Journal of Nutrition and Food Security
Shahid Sadoughi University of Medical Sciences
School of Public Health
Department of Nutrition
Nutrition & Food Security Research Center

eISSN: 2476-7425 pISSN: 2476-7417 JNFS 2024; 9(1): 34-44 Website: jnfs.ssu.ac.ir

The Relationship between Food Security and Total Factor Productivity in Apple Producers in Semirom

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ARTICLE INFO

ORIGINAL ARTICLE

Article history:
Received: 29 Jan 2022
Revised: 6 Jul 2022
Accepted: 6 Jul 2022

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ABSTRACT

Background: Food security and productivity are very important variables that affect social welfare and production level. Since a large proportion of employees in Semirom are engaged in apple gardening, this study aims to investigate the effect of increasing the productivity of all factors of apple production in improving the level of food security in Semirom city. **Methods:** In order to answer the research questions, using Cochran's formula, 139 gardeners were selected and the required data were collected through interviews and completing a questionnaire by cluster sampling in 2020. First, the productivity of all factors of production and the level of food security of the surveyed households were measured using the Household Food Insecurity Access (HFIA) index. **Results:** The results of this analysis showed that gardeners are not in a good food security situation. Then, using Shazam software and estimating the coefficients of the variables in the logit model, the relationship between productivity and food security was investigated. The results showed that productivity had a positive and significant effect on food security of the studied farmers. Based on the final effect, the variables of productivity, income, and savings had the greatest effect on food security of the farmers. In order to create more employment and increase income for gardeners and their families, apple-related processing industries should be established. **Conclusion:** The results of the study showed that apple gardeners of Semirom do not have good food security. It is recommended that younger people be educated by experienced farmers in the region.

Keywords: *Food security; Organizational productivity; Social welfare; Multifactorial causality*

Introduction

With the global population growth, the need for food is increasing day by day at a tremendous rate (Food and agliculture organization, 2016). In recent decades, annual food consumption has increased by about 20%, and according to current estimates, food production in developing countries must be 70% higher over the next twenty-five years than their current

This paper should be cited as: Rahimirigi R, Fehresti-Sani M, Fatahi A, Pakravan MR. ***The Relationship between Food Security and Total Factor Productivity in Apple Producers in Semirom.*** *Journal of Nutrition and Food Security (JNFS)*, 2024; 9 (1): 34-44.

[DOI: 10.18502/jnfs.v9i1.14838]

production to meet the needs of their growing population (Mehrabi and Owhadi, 2014).

FAO provides a comprehensive definition of food security: Food security exists when all people, at all times, have physical and economic access to food to meet their nutritional needs and to achieve a healthy and active life (Food and agliculture organization, 2016).

At the same time, scientists, while emphasizing the emergence of a food crisis in the future, have come up with various solutions to address this crisis, most of which have focused on increasing the productivity of the agricultural sector. Since in the low-income countries, agricultural sector is the primary engine of economic growth due to its expansion and strong links with other economic sectors, increasing the use of technology to produce agricultural products will lead to improved productivity and growth of agricultural sector (Hosseini *et al.*, 2014).

Hashemi Tabar *et al.*, in a study aimed at analyzing food security situation and factors affecting it, using indicators of food coping strategy. They measured the amount of calories received by households and the index of food diversity in Jabalbarz region in the south of Kerman province (Hashemi Tabar *et al.*, 2017). Karbasi *et al* examined factors affecting food security of urban and rural households by emphasizing the role of agricultural sustainability (Karbasi and Mohammadzadeh, 2017).

Cafiro *et al.* measured food safety in a global context on the scale of food insecurity experience. Food insecurity survey data were collected by the FAO from national adult population samples, in 2014, 2015, and 2016, from 153 countries, to develop moderate to severe food insecurity estimates (Cafiero *et al.*, 2018). Schindler *et al*. examined the development of community-based food standards in rural Tanzania (Schindler *et al.*, 2017).

Hertel and Baldos examined food and environmental implications of various policies affecting the global food economy and terrestrial ecosystems (Hertel and Baldos, 2016). Akerele *et al*. in a study examined pattern of food distribution and energy adequacy among households in southwestern Nigeria (Akerele *et al.*, 2013). The results showed that younger men had a higher energy factor than older men. They also studied factors affecting food security index.

