Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 24, Issue 3, 2024
PRINT ISSN 2284-7995, E-ISSN 2285-3952

TOMATO PRODUCTION QUANTITY ESTIMATES FOR 2023-2027 WITH ARIMA MODEL: EVIDENCE FROM LEADING PRODUCING COUNTRIES INCLUDING TURKEY

Adem AKSOY*, Haluk Çağlar KAYMAK**

Atatürk University, Faculty of Agriculture, *Department of Agricultural Economics, **Department of Horticulture, 25240-Erzurum, Turkey, E-mails: aaksoy@atauni.edu.tr; hckaymak@atauni.edu.tr

Corresponding author: aaksoy@atauni.edu.tr; hckaymak@atauni.edu.tr

Abstract

A study was conducted to analyze the changes in tomato production, which holds significant global importance, from 1961 to 2022 and to provide forward-looking predictions. The primary data for this study were derived from statistics obtained from the Food and Agriculture Organization (FAO) spanning the years 1961 to 2022. Utilizing the ARIMA model, the study aimed to forecast trends in tomato production from 2023 to 2027. The most suitable ARIMA models selected for China, India, Turkey, the United States, and Egypt were (1,1,3), (4,1,3), (2,1,0), (5,1,1), and (4,1,3), respectively. Upon comparing the actual production figures from the period 2018-2022 with the forecasted results for the period 2023-2027, a 4.09% increase in global tomato production is anticipated. Analysis of production forecasts for leading countries during the 2023-2027 period suggests that China, India, and Turkey are expected to experience production growth. Notably, a 7.38% decrease in production is forecasted for the United States during these years. The analytical findings indicate a strengthening influence of China and India in the tomato production sector in the forthcoming years. To enhance competitiveness in the tomato industry, countries like Turkey must focus on reducing production costs while ensuring the production of high-quality goods.

Key words**:** *tomato industry, ARIMA model, competitiveness in tomato production*

INTRODUCTION

Tomato is one of the most produced and consumed vegetables worldwide. According to 2022 statistics, global tomato production reached 186.1 million tons [11]. China leads the world in tomato production with an annual output of 68.3 million tons, followed by India and Turkey. Tomato production is not only significant in terms of quantity but also economically and nutritionally valuable.

The consumption of tomatoes has been associated with various health benefits and medicinal properties. Due to its low calorie content and essential nutrients such as amino acids, fiber, monounsaturated fatty acids, and carotenoids, tomatoes are considered ideal for weight control [6, 16]. Rich in vitamins A and C, potassium, and lycopene, a potent antioxidant linked to reduced risk of certain cancers and heart disease, tomatoes are considered a cornerstone of a healthy and balanced diet [5, 13, 15].

Given its numerous health benefits, tomatoes hold a prominent position as one of the most produced, consumed, and traded vegetable crops globally. Its versatility in various forms such as fresh, frozen, canned, paste, sauce, ketchup, pickled, pureed, peeled, sliced, diced, and dried expands its significance in the food industry [2, 3, 10]. Therefore, tomato production makes substantial contributions to the economies of various countries worldwide, including those in Europe, the Balkans, and Asia [2, 9].

With the world's population steadily increasing, the demand for food continues to rise. In this context, it becomes crucial to determine people's dietary needs and anticipate future production levels. Various models, including the "Autoregressive Integrated Moving Average" (ARIMA) model, are commonly used in agriculture to forecast future production based on historical data. The ARIMA model has been successfully applied to predict the production of various fruits and vegetables, such as strawberries [4], figs [8], hazelnuts [18], and apricots [19, 20].

Despite its importance in vegetable production, the use of the ARIMA model for predicting

tomato production has been limited. Forecasting tomato production among the leading tomato-producing countries for the years 2022-2027 will provide insights into future supply and the role of tomatoes in international trade. This study aims to forecast future tomato production and determine the dynamics among leading countries in the tomato sector. Predicting the changes in tomato production in Turkey, one of the leading tomato-producing countries, as well as in other significant tomato-producing nations, will contribute to gaining a competitive advantage in the international market and developing sustainable agricultural policies.

