Technical efficiency of greenhouse strawberry production: a case study in Aydın province of Turkey

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Vecdi Demircan (Corresponding author)
PhD in Agricultural Economics
Institution: Isparta University of Applied Sciences
Address: Department of Agricultural Economics, Faculty of Agriculture, Isparta University of Applied Sciences, 32260, Isparta, Turkey.
E-mail: **vecdidemircan@isparta.edu.tr**

Deniz Sarica
PhD in Agricultural Economics
Institution: Isparta University of Applied Sciences
Address: Department of Agricultural Economics, Faculty of Agriculture, Isparta University of Applied Sciences, 32260, Isparta, Turkey.
E-mail: **denizsarica@isparta.edu.tr**

Asli Dalgic
M.Sc in Agricultural Economics
Institution: Isparta University of Applied Sciences
Address: Department of Agricultural Economics, Faculty of Agriculture, Isparta University of Applied Sciences, 32260, Isparta, Turkey.
E-mail: **aslidalgic@isparta.edu.tr**

Abstract

The purpose of the study is to determine the efficiency of greenhouse strawberry production in the province of Aydın, which has an important position in Turkey's strawberry production. The main material of the study consists of the primary data collected via the survey method from 59 greenhouse strawberry producers in Aydın province. Neyman Method, one of the stratified sampling methods, was employed to determine the number of surveyed producers. The data was collected through face-to-face interviews with the producers. In the study, input-oriented Data Envelopment Analysis (DEA) was conducted to establish the technical efficiency of the producers. The relationship between some selected socio-economic variables and producers' efficiency scores was also investigated by Tobit Regression analysis to identify the factors causing inefficiency. According to the research results, the mean efficiency of the producers was 0.62 for constant return to scale, 0.98 for variable return to scale, and 0.63 for scale efficiency. Mean efficiency levels of the producers were found to be high under the assumption of the variable return to scale. It was also determined that they were able to evaluate the inputs they used at a rate of 98%. In this case, the producers will be able to reduce their inputs by 2% without changing the output amount. It was seen that there was a positive relationship between efficiency and strawberry yield and certified seedling use ($P<0.05$); and a negative relationship between efficiency and producers' age and labour use ($P<0.10$). These relationships were statistically significant. Finally, a negative relationship was found between fertiliser use and efficiency, but it was not statistically significant (P>0.10).

Keywords: Greenhouse strawberry. Technical efficiency. Data envelopment analysis (DEA).

1. Introduction

Strawberry (*Fragaria sp.*) is the most common type of cultivation in berry fruits. The reason is that its cultivation is very old and is fondly consumed all around the world. The biggest reason for the increasing demand for strawberry plant day by day is that they can be grown economically under different climate and soil conditions. It is also suitable for a small family-run farm due to the short payback period for investments in strawberries and the high income per unit area (Türemiş et al., 2000). The fact that the availability of many other fruit varieties in the market during the months when it is not yet on the market, its appeal and high vitamin C content have caused this fruit to be very popular in some country markets and sold at high prices. It has become an appeal to a wide range of consumers in recent years since it is a fruit used for processing or freezing in addition to its fresh consumption and being a sought-after (Anonymous, 2001).

Turkey has a significant potential for strawberry cultivation due to having a different climate and soil characteristics. She ranks fourth with 486 705 tons of strawberry production in the world, following China, the United States and Mexico (Anonymous, 2021a). Its production in the modern sense has begun in Turkey in the 1970s. Most of the production in Turkey is carried out in Mersin province. The share of Mersin is about 35% of Turkey's total strawberry production. Aydın province, where the research was conducted, ranks second, following Mersin. It accounts for approximately 12% of Turkey's total strawberry production with 67 698 tons (Anonymous, 2021b).