Sarkheil *et al.* measured the efficiency and productivity of Tehran water consumption using data envelopment analysis (Sarkheil *et al.*, 2015). Rafiei *et al.* have studied the total productivity of production factors and calculated the efficiency of industrial dairy farms (Rafiei *et al.*, 2011). Khan and Shah, studying 139 Indian households, investigated the relationship between poverty and productivity (Khan and Shah, 2012).

According to the studies, it seems that food productivity and food security are among the most important and necessary issues in economic and managerial studies. Although several studies have been conducted on the role of each method in different parts of the country, no study was observed on total factor productivity of crop cultivation at the level of food security.

From the perspective of economic development, agricultural sector has important responsibilities in the process of growth and development of the country. Due to the political situation and sanctions, ensuring food security by supporting the production of domestic agricultural products is pursued with more sensitivity and accuracy in the country. The agricultural sector contributes to economic growth and improves the country food security environment directly by increasing production and exports and indirectly by increasing the demand for industrial services and goods in rural communities (Hosseini *et al.*, 2014). Therefore, the most important goals of sustainable agriculture include indicators of job creation, income increase, quantitative and qualitative improvement of rural lives, land use, and food security. It is very important to pay attention to the relationship between agricultural productivity and food security in sustainable agriculture. Although several studies have been conducted on productivity or food security in different parts of the country, no study was found on total factor productivity in the cultivation of a crop on the

[DOI: 10.18502/jnfs.v9i1.14838]

level of food security. Therefore, it is important to examine the relationship between productivity and food security. Also, the most important occupation of people in Semirom city is agriculture, especially apple production. In 2020, apple cultivation area in Semirom was 18580 hectares, accounting for about 72% of the total horticultural area and about 37% of the total area of horticultural and agricultural cultivation of this city (Agricultural organization of Semirom, 2020).

The social welfare of many Semirom families depends on the income from apple production. By examining food security and productivity index and other important socio-economic variables of apple producers, the relationship between food security and productivity of apple crop for gardeners in Semirom city was investigated.

Materials and Methods

In the present study, the required information was obtained by completing 139 questionnaires and cluster sampling method. The study population included gardeners in Semirom city. First, several villages or sections were selected and finally, questionnaires were randomly completed among gardeners in that area. The samples size was determined using Cochran's formula as follows:

$$n = \frac{Nz^2pq}{nd^2 + z^2pq} \quad (1)$$

N is community size, Z equals 1.96, p = q = 0.5, and d is the error percentage. In this study, community size was 2000 farmers.

In the process of completing the information, two types of questionnaires related to calculating the productivity of total production factors and the level of food security were completed.

In order to investigate the relationship between productivity and food security, it is necessary to first introduce and calculate the productivity criteria of the total production and food security factors. The most anonymous criterion for measuring the productivity of the production index was Törnqvist productivity index and aggregate household food security index (AHFSI) for measuring food security of the households.

Törnqvist productivity index: Increasing production was possible by increasing the quantitative level of production factors. Due to the scarcity of resources, production amount cannot be increased in this way, so in order to increase production, another solution must be sought that improving productivity is the key to solving the problem. Productivity index is calculated by dividing the total index of the output value by the total index of the amount of input used during production. Törnqvist productivity index was estimated for cross-sectional data, indicating the status of each unit relative to the reference unit. The reference production unit can be defined as the best or worst unit in terms of performance or the average production units in the consumption of inputs and production of outputs. The Törnqvist Productivity Index is defined by Equation 2:

$$TFP = \frac{\prod_{r=1}^{s}\left(\frac{y_r}{\bar{y}_r}\right)^{\frac{1}{2}(R_r+\bar{R}_r)}}{\prod_{r=1}^{s}\prod_{i=1}^{m}\left(\frac{x_{ir}}{\bar{x}_{ir}}\right)^{\frac{1}{2}(S_{ir}+\bar{S}_{ir})}} \quad (2)$$

Where TFP is productivity index of total production factors for each operator, y_r and $\bar{y}_r$ aree production quantity and production average for r *th* output, respectively, R_r and $\bar{R}_r$ are income share and average income share of total income for r *th* output, respectively, x_{ir} and $\bar{x}_{ir}$ show the amount of consumption and the average consumption of i *th* input for r *th* output, respectively, and S_{ir} and $\bar{S}_{ir}$ are cost share and average cost share of input costs of i *th* input in r *th* output, respectively.