Therefore, this study was conducted to predict the changes in tomato production in Turkey and other leading producer countries in the foreseeable future using the ARIMA model.

MATERIALS AND METHODS

To ensure sustainability in tomato production, which holds significant importance in human nutrition and is affected by climate change, it is crucial to estimate the production amounts of countries with substantial shares in production for the forthcoming years. The primary data source for this study is the Food and Agriculture Organization (FAO) data. In this context, tomato production data from 1961 to 2022 in major tomato-producing countries were analyzed.

Tomato production quantity data spanning 1961-2022 were obtained from the FAO. Future production quantity estimates were derived using the ARIMA model. Stationarity of the data was assessed through root tests, and if non-stationarity was observed, adjustments were made to ensure stationarity at lags of 1, 2, or 3 years. In instances where the data did not exhibit a normal distribution, adjustments were made to achieve normality, and predictions for the years 2023-2027 were generated using the ARIMA model based on 62 years of data.

For enhanced accuracy and consistency in predictions, the p and q values were determined based on Bayesian Information Criterion (BIC) values obtained through SCAN and ESACF in the SAS 9.4 program. The selection criteria prioritized the smallest Schwarz Bayesian Criterion (SBC), Mean Squared Error (MSE), Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), Root Mean Square Error (RMSE), Durbin-Watson statistic closest to 2, and the highest R-squared value.

The most suitable ARIMA model was identified based on the p and q values that best fulfilled these criteria.

The formulation of the difference operation is as follows [21]:

$d=0$: $y_t = Y_t$ (1)

$d=1$: $y_t = Y_t - Y_{t-1}$ (2)

$d=2$: $y_t = (Y_t - Y_{t-1}) - (Y_{t-1} - Y_{t-2}) = Y_t - 2Y_{t-1} + Y_{t-2}$ .....(3)

The ARIMA model was expressed as in the formula 4 [21].

$$(1 - a_1B^1 - a_2B^2 \ldots - a_PB^P) * (1 - B)^d y_t = (1 - \theta_1B^1 - \theta_2B^2 - \cdots - \theta_qB^q)\varepsilon_t \quad \text{.....(4)}$$

The term $(1-B)^d$ is difference process from the d[nd] degree, $(1-B)^d y_t$ can be written for d=1 as $B\,y_t = y_{t-1}$. Also, it can be written for d=2 as $B^2 y_t = y_{t-2}$ or $B^1 y_{t-1} = y_{t-2}$.

RESULTS AND DISCUSSIONS

The past-to-present production values of the world's leading tomato-producing countries and the predictions generated by the ARIMA model were examined. Table 1 presents the discrepancies between actual and estimated tomato production for the top 5 countries, as well as other producing nations, and global tomato production from 1962 to 2022.

As the methodology section outlines, the ARIMA model provides the most suitable prediction results by considering various criteria. In Table 1, the optimal model for China was identified as ARIMA (1,1,3). In contrast, for other countries, the preferred models were ARIMA (4,1,3) for India, ARIMA (2,1,0) for Turkey, ARIMA (5,1,1) for America, and ARIMA (4,1,3) for Egypt.

Upon reviewing the literature, it was found that [7] and [14] used ARIMA (0,1,1) and ARIMA (1,0,1) models respectively for predicting

tomato prices, while [17]employed SARIMA (2,0,0) and ARIMA (1,1,0) models for forecasting monthly tomato prices in India.

China, India, Turkey, America, and Egypt collectively contribute 52.8% of global tomato production [11]. Comparison of actual values with ARIMA model predictions for the top 5 tomato-producing countries revealed near-perfect forecasts across all leading nations, with the highest deviation observed globally at -0.1 percent. Overall, the predicted values are closely aligned with actual figures, demonstrating the effectiveness of the models.