Several factors can be obtained for production line analysis by dividing the capital amounts, production costs and production values (gross profit) of production lines into basic input and scale units such as land width, animal unit, labour unit etc. These are practically referred to as productivity and efficiency factors. Even though efficiency and productivity factors are two concepts that are sometimes used interchangeably, their meanings are different. Productivity is the ability of a production unit (land, etc.) to produce, which is expressed in a certain measure (kg, tons, etc.). As for efficiency, it is the achievement of the desired result with a minimum amount of resources (time, money, energy or material). The same productivity level can be achieved using different efficiency levels. For example, the same productivity level can be obtained by using different levels of input in two strawberry fields with the same conditions. While one of them is more efficient at using inputs, the other may be less efficient (Rehber and Tipi, 2016). The purpose of every producer that acts rationally is to achieve the highest output with available resources or a certain amount of output using the lowest possible resources. The producers who realise this goal have used their resources more efficiently. Therefore, it is very important to determine the resource utilisation efficiencies of producers and the sources of inefficiency in farms that do not work efficiently with current technology (Parlakay and Alemdar, 2011).

In the literature review, it was observed that some studies (Banaeian et al., 2011; Lee and Song, 2013; Tariq et al., 2018; Poernomo et al., 2019; Afzal et al., 2020 and Eka Wijayanti et al., 2020) are investigating the technical efficiency of strawberry production for different countries. Regarding Turkey, some studies were conducted related to the technical efficiency of other agricultural products except strawberries. For Turkey, the technical efficiency was determined for apple by Gül (2006), tobacco by Ören and Alemdar (2006), cotton by Gül et al. (2009), dried apricot by Gündüz et al. (2011), peanut by Parlakay and Alemdar (2011) and grape by Örmeci Kart et al. (2018). However, no study has been encountered regarding the technical efficiency of strawberry production in Turkey. Therefore, this study on the technical efficiency of strawberry production is quite significant. Consequently, the study aims to determine the technical efficiency of greenhouse strawberry production in Aydın province, which has significant potential in producing strawberries in Turkey. In the study, the efficiency scores of the farms were investigated using the Data Envelopment Analysis (DEA) method. Also, the relationship between the efficiency scores and some selected socio-economic variables was examined to ascertain the factors causing inefficiencies via Tobit Regression analysis. It is hoped that the findings from this research will be beneficial to policymakers, strawberry producers, researchers, and related institutions and organizations.

2. Literature Review

Some previous studies on the determination of the technical efficiency of strawberry production are summarised below:

In the study conducted by Banaeian et al. (2011), the level of mean technical efficiency for greenhouse strawberry production was found as 0.73. It was also emphasised that producers could save 27% of the input amount. In the study, it was suggested that the vast majority of inefficient farms in terms of scale operate under the increasing returns to scale and that the size of these farms should be increased to save costs.

Lee and Song (2013) determined that the technical efficiency, pure technical efficiency and scale efficiency of strawberry production, which is environmentally friendly and pesticides free, were 0.967, 0.995 and 0.968, respectively. In technical efficiency, the average lower and upper confidence bounds were found as 0.807 and 0.960.

In Tariq et al. (2018), it was determined that the minimum, maximum, and mean efficiency levels of farms engaged in strawberry cultivation were 42%, 98% and 82%, respectively. In the study, it was revealed that the technical efficiency of approximately 47% of 382 producers was over 90%. At the same time, it was indicated that education, experience and credit usage have a significant role in increasing output.

Regarding the study of Poernomo et al. (2019), the researchers presented that strawberry and vegetable producers were effective, and their welfare levels were high according to the Data Envelopment Analysis results.

Afzal et al. (2020) were calculated the minimum, maximum, and mean technical efficiency levels of strawberry producers as 39%, 97% and 64%, respectively. In the research, the factors causing inefficiency were determined as family size, experience and credit usage ($P \leq 0.05$). It was found that there was a positive relationship between the age of the producers and the efficiency level of the farms, and a negative relationship between the other factors (family size, farm size, experience, education and credit usage) and the efficiency level.

In the study carried out by Eka Wijayanti et al. (2020) on strawberry farms, the minimum, maximum, and mean efficiency levels were discovered as 26.50%, 99.40% and 77.80%. It was determined in the study that the variables of the producers' education level and family size affected technical efficiency. Furthermore, they suggested that strawberry producers should improve their knowledge and skills through training and consultancy to improve their effectiveness.

3. Material and Method

The main material of the study was the primary data collected by survey method from the greenhouse strawberry producers in Aydın province. In addition to the primary data, similar studies, reports and statistics prepared by various persons and organizations related to the subject were also utilised. The survey data cover the production period of 2015.