In calculating the quantitative index of input consumption, consumption of each input was compared with the average consumption of each output according to its share of costs. This means that the effect of the difference in consumption of inputs on different outputs (technology difference) was considered. The productivity of the users can be easily compared and evaluated with the difference in their products. In Törnqvist index, a value greater than one indicates good productivity and a value less than one indicates poor productivity. Variability of the share of inputs and outputs, enables Törnqvist Productivity Index to

[DOI: 10.18502/jnfs.v9i1.14838]

absorb the effects of price changes, quality and consumption of inputs and output production on different operators and thus better and more accurately reflects the realities that occur during production (See and Coelli, 2014). Considering the advantages and disadvantages of different indicators to evaluate productivity, Törnqvist productivity index was used in the present study.

Food security: Food security is one of the most important aspects of national security; it indicates that providing an optimal level of national security requires the provision of an optimal level of food security. Food security is the cornerstone of a developed society and the main element of mental, physical, and health of that society. Different indicators have been used to calculate food security status. Some indicators focus only on one dimension and component of food security, such as food supply or demand, the ratio of imports to total demand, and food price growth. Therefore, some other indicators that have used a combination of several components to calculate food security situation are introduced.

AHFSI index: Decomposable index determines the rank of food security in a country based on the severity of food poverty, inequality in food distribution among households, and instability in annual access to food (a raw alternative to the risk of food shortages nationwide). The general household food security index is expressed as Equation 3:

$$AHFSI = 100 - \Big\{H(G + (1 - G)I^P) + \frac{1}{2}CV(1 - H(G + (1 - G)I^P)\Big\} \times 100 \quad (3)$$

So that:

$$G = \frac{C_s - C_{AU}}{C_s \times H} \quad (4)$$

$$H = \frac{P_U}{P_T} \quad (5)$$

In this equation, P_U and H are, respectively, the percentage and number of people who received less than the standard energy or protein and also the total population studied. G is severity of food poverty, C_S shows standard energy or protein, C_{AU} is average energy or protein intake less than standard, and I^P Gini coefficient is the distribution of energy or protein between poverty (Khodadadkashi and Heidari, 2004).

The above index can be used to compare food security situation of countries or provide a picture of the progress of a country over time. It is also possible to compare food security situation of different income groups. In this study, nine questions were used in the form of a questionnaire to assess household food security. **Table 1** represents nine questions for calculating household food security on the basis of AHFSI.

The arithmetic index is the AHFS index that must first be calculated as the AHFSI classification variable for each family. A code was then specified for accessing food insecurity. Code zero was given when all items were answered "No" (i.e. if Q1 = 0 and then Q1a = 0, if Q2 = 0 and then Q2a = 0 etc.). The four food classes in a row are shown in **Table 2**, to ensure that households are categorized according to the intensity of their response. In determining the classification of food security for a household level, food access was considered economically and physically.

After calculating **Table 2**, the prevalence of different levels of access to household food insecurity was calculated using **Table 3**.

Investigating the relationship between total factor productivity and food security: Food security and productivity are very important variables, on which social welfare directly or indirectly depends on them in the field of production, especially agriculture. Investigating the relationship between total factors productivity and food security leads to a more accurate understanding of how to use different agricultural inputs and their effect on productivity, especially food security of households. No study has been conducted in the country on the relationship between productivity and food security. Therefore, the present study is one of the first studies in this field. In the present study, the level of food security was calculated using the AHFSI and total factor productivity was calculated using the Törnqvist method. Households were divided into two groups including food secure and food insecure. After this stage, the effect of total factors

[DOI: 10.18502/jnfs.v9i1.14838]

productivity along with other factors was investigated in the form of logit model on the level of food security. Producers benefit from enhancing productivity to maximize their revenues and decrease their costs. Therefore, a producer benefits from improving the total factor productivity indirectly.