Table 1. Deviations between the realized and the ARIMA model estimation of average tomato production for the 1962-2022 period

Country	Model	Realized (thousand tons) (A)	Estimation (thousand tons) (B)	Deviation (%) (100*(B-A)/A)
China	1.1.3	21,765.44	21,765.44	0.00
India	4.1.3	6,929.11	6,929.3	0.00
Turkey	2.1.0	6,647.84	6,649.17	0.02
USA	5.1.1	9,843.1	9,839.24	-0.04
Egypt	4.1.3	4,761.16	4,761.45	0.01
Other	2.1.4	44,024.21	44,038.12	0.03
World	5.1.0	93,993.45	93,900.54	-0.10

Source: Calculated by author.

The differences between the actual production values from 1961 to 2022 and the predictions obtained from the ARIMA model from 2023 to 2027 for the leading countries in global tomato production are presented in Table 2. While the total share of the top 5 countries in tomato production increased from 53.14% from 1961 through 2022 to 64.56% in the years 2023-2027, China experienced the highest increase rate of 14.36%, followed by India with 3.90%. The greatest decrease, estimated at 5.18%, is expected to occur in the United States, indicating a decrease in the total production shares of America and Egypt. Moreover, during the same period, it is anticipated that there will be an increase of 11.42% in the total production share of the top five countries.

Table 2. Countries Leading in Tomato Production: Their Shares of Global Tomato Production and the Differences Among Them (%)

Country	A (1961-2022)	B (2023-2027)	Difference (B-A)
China	23.16	37.51	14.36
India	7.37	11.27	3.90
Turkey	7.07	7.14	0.07
USA	10.47	5.30	-5.18
Egypt	5.07	3.34	-1.72
Total share %	53.14	64.56	11.42

Source: Calculated by author.

According to these findings, it is evident that China and India will emerge as dominant players in global tomato production. Considering this, current leading tomato-producing countries must take pre-emptive measures to counteract this trend and rectify any shortcomings in their production goals.

Table 3 illustrates the changes between the actual production quantities observed in leading tomato-producing countries from 1961 to 2022, 2018 to 2022, and the estimated quantities to be produced between 2023 and 2027. When comparing the production quantities realized during the 2018-2022 period with the forecasted results from the model for the 2023-2027 period, a 4.09% increase in global tomato production is expected. Upon examining the production predictions for the leading countries during the 2023-2027 period, it is anticipated that China, India, and Turkey will increase their production. Specifically, a 7.38% decrease in production is expected for the USA during the forecasted years. Based on these findings, diverse developments can be expected both in tomato production and in international trade.

Alongside Turkey, a competitive player in tomato production [2], China and India may play a more influential role in tomato

international trade compared to other countries. Furthermore, anticipated changes in tomato production and trade should also be considered for other fruits and vegetable species [1].

Table 3. Comparison of Tomato Production of the Five Countries Between the Periods (1,000 tons

Country	A (1961-2022)	B (2018-2022)	C (2023-2027)	Change 100*(C-A)/A	Change 100*(C-B)/B
China	21,514.44	64,744.92	72,211.15	235.64	11.53
India	6,824.83	20,238.2	21,691.57	217.83	7.18
Turkey	6,558.68	12,858.25	13,752.05	109.68	6.95
USA	9,762.09	11,009.08	10,196.83	4.45	-7.38
Egypt	4,698.38	6,550.18	6,433.16	36.92	-1.79
Others	43,564.43	69,540.01	73,231.02	68.10	5.31
World	92,922.87	184,940.64	192,503.83	107.17	4.09

Source: Calculated by author.

The relationship between the actual production values of leading countries in global tomato production (excluding China) from 1961 to 2027 and the predictions obtained from the ARIMA model is depicted in Figure 1. When Figure 1 is examined, it is noteworthy that the predictions are quite consistent. The changes presented in Table 3 are further clarified in Figure 1. It is noteworthy that while India and Turkey have consistently increased their production over the years, a decline in production quantity is observed in Egypt after 2009 and in the United States after 2015. Similar predictions have been made for countries in small-scale studies focusing on tomato production and demand estimation. For instance, [12] noted an increase in tomato production within Bangladesh over the years but highlighted the inability to meet domestic demand, with production falling significantly short of demand.