In line with the data obtained from the records of Aydın Directorate of Provincial Agriculture and Forestry, ten villages and centres of the Sultanhisar and Köşk districts, where strawberry production is intensely made, were selected as data collection areas. In these districts and affiliated villages, all agricultural farms, which are suitable for the study, constituted the population of the research. Selected districts as research areas compound approximately 75% of the strawberry production area in Aydın province (Anonymous, 2021b). Neyman Method, one of the stratified sampling methods, was used to determine the number of producers collected data (Yamane, 2001). Employing the Neyman method, the number of producers to represent the population was calculated as 59 with a 95% confidence interval and a 5% margin of error.

3.1. Efficiency analysis

The methods applied to measure the efficiency levels of farms can be classified into three groups. These are ratio analysis, parametric, and non-parametric methods. Ratio analysis is a method applied by proportioning a single output value to a single input value (Yeşilyurt and Alan, 2003). Parametric methods are based on multiple regression analysis. These methods are tools for investigating the structure of the relationship between the dependent and independent variables, which is known to have a cause-effect relationship among them. In parametric methods, if the efficiency value of any farm is above the regression line showing the mean efficiency in general, the farm is efficient, otherwise, it is not (Sherman, 1984). Regarding non-parametric methods, they are used in cases where there are multiple output and input variables, and these are measured with different measurement units. These methods are techniques that measure the distance of farms from the production line. There are three different non-parametric efficiency analysis methods: Data Envelopment Analysis (DEA), Free Disposable Hull (FDH) (Deprins et al., 1984) and Stochastic DEA (Cazals et al., 2002). Data Envelopment Analysis (DEA) is a technique based on linear programming principles and designed to measure the relative efficiency of farms/economic organisations, which are responsible for converting input into an output. It is also referred to as "Decision Making Units" in the literature. The DEA approach is the most applied analysis method among the non-parametric methods. In the technique, the activity boundary is drawn from the best behaving observations using linear programming, and the distance of all observations to this boundary (i.e. relative efficiency) is measured. As a result of linear programming, decision units whose objective function value is equal to one called “efficient” and less than one called “inefficient” (Coelli et al., 2003).

The input-oriented DEA model for N farms, each producing M outputs using K inputs, is given below (Coelli et al., 2003):

$$\text{Min}\ \theta, \lambda\ \theta$$

limitations

$$-y\ i + Y\lambda \geq 0$$

$$\theta\ xi - X\lambda \geq 0$$

$$N1\ '\lambda = 1$$

$$\lambda \geq 0$$

Here θ is a scalar value, N is the constraint for the convex condition, and λ is an N x 1-dimensional vector. Y is the output matrix, and X represents the input matrix. The efficiency scores of the farms are shown with θ, which takes a value between zero and one. Also, the linear programming model requires to be resolved separately for each farm.

In this study, the DEA method was used to determine the technical efficiency of greenhouse strawberry production in Aydın province, which ranks second in terms of strawberry production in Turkey. In the research, a model with four inputs and one output was designed. Gross profit per hectare ($/ha) is used as output in the model. Labour use (hour/ha), machinery use (hour/ha), total fixed costs ($/ha) and other costs ($/ha) were considered as inputs.

4. Results and Discussions

General features of the producers are given in Table 1. As seen in Table 1, it was determined that the average age of the producers was 46.29 years, their education level was 7.59 years, their experience in strawberry cultivation was 15.63 years, and the family population was 3.46. The average land size of the producers was calculated as 5.17 hectares (ha), and the strawberry land size was 2.72 ha. The share of strawberry land in the total land size calculated as 52.61%. It ascertained that 35.59% of the producers were cooperative members, and 67.80% of them were involved in the farmer registration system.