In fact, the next step after calculating the indices of productivity and food security is to put the computational indices in a parametric model that can measure the effect of one factor on another factor. Since food security index can be divided into two groups of safe food and unsafe food, a model can be used whose dependent variable is binary. Therefore, the most well - known parametric model with this feature is Logit model, providing a description of its model structure.

Logit model: The logit model follows the cumulative logistic distribution function in the form of Equation 6 (Wooldridge, 2012):

$$f(x_i)=f(x') = \int_{-\infty}^{x_i} \frac{1}{\sqrt{2n}} \exp\left(-i^2/2\right) di \qquad (6)$$

Where: $f(x_i)$ is a density function of the cumulative normal of the individual *i*; f(x') is linear function of model descriptive variables. X_i is matrix of descriptive variables that x' is transposed of it.

If B is a matrix of estimated parameters, the logit model can be expressed as the following equation:

$$P_i=F(x'_iB)=\frac{1}{1+\exp(-x'B)} \qquad (7)$$

Where P_i is the probability of a dependent variable and means food insecurity.

The parameters of logit model were estimated using the maximum likelihood method. In estimating these models, predicting the effects of changes in descriptive variables on the probability of the problem by the first person was of particular importance. The value of the final effect represented the amount of change in the probability of increasing or decreasing food security per unit of change in each descriptive variable (Equation 8):

$$\frac{\delta P_i}{\delta x_i}=F(x'_iB)=\frac{\exp(-x'_iB)}{1+\exp(-x'_iB)} \qquad (8)$$

In logit model, since the dependent variable is a binary variable, in the interpretation of the model, the effect of change in the independent variable was examined on the probability of that feature.

Results

Calculating the total factors productivity: Based on Törnqvist productivity index, the total factors productivity was obtained from 139 surveyed gardeners (**Figure 1**).

According to the Törnqvist index, the larger the calculated number, the more efficient the total productivity factors of the horticultural production is compared to the community average. However, the smaller the calculated number, the lower the total productivity factors of horticultural production is compared to the community average. Also, the distance obtained from number 1 indicates the intensity of increase or decrease in productivity compared to the average. **Table 4** shows the frequency of total factor productivity.

Table 4 reveals that the productivity of Semirom gardeners is less than one, indicating that Semirom apple orchards do not have good productivity. **Table 5** shows the intensity of total factors productivity in relation to number 1 and total productivity average. According to Table 5, about 61% of gardeners had poor productivity.

Food security estimation: The household food security assessment over the past month, which was reviewed by farmers, is shown in **Table 6**. According to **Table 6**, more than 90% of families with apple orchards did not sleep hungry at night and there was minimal food for families to eat. Moreover, less than 40 percent of households and gardeners were concerned about food preparation and food shortages and the consumption of common and favorite food during the past month. Using the statistics mentioned in **Table 6** and the HFIA index, food security was calculated and coded at two levels to enter the econometric model as a dependent variable. Based on results, up to 48 people (35%)

[DOI: 10.18502/jnfs.v9i1.14838]

had relative food security and over 91 people (65%) had relative food insecurity.

Logit model: To investigate the relationship between productivity and food security, due to the duality of the dependent variable (with or without food security), the logit model was used and the explanatory variables of the model, socio-economic characteristics of individuals, and the productivity variable were considered. The results of model estimation with explanatory variables are presented in **Table 7**.

In the logit model, McFadden R^2 coefficients showed that explanatory variables well explain the changes in the model dependent variable. The percentage of prediction accuracy in the estimated model was 77%; therefore, the estimated model was able to predict an acceptable percentage of dependent values with respect to explanatory variables. All variables except gender and participation in high-level household nutrition training programs were statistically significant. Food utilization indicator was considered in the calculation of food safety criteria.

Results showed that the productivity coefficient was statistically significant at the level of five percent, indicating an increased likelihood of food security for gardeners who are more productive. Based on the weight elasticity of this variable, a one-percent increase in respondents' productivity increased the probability of food security by 0.11 percent. The final effect of productivity showed that by increasing one unit in the productivity of gardeners, the probability of farmers' food security increased by 0.19 units.