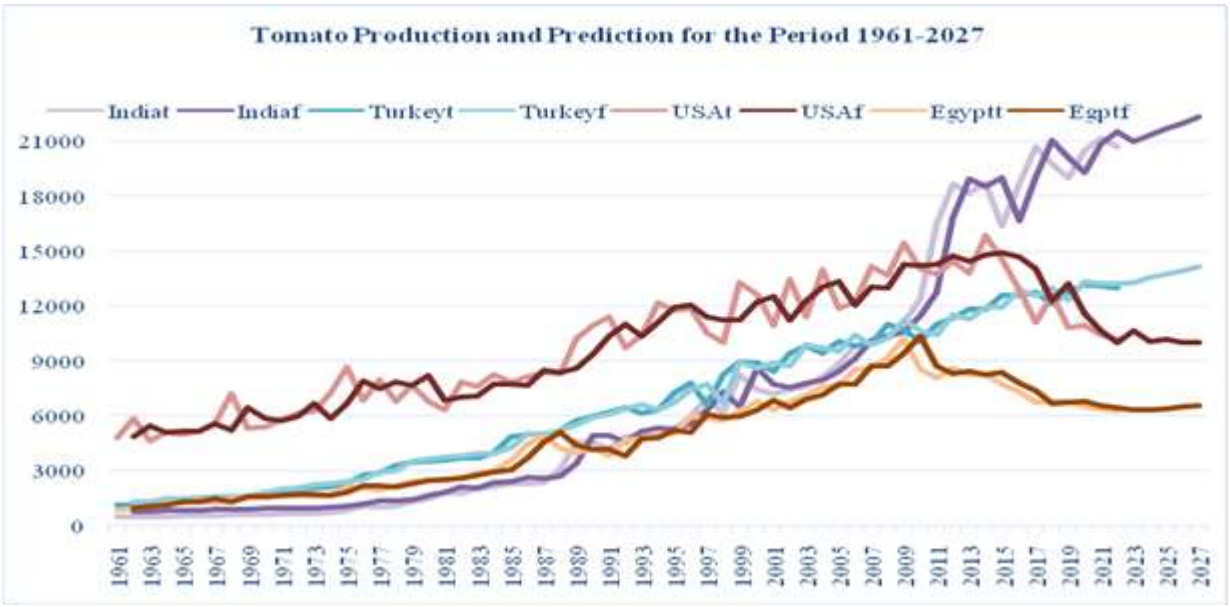

Fig. 1. Tomato production ın India, Turkey, USA and Egypt in1961-2022 and forecast chart for 1962-2027
Source: Calculated by author.
Note: t= production, f = prediction

The production quantities and forecast values of China and world tomato production are examined in Figure 2. A perfect alignment between the production values of China, the leading country in global tomato production, and the ARIMA model estimates from 1961 to 2022 is observed. It is also evident from Figure 2 that there is no deviation in the obtained predictions. Particularly after the 1990s, significant increases in tomato production have

been observed in China. A remarkably low deviation of 0.1% has been observed between the actual world tomato production and the predictions during the study years. This can be considered as evidence that the ARIMA model, which has been successfully applied in hazelnut, apricot, fig, and strawberry production forecasts, can also be reliably used for tomatoes [4, 8, 18, 19, 20].