Table 1: Producers' general features

Features	Min.	Max.	Mean	SD
Age (year)	23	80	46.29	13.11
Education level (year)	5	15	7.59	3.38
Experience in strawberry production (year)	2	37	15.63	7.93
Population (person / family)	1	8	3.46	1.37
Total land size (ha)	0.45	32.5	5.17	5.50
Strawberry land size (ha)	0.1	12	2.72	2.89
Membership of cooperative (%)	-	-	35.59	-
Involvement in farmer registration system (%)	-	-	67.80	-

Descriptive statistics of the variables used in efficiency analysis are given in Table 2. While the mean gross profit of the 59 producers examined was found as 41378.06 $/ha, the minimum and maximum gross profits were determined as 4277.05 and 79189.86 $/ha, respectively. The mean values of the variables were as follows: "labour use" was 6425.13 hours/ha, "machinery use" was 709.62 hours/ha, "fixed costs" was 6043.30 $/ha, and "other costs" was 1626.73 $/ha. With the standard deviation, it is found how much of the data is close to the mean. The low standard deviation of the inputs in strawberry production indicates that the difference of the inputs used from the mean is distributed close to the mean. In the case of excess, it indicates that it is distributed far from the mean. The variation coefficient expresses how much the standard deviation varies (%) concerning the mean. When the variation coefficients of the inputs in the table were analysed, it was seen that the greatest variation was in other costs per hectare (45.66%). The other costs were followed by labour use per hectare (14.50%), total fixed costs per hectare (12.91%) and machinery use per hectare (4.74%).

Table 2: Descriptive statistics of DEA variables

Variables	Min.	Max.	Mean	SD	Variation coefficient (%)
Output					
Gross profit ($/ha)	4277.05	79189.86	41378.06	15639.06	37.80
Inputs					
Labour use (hour/ha)	5688.71	9204.89	6425.13	931.93	14.50
Machinery use (hour/ha)	678.57	882.00	709.62	33.66	4.74

Total fixed costs ($/ha)	4772.92	8455.61	6043.30	780.40	12.91
Other costs ($/ha)	785.33	3537.08	1626.73	742.83	45.66

Mostly input-oriented models are used in agriculture. The analysis for input aims to determine how much the amount of input used can be reduced proportionally without any change in the amount of output produced. The input-oriented technical efficiency scores of strawberry producers are given in Table 3. It was determined that producers other than 6.78% were under constant return to the scale, and those other than 30.51% were under variable return to the scale. The mean efficiency of producers was 0.62 under the assumption of the constant returns to scale and 0.98 under the assumption of the variable return to the scale. In this case, it may be possible for the producers to reduce their inputs by 2% without changing the output amount. In other words, the producers can evaluate the inputs they use at a rate of 98%. The mean efficiency of producers varied between 0.83 and 1.00 under the assumption of variable returns to scale. According to the producers who use the input most efficient, the producers with the minimum technical efficiency can use their inputs efficiently by 83%. Thus, they will be able to increase their efficiency by 17% with the appropriate input combination. Commonly, technical inefficiency can be generated by two main factors. These factors are the farms working with unsuitable input combinations or on an unsuitable scale. According to the DEA results, the scale efficiency (0.63) was relatively lower than the efficiency under the variable return to scale assumption (0.98). This situation shows that the technical inefficiency is mainly due to not working at an appropriate scale.

Table 3: Frequency distributions of technical efficiency scores obtained with Data Envelopment Analysis model

Efficiency score	CRS	VRS	SE
1.00	4	18	4
0.91-0.99	1	39	1
0.81-0.90	8	2	8
0.71-0.80	8	0	8
0.61-0.70	11	0	14
0.51-0.60	8	0	6
0.41-0.50	8	0	8
<0.41	11	0	10
Min.	0.07	0.83	0.07

Max.	1.00	1.00	1.00
Mean	0.62	0.98	0.63

In the study carried by Banaeian et al. (2011), they found that the mean technical efficiency level of greenhouse strawberry production was 0.73, and it was emphasised that the producers could save 27% in the input amount. In Tariq et al. (2018)'s study, the minimum, maximum, and mean efficiency levels of the farms engaged in strawberry cultivation were determined as 42%, 98% and 82%, respectively. As for the research of Afzal et al. (2020), the minimum, maximum, and mean technical efficiency levels of strawberry producers were calculated as 39%, 97% and 64%, respectively.