Revenue variable above 20 million Rials at the level of five percent was significant and the increase in income of gardeners, increased food security of gardeners. Based on the weight traction of this variable, a-one percent increase in revenue increased food security by 0.45 percent. The final effect of this variable showed that an increase of one million Rials in income, food security of gardeners increased by 0.39 units.

The coefficient of saving variable was significant at the level of one percent, indicating that the more you save, the more likely you are to increase food security. The saving variable is aligned with the income variable, since the higher the income, the more savings. Based on the weight traction of this variable, a one-percent increase in saving, food security increased by 0.40 %. The final effect of this variable indicated that by increasing a one-unit in savings, food security of gardeners increased by nearly 0.58 units.

The experience variable (agricultural experience) was significant at the level of 10%. In other words, people who had a long history in apple gardening had higher food security than others. Also, the weight elasticity of this variable showed that a one-percent increase in the gardener's experience increased the probability of food security by 0.09%. The final effect of this variable showed that by increasing a one-unit in the agricultural experience of individuals, the probability of food security increased by 0.20.

The education coefficient was significant at the level of 10%, indicating that the higher the level of education of individuals, the greater the food security. Based on the weight traction of this variable, a one-percent increase in the level of education increased the probability of food security of gardeners by 0.42%. Also, the final effect of this variable showed that a unit increase in the level of education of individuals increased their food security by 0.07 units. The coefficients of participation in the household nutrition training program and gender were not significant.

[DOI: 10.18502/jnfs.v9i1.14838]

Table 1. Measuring household food security (Coates *et al.*, 2007).

Row	Please tell me how each of the following has happened to you over the past month	Never	Rarely	Sometimes	Often
1	Have you been worried about your family not having enough food over the past month?				
2	Has it happened in the last month that you or any of your family members do not eat the food you prefer due to lack of food resources?				
3	Has it happened in the last month that you or any members of your family consume limited types of food due to lack of resources?				
4	Has it happened over the past month that you or any of your family members have to eat food that you do not really like due to a lack of food resources?				
5	Have you ever had to eat less than you needed because you did not have enough food in the past month?				
6	Has it happened in the last month that you have reduced the number of meals you eat per day?				
7	Has it happened over the past month that you have no food to eat at home due to lack of resources?				
8	Has it ever happened that during the last month, you or your family members go to bed hungry at night because there was not enough food?				
9	During the past month, has it happened that family members spend the whole day and night without eating anything due to lack of food?				

Table 2. Food security classification.

Calculate the access floor of household food insecurity for each household. 1 = food security, 2 = relatively food insecurity , 3 = high food insecurity, 4 = very severe food insecurity	
AHFSI category	category AHFSI =1 if [(Q1a = 0 or Q1a = 1) and Q2 = 0 and Q3 = 0 and Q4 = 0 and Q5 = 0 and Q6 = 0 and Q7 = 0 and Q8 = 0 and Q9 = 0] category AHFSI =2 if [(Q1a = 2 or Q1a = 3 or Q2a = 1 or Q2a = 2 or Q2a = 3 or Q3a = 1 or Q4a = 1 and Q5 = 0 and Q6 = 0 or Q7 = 0 or Q8 = 0 or Q9 = 0] category AHFSI =3 if [(Q3a = 2 or Q3a = 3 or Q4a = 2 or Q4a = 3 or Q5a = 1 or یا Q5a = 2 or Q6a = 1 or Q6a = 2) and Q7 = 0 and Q8 = 0 and Q9 = 0] category AHFSI =4 if Q5a = 3 or Q6a = 3 or Q7a = 1 or Q7a = 2 or Q7a = 3 or Q8a = 1 or Q8a = 2 or Q8a = 3 or Q9a = 1 or یا Q9a = 2 or Q9a = 3].

Table 3. Prevalence of different levels of access to household food insecurity (Coates *et al.*, 2007).