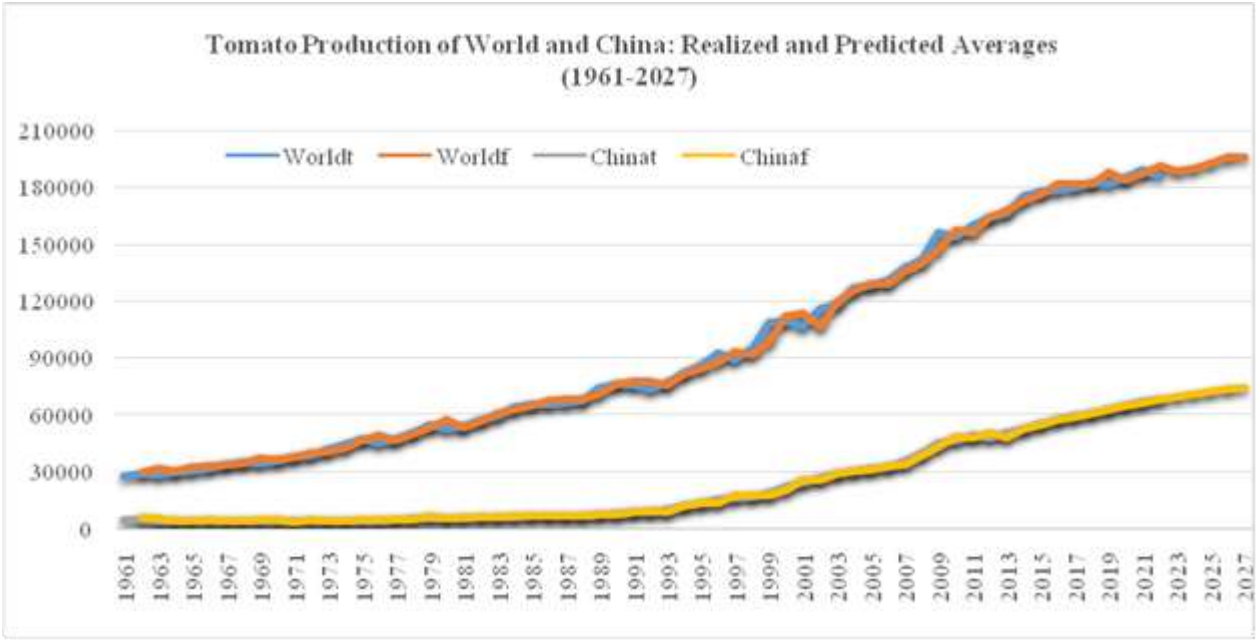

Fig. 2. Tomato production in China and the world in 1961-2022, and prediction graph of 1962-2027
Source: Calculated by author.

CONCLUSIONS

In this work, changes in tomato production between 2023 and 2027 for the leading tomato-producing countries were estimated using the ARIMA model, based on FAO data from 1961 to 2022. According to FAO data, China is the largest tomato producer, followed by India, Turkey, and the United States. Findings from the study suggest that the annual growth rate in world tomato production was 9.41% during the 1961-2022 period, but it is expected to decrease to 0.75% between 2023 and 2027. Significant increases are anticipated in China and India, the top two tomato-producing countries, which could raise the total production share of the top 5 countries in the global market from 53.14% to 64.56% during 2023-2027. However, the production of the USA, among the top tomato- producing countries, is estimated to decrease by 7.38%. With the increasing world population,
there will also be significant growth in demand for tomatoes and tomato-based food products. The analysis results indicate that the influence of China and India in the sector is expected to grow in the next years. Countries like Turkey need to reduce production costs and ensure quality production to compete in tomato production and related sectors. As a result, it can be said that the risk of China and India dominating tomato production and related sectors in the coming years should be taken into consideration, and other significant tomato-producing countries need to take necessary precautions against this situation.

REFERENCES

[1]Aksoy, A., Kaymak, H.Ç., Avcıoğlu, Ü., 2020, Walnut (*Juglansregia* L.) trade: competition power of Turkey with Balkan countries. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 20(4):11-18.
[2]Aksoy, A., Kaymak, H.Ç., 2021, Competition power of Turkeys tomato export and comparison with Balkan countries. Bulgarian Journal of Agricultural Science, 27(2):253-258
[3]Bashimov, G., 2016, Turkey's export performance of tomato and competitiveness. Alınteri, 31(B):1-8.
[4]Begüm, A., Baylan, E.B., 2022, Establishing a forecast model for strawberry sales prices by Box-Jenkins method and evaluation of the forecast results.

