average yield of 295 tons per hectare has the highest crop yield and the greenhouse with traditional furnace system with an average yield of 251 tons per hectare has the lowest crop yield. It should be noted that the greenhouse equipped with gas heater system with an average yield of 274 tons per hectare in terms of crop yield is between greenhouses with central heating system and traditional furnace system.

Carefully in the results of crop yield, it can be seen that the use of central heating system in comparison with gas heater system, increases crop yield by 21 tons per hectare or 7.7% increase in crop yield, and the use of central heating system in comparison with traditional furnace system, increases crop yield by 44 tons per hectare or 17.5% increase in crop yield. In

**Table 2** Mean values of crop yield, and volume and cost of gas consumed in two consecutive periods of greenhouse cucumber cultivation in the cold season (from January to June) under the influence of three conventional heating systems in the greenhouses of Varamin region.

Heating system	Crop yield (t ha <sup>-1</sup> )	Volume of gas consumed (1,000 m <sup>3</sup> ·ha <sup>-1</sup> )	Cost of gas consumed (Million Rials·ha <sup>-1</sup> )
Central heating system	295	100	210
Gas heater system	274	409	450
Traditional furnace system	251	500	550



**Fig. 4** Crop yield (mean values) in two consecutive periods of greenhouse cucumber cultivation in the cold season (from January to June) under the influence of three conventional heating systems in the greenhouses of Varamin region.

this regard, the use of gas heater system in comparison with traditional furnace system, increases crop yield by 23 tons per hectare or 9.2% increase in crop yield.

### 3.2 Volume of Gas Consumed

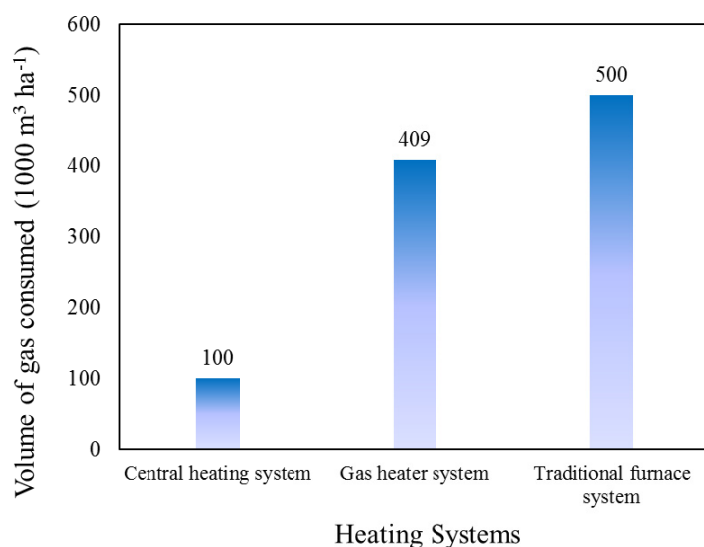
Average volumes of gas consumed in two consecutive periods of greenhouse cucumber cultivation in the cold season (from January to June 2018 and 2019) under the influence of three conventional heating systems in greenhouses producing greenhouse cucumber in Varamin region, namely central heating system, gas heater system and traditional furnace system are shown in Table 2 and Fig. 5.

The results show that the greenhouse equipped with central heating system with an average volume of gas consumed of 100 thousand cubic meters per hectare has the lowest volume of gas consumed and the greenhouse with traditional furnace system with an

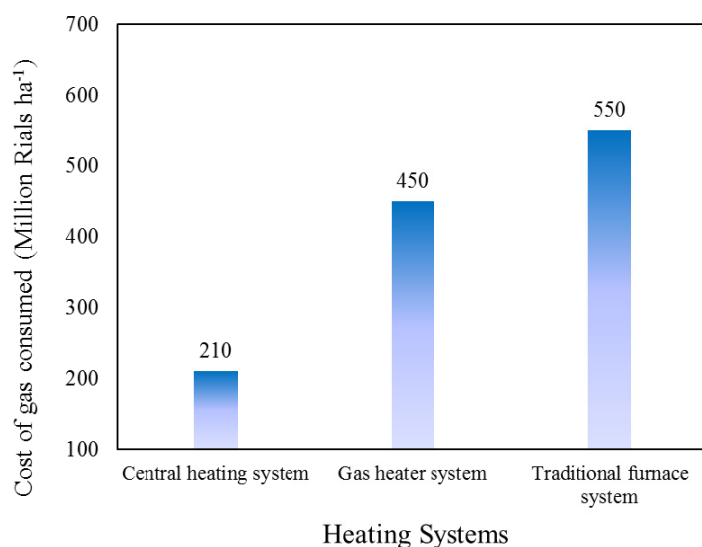
average volume of gas consumed of 500 thousand cubic meters per hectare has the highest volume of gas consumed. It is worth mentioning that the greenhouse equipped with gas heater system with an average volume of gas consumed of 409 thousand cubic meters per hectare in terms of volume of gas consumed with a short distance is after the greenhouse with traditional furnace system.