HFIA category	Percentage of households in any type of food insecurity. For example: "Percentage of food insecure households". Example: $\frac{4 = \ HFIA\ Number\ of\ fertile\ households}{HFIA\ All\ \ \ Number\ of\ fertile\ households} \times 100$ For example: "Percentage of food-secure households" $\frac{1 = \ HFIA\ \ Number\ of\ fertile\ households}{HFIA\ \ \ All\ \ \ Number\ of\ fertile\ households} \times 100$

[DOI: 10.18502/jnfs.v9i1.14838]

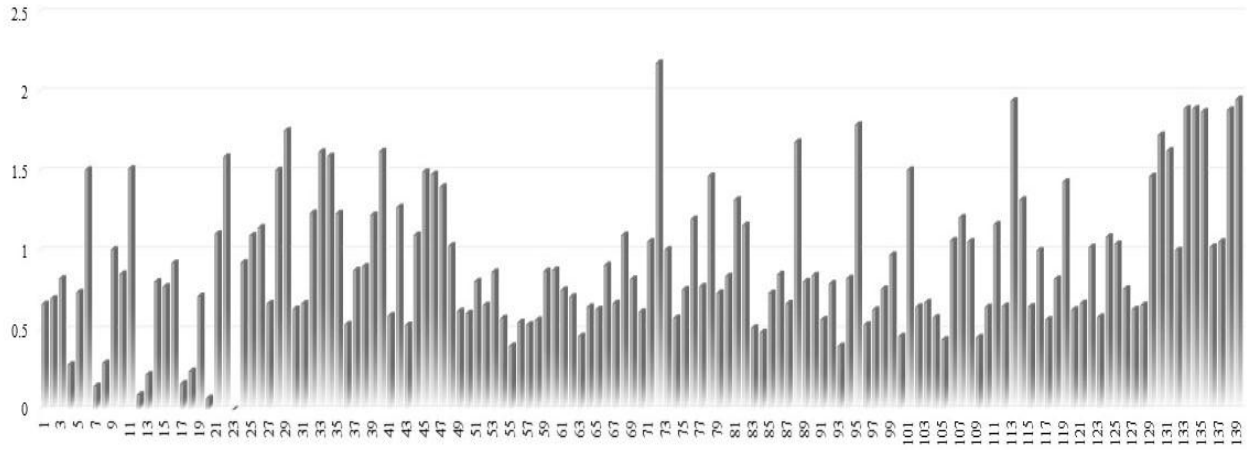

Figure 1. Total factors productivity index of Semirom apple production.

Table 4. Frequency of total productivity factors of apple orchards in Semirom city.

Coefficient of variation	Standard deviation	Minimum	Maximum	Average
2.09	0.44	0.008	2.18	0.92

Table 5. Intensity of total productivity factors of apple production in Semirom city.

Efficiency	Larger than one	Less than one	Larger than the average sample	Smaller than average sample	Total
Number	54	85	56	83	139
Percentage	38.84	61.15	40.28	59.71	100

Table 6. Results of calculating food security index.

Question	Never	Rarely (1 to 2 times)	Sometimes (3 to 10 times)	Most of the time(more than 10 times)
1	0 (0)[a]	21(15)	58(42)	60(43)
2	0(0)	36(26)	65(47)	38(27)
3	0(0)	48(35)	53(38)	38(27)
4	3(2)	46(33)	61(44)	29(21)
5	8(6)	64(46)	52(37)	15(11)
6	30(22)	59(42)	39(28)	11(8)
7	64(46)	56(40)	17(12)	2(1)
8	114(82)	24(17)	1(1)	0(0)
9	136(98)	3(2)	0(0)	0(0)

[a]: n (%)

[DOI: 10.18502/jnfs.v9i1.14838]

Table 7. Results of estimating the logit model for food security.

Variables	Coefficients	Standard error	t statistic	Elasticity	Final effect
Productivity	1.00[b]	0.46	2.16	0.11	0.19
Gender	-1.88	1.26	-1.49	0.02	0.28
Income over 20 million Rials	1.98[b]	0.83	2.39	0.45	0.39
Saving	3.28[c]	0.76	4.32	0.40	0.58
Experience	0.99[a]	0.54	1.85	0.09	0.20
Education	0.34[a]	0.19	1.81	0.42	0.07
Participate in a family nutrition training program	0.41	0.48	0.87	0.04	0.08
Itercept	-5.60[c]	1.45	-3.86	-	-

[a] ,[b], and [c] are significant at the levels of 10, 5 and 1%, respectively.