İstanbul Commerce University Journal of Science, 21(42):211-234.
[5]Bhowmik, D., Sampath Kumar, K.P., Paswan, S., Srivastava, S., 2012, Tomato-A natural medicine and its health benefits. Journal of Pharmacognosy and Phytochemistry, 1(1):33-43.
[6]Campestrini, L.H., Melo, P.S., Peres, L.E., Calhelha, R.C., Ferreira, I.C., Alencar, S.M., 2019, A new variety of purple tomato as a rich source of bioactive carotenoids and its potential health benefits. Heliyon, 5(11):e02831.
[7]Cryer, J.D., Chan, K.S., 2008,Time Series Analysis: With Applications In R, Springer, Science + Business Media, LLC, New York, p.249-276.
[8]Çakan, V.A., 2020,Forecasts for Turkey fresh fig production and dried fig export: ARIMA model approach. Journal of Tekirdag Agricultural Faculty,17(3):357-368.
[9]Durmus, M., Yetgin, Ö., Abed, M.M., Haji, E.K., Akçay, K., 2018, Tomato plant, evaluation in terms of nutrient content and healthy. International Journal of Life Sciences and Biotechnology, 1(2):59-74.
[10]Ertürk, Y.E., Çirka, M., 2015, Tomato- production and marketing in Turkey and north eastern Anatolia region. Yuzuncu Yıl University Journal of Agricultural Sciences, 25(1):84-97.
[11]FAO, 2024, Food and Agriculture Organization. https://www.fao.org/faostat/en/#data/QCL, Accessed on Feb 5, 2024.
[12]Hossain, M.M., Abdulla, F., 2015, On the production behaviors and forecasting the tomatoes production in Bangladesh. Journal of Agricultural Economics and Development, 4(5):066-074.
[13]Karadaş, K., Güler, F., 2021, Determination of tomato production cost in Igdır province. Journal of the Institute of Science and Technology, 11(3):2350-2356.
[14]Mutwiri, R.M., 2019, Forecasting of tomatoes wholesale prices of Nairobi in Kenya: time series analysis using SARIMA model. International Journal of Statistical Distributions and Applications,5(3):46-53.
[15]Navarro-González, I., García-Alonso, J., Periago, M.J., 2018, Bioactive compounds of tomato: Cancer chemopreventive effects and influence on the transcriptome in hepatocytes. Journal of Functional Foods, 42:271-280.
[16]Ramos-Bueno, R.P., Romero-Gonzalez, R., Gonzalez-Fernandes, M.J., Guil-Guerrero, J.L., 2016, Phytochemical composition and in vitro anti-tumour activities of selected tomato varieties.Journal of the Science of Food and Agriculture97:488–496.
[17]Reddy, A.A., 2019, Price forecasting of tomatoes. International Journal of Vegetable Science, *25*(2):176-184.
[18]Türkay, B., İlkay, U., Akbay, C., 2018, Turkey hazelnut production projection with ARIMA model. Journal of Agriculture and Nature, 21:154-160.
[19]Uçar, K., Güler, D., Engindeniz, S., 2021, Estimating of Apricot Production of Turkey Using ARIMA Model. Turkish Journal of Agricultural Economics, 27(2):55-62.
[20]Uzundumlu, A.S., Karabacak, T., Ali, A., 2021, Apricot production forecast of the leading countries in the period of 2018-2025. Emirates Journal of Food and Agriculture, 33(8):682-690.
[21]Uzundumlu, A.S., Kurtoglu, S., Şerefoğlu, Ş., Algur, Z., 2022, The role of Turkey in the world hazelnut production and exporting. Emirates Journal of Food and Agriculture, 34(2):117-127.