Carefully in the results of volume of gas consumed, it can be seen that the use of central heating system in comparison with gas heater system, reduces the volume of gas consumed by 309 thousand cubic meters per hectare or 75.6% reduction in the volume of gas consumed and the use of central heating system in comparison with traditional furnace system, reduces the volume of gas consumed by 400 thousand cubic meters per hectare or 80% reduction in the volume of gas consumed. In this case, the use of gas heater system





**Fig. 5** Volume of gas consumed (mean values) in two consecutive periods of greenhouse cucumber cultivation in the cold season (from January to June) under the influence of three conventional heating systems in the greenhouses of Varamin region.



**Fig. 6** Cost of gas consumed (mean values) in two consecutive periods of greenhouse cucumber cultivation in the cold season (from January to June) under the influence of three conventional heating systems in the greenhouses of Varamin region.

in comparison with traditional furnace system reduces the volume of gas consumed by 91 thousand cubic meters per hectare or 18.2% reduction in the volume of gas consumed.

### 3.3 Cost of Gas Consumed

Average costs of gas consumed in two consecutive periods of greenhouse cucumber cultivation in the

cold season (from January to June 2018 and 2019) under the influence of three conventional heating systems in greenhouses producing greenhouse cucumber in Varamin region, namely central heating system, gas heater system and traditional furnace system are shown in Table 2 and Fig. 6.

The results show that the greenhouse equipped with central heating system with an average cost of gas

consumed of 210 million Rials per hectare has the lowest cost of gas consumed and the greenhouse with traditional furnace system with an average cost of gas consumed of 550 million Rials per hectare has the highest cost of gas consumed. It should be noted that the greenhouse equipped with gas heater system with an average cost of gas consumed of 450 million Rials per hectare in terms of cost of gas consumed is located a short distance after the greenhouse with traditional furnace system.

Carefully in the results of cost of gas consumed, it can be seen that the use of central heating system in comparison with gas heater system, reduces the cost of gas consumed by 240 million Rials per hectare or 53.3% reduction in the cost of gas consumed and the use of central heating system in comparison with traditional furnace system, reduces the cost of gas consumed by 340 million Rials per hectare or 61.8% reduction in the cost of gas consumed. In this regard, the use of gas heater system in comparison with traditional furnace system reduces the cost of gas consumed by 100 million Rials per hectare or 18.2% reduction in the cost of gas consumed.

Comparison of results, i.e. crop yield, volume and cost of gas consumed under the influence of three conventional heating systems in greenhouses producing greenhouse cucumber in Varamin region, namely central heating system, gas heater system and traditional furnace system clearly confirms Dalgaard's [5] view that agriculture is looking for production methods that increase crop yield while reducing energy consumption. These results are also in line with Rezadoust [7] that increasing crop yield regardless of energy consumption method has been outdated and the amount of production and crop yield can be measured based on energy efficiency and the most important goal and principle of modern agriculture is the optimal and sustainable use of energy resources in order to preserve these resources for future generations and reduce the environmental effects of excessive and inappropriate energy consumption.

#### 4. Conclusion

It can be concluded that the central heating system with the highest crop yield ( $295 \text{ t}\cdot\text{ha}^{-1}$ ), and the lowest volume ( $100,000 \text{ m}^3\cdot\text{ha}^{-1}$ ) and cost (210 Million Rials $\cdot\text{ha}^{-1}$ ) of gas consumed was the best and most suitable heating system.