Discussion

The role of nutrition in health, increasing efficiency, human learning and its relationship with economic development has been proven in extensive global research and the study of food security in the current decade is important due to its prominent role in the prosperity and fertility of human capital (Khanzadi *et al.*, 2018). Therefore, various international organizations, such as the United Nations, the Food and Agriculture Organization (FAO), and the World Bank, have sought to address the issue of food security by providing various definitions and indicators. In a comprehensive definition, food security is a situation in which all people have physical and economic access to adequate, healthy, and nutritious food at all times. The available food provides the needs of a nutrition program consistent with their preferences for an active and healthy life (Kalhori *et al.*, 2016).

Tabar *et al*. reported the unfavorable situation of food security, food diversity, and food groups of the studied households (Hashemi Tabar *et al.*, 2017). Also, the consumption pattern of households in terms of nutrition quality and diversity, especially in the dairy group based on nutrition sciences, should be changed. Using the logit model, they reported that the variables of gender and education of the head of the household, number of household members, age of the person in charge of the household, and having a fixed monthly income affected the level of food security.

Karbasi and Mohammadzadeh concluded that the variables of per capita income, crop diversity, import of agricultural products, and sustainable agricultural index had a positive and significant effect (Karbasi and Mohammadzadeh, 2017). However, they stated that variables of Gini coefficient and government support policies for the agricultural sector had a negative and significant effect on food security of urban and rural households in the short-run and long-run period.

Hertel and Baldos reported that environmental products, increasing farm efficiency and reducing post-harvest wastes and reducing food waste in the economy have positive effect of food security (Hertel and Baldos, 2016). Akerele *et al*. showed that the level of income, gender of the head of the household, and agricultural occupation have a positive and significant effect on household energy absorption and food security (Akerele *et al.*, 2013). Sarkhil *et al*. reported that total productivity improved in terms of technical efficiency variable and scale efficiency variable (Sarkheil *et al.*, 2015).

Rafiei *et al*. reported that with a one-percent increase in the capacity of production units, the productivity of the target units will increase by 0.33% (Rafiei *et al.*, 2011). Also, a one-percent improvement in feed productivity will lead to an improvement of 0.69% in total factor productivity. Khan and Shah concluded that poverty reduces in rural areas by improving total factor productivity (Khan and Shah, 2012).

The results of the present study showed that there was a positive and significant relationship between

[DOI: 10.18502/jnfs.v9i1.14838]

productivity and food security. This finding is in line with the study of Khan and Shah and Akerele *et al*. on increasing productivity and its effect on rural poverty (Akerele *et al*., 2013, Khan and Shah, 2012). According to the logit models estimated in the present study, all socio-economic variables except gender and household nutrition education program were not significant. In other words, there was no significant relationship between all socio-economic variables used in the logit model. This finding is consistent with studies by Hashemi Tabar *et al*., Karbasi and Mohammadzadeh, and Akerele (Akerele *et al*., 2013, Hashemi Tabar *et al*., 2017, Karbasi and Mohammadzadeh, 2017)

Conclusion

The results of the study showed that apple gardeners of Semirom do not have good food security. The productivity, income, higher education, and saving variables had a positive and significant effect on farmers' food security. Productivity plays an important role in promoting food security in farmers. Given the consequent relationship between food security and productivity, it is required to increase the productivity of gardeners and farmers using different policies in the agricultural sector in order to improve their food security. Regional policy makers should promote more farmers to participate in agricultural trainings. Given that the experience in agricultural activities affects the level of food security, it is recommended that younger people be educated by experienced farmers in the region.

Acknowledgments

The Authors thank all participants in this work.

Authors' contributions

Rahimirigi R: Data collection, data mining, data analysis and writing first draft; Fehresti-Sani M: supervision, revising and editing, conceptualization and visualization; Fatahi A: Editing and revising and Pakravan-Charvadeh MR Analysis, Eeiting and Rrviewing.

Funding

None

Conflict of interest

All authors declare that they don't have any conflict of Interest.

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