The input losses of producers due to inefficiency are calculated by subtracting the targeted input use amounts for an efficient production from the current input use of the producers who have not achieved efficiency in production. Accordingly, the redundant labour (hour/ha), machinery (hour/ha), total fixed costs ($/ha) and other costs ($/ha) were determined according to reference producers producing above the efficiency limit of producers. It was calculated that approximately 20% of the producers overused their labour by 2.48%,17% of them overused machines by 0.67%, %53 of them overused total fixed costs by 6.64%, and 31% of them overused other costs by 12.32% (Table 4). In the research conducted by Ören and Alemdar (2006) on tobacco, they revealed that 42.28% of the farms used nitrogen fertiliser excessively by 35%, and 40.94% of them overused labour by 29%.

Table 4: Input losses and excessive usage

	Number of farms	Average input losses	Average input usage	Excessive input usage (%)
Labour use (hour/ha)	12	159.48	6425.13	2.48
Machinery use (hour/ha)	10	4.76	709.62	0.67
Total fixed cost ($/ha)	31	400.98	6043.30	6.64
Other costs ($/ha)	18	200.47	1626.73	12.32

The relationship between some socioeconomic variables and efficiency scores was investigated using the Tobit regression model to determine the factors causing inefficiency. In the Tobit regression analysis, the effects of the variables of strawberry yield (ton/ha), certified seedling use, producer's age (year), labour use (hour/farm) and fertiliser use (ton/ha) on the technical efficiency levels of greenhouse strawberry producers were analysed. The coefficients, standard error and P values acquired by Tobit regression analysis are presented in Table 5. As seen in the Table, it was determined that strawberry yield positively affected the farms' technical efficiency and their relationship was statistically significant (P<0.05). Hence, the technical efficiency of the farms increases as the strawberry yield increases. There was also a positive relationship between the use of certified seedlings and efficiency in farms. The relationship was statistically significant (P<0.05). It was seen that when the use of certified seedlings in farms increases, the efficiency increases. A negative relationship was found between the producers' age and the farms' efficiency, and it was statistically significant (P<0.10). It was determined that efficiency decreases when the producers' age increases. In other words, the lower the age, the higher the efficiency. Furthermore, there was a negative relationship between the labour used in farms and efficiency. It was found statistically significant (P<0.10). In line with the result obtained, efficiency decreases as the use of labour in farms increases. Finally, a negative relationship was determined between fertiliser use and efficiency in farms. It was found that the efficiency decreases as the use of fertilisers increases. However, this relationship was not found statistically significant, as expected (P>0.10).

Table 5: Results of Tobit regression analysis

Variable	Coefficient	Std. Error	Z-value	P-value
Constant	0.965624	0.024866	38.83288	0.0000*
Strawberry yield (ton/ha)	0.000672	0.000316	2.126266	0.0335**
Certified seedling use	0.018143	0.008225	2.205906	0.0274**
Producers' age (year)	-0.000508	0.000291	-1.746514	0.0807***
Labour use (hour/farm)	-2.920134	1.726163	-1.691691	0.0907***
Fertiliser (ton/ha)	-1.036005	1.439622	-0.724670	0.4687

*: p<0.01; **: p<0.05; ***: p<0.10

Tariq et al. (2018) emphasised that education, experience and credit use had an important role in increasing output. Afzal et al. (2020) revealed that family size, experience and credit use were the factors causing inefficiencies (P≤0.05). Moreover, in the research of Eka Wijayanti et al. (2020), it was determined that the variables of producers' education level and family size affected technical efficiency.

5. Conclusions

This study is significant in terms of measuring the technical efficiency of greenhouse strawberry farms and determining the factors causing inefficiency. According to the results, the mean efficiency of the producers was found 0.98 under the variable return to scale assumption. In this case, it may be possible for the producers to diminish their inputs by 2% without changing the amount of output. The mean efficiency of producers varied between 0.83 (the minimum) and 1.00 (the maximum) under the assumption of the variable returns to scale. It means that the producer with the minimum technical efficiency will be able to increase its efficiency up to 17% with the proper input combination. When the factors causing inefficiency were examined, it was determined that there was a positive relationship between the farms' efficiency and strawberry yield and certified seedling use, and this relationship was statistically significant (P<0.05). It was found that there was a negative relationship between the efficiency and producers' age and the use of labour in the farms, and it was statistically significant (P<0.10). Lastly, it was determined that there was a negative relationship between fertiliser use and efficiency in farms, but it was not statistically significant (P>0.10).

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