#### 5. Recommendations

Issuance of construction and/or operation license for greenhouse units equipped with central heating system or newer and more advanced heating systems;

Legal coercion of greenhouse units with traditional, old and inefficient heating systems to equip and use central heating system or newer and more advanced heating systems in the shortest possible time;

Supportive policies such as tax exemptions and/or granting low-interest and interest-free banking facilities to encourage greenhouse owners to equip their greenhouse units with central heating systems or newer and more advanced heating systems;

Incentive policies such as calculating the cost of gas consumed with special discounts for low-consumption subscribers, i.e. greenhouses equipped with efficient heating systems;

Punitive policies such as calculating the cost of gas consumed with special penalties and progressive increase for high-consumption subscribers, i.e. greenhouses with inefficient heating systems.

#### Acknowledgment

The supports provided by the Agricultural Research, Education and Extension Organization, Iran in research project number 2-41-14-031-960719 are gratefully acknowledged.

#### References

- [1] Momeni, D. 2019. "Investigation of Energy Consumption Indices in Greenhouse Cucumber Production in Southern Kerman." *Extension Journal of Greenhouse Vegetables* 2 (2): 27-33. (in Farsi)
- [2] Rashidi, M. 2020. *Investigation of Energy Consumption of Different Heating Systems in Cucumber Production*



- Greenhouses in Varamin Region*. Final Research Report, Agricultural Engineering Research Institute, Karaj, Iran. (in Farsi)
- [3] Agricultural Statistics of Iran. 2015. *Volume Three: Horticultural Products*. Ministry of Jihad Agriculture, Deputy of Planning and Economy, Information and Communication Technology Center, Iran.
- [4] De Cock, L., and Van Lierde, D. 1999. "Monitoring Energy Consumption in Belgian Glasshouse Horticulture." *Studie Centrum voor Landbouweconomie Brussels*, No. A83, 70.
- [5] Dalgaard, T. 2000. "Farm Types—How Can They Be Used to Structure, Model and Generalize Farm Data?" *Report 2.00.01* 2: 98-114.
- [6] Saye, A., van Loon, W. K. P., Bot, G. P. A., de Zwart, H. F. 2000. "The Solar Greenhouse: A Survey of Energy Saving Methods." In: *Proceedings of the International Conference and British-Israeli Workshop on Greenhouse Techniques Towards the 3rd Millennium*, Haifa, Israel, 5-8 September, 1999, *Acta Horticulturae*, No. 534, 131-138.
- [7] Rezadoust, S. 2001. "Energy Efficiency in Agricultural Ecosystems." In *Proceedings of the Third National Energy Conference*, National Energy Committee of the Islamic Republic of Iran, Deputy Minister of Electricity and Energy, Ministry of Energy, Tehran, Iran. (in Farsi)
- [8] Sherafati, K. 2008. *Investigation of Energy Efficiency Indices of Cucumber Production in the Dominant Greenhouses of Tehran Province*. Final Research Report, Agricultural Engineering Research Institute, Karaj, Iran. (in Farsi)
- [9] Mohammadi, A., and Omid, M. 2010. "Economical Analysis and Relation between Energy Inputs and Yield of Greenhouse Cucumber Production in Iran." *Applied Energy* 87 (1): 191-6.
- [10] Taki, M., Ajabshirchi Oskui, Y., Abdi, R., and Akbarpour, O. 2012. "Analysis of Energy Efficiency for Greenhouse Cucumber Production Using Data Envelopment Analysis (DEA) Technique; Case Study: Shahreza Township." *Journal of Agricultural Machinery* 2 (1): 28-37.
- [11] Agha-Alikhani, M., Haj-Ghani, M., and Izadi, Z. 2012. "Comparison of Consumption Inputs, Yield and Energy Efficiency in Tomato Greenhouses of Hamadan and Kerman Provinces." In *Proceedings of the Second National Congress of Hydroponics and Greenhouse Production*, Iran. (in Farsi)
- [12] Rostami, S., Alaei, A., and Imanmehr, A. 2013. "Investigation of Energy Indices for Cucumber Production in Borujen City." *Biosystems Engineering Quarterly* 2 (2): 12-23. (in Farsi)
- [13] Ahmadbeigi, A., Mohammadzamani, D., and Gholami-Parshekouhi, M. 2013. "Investigation and Determination of Energy Indices of Greenhouse Cucumber Production by Data Envelopment Analysis Method in Qazvin Province." *Biosystems Engineering Quarterly* 2 (3): 77-94. (in Farsi)