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Modelling of the milk supplied to the industry in Turkey through Box-Jenkins and Winters' Exponential Smoothing methods

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ABSTRACT:

Analysis of the quantity of cow milk supplied to the industry in Turkey is one of the methods that could provide stakeholders with the most accurate results from the perspective of raw milk projections and the interpretation of the sector. Therefore, it is important that the amount of milk supplied to the industry is used instead of the total amount of milk produced in the projections of the sector. The present study is intended to model the time series data of the amount of milk supplied to the dairy industry in Turkey between 2013/01 and 2018/03 using Box-Jenkins and Winters' Exponential Smoothing methods, and to analyse the production of milk and the future of the dairy industry in Turkey utilising the forecasts obtained from such models. The results of the analyses indicate that the Winters' Exponential Smoothing model gives more consistent results than the Box-Jenkins model with respect to the future forecast value and decision-making criterion of the amount of milk supplied to the industry.

Türkiye'de sanayiye aktarılan sütün Box-Jenkins ve Winter's Üstel Düzgünleştirme yöntemleri ile modellenmesi

ÖZET:

Türkiye'de sanayiye aktarılan inek sütü miktarı üzerinden gerçekleştirilecek analizler, geleceğe yönelik çiğ süt projeksiyonları ve sektörün yorumlanması noktasında paydaşlara en doğru sonucu verebilecek yöntemlerden birisidir. Bu nedenle üretilen toplam çiğ süt miktarı yerine sanayine aktarılan çiğ süt miktarının kullanımı ve bunun üzerinden bir takım projeksiyonların yapılması önem arz etmektedir. Yapılan bu çalışmayla, 2013/01-2018/03 dönemleri arası Türkiye'de süt sanayine aktarılan çiğ süt miktarı zaman serisinin Box-Jenkins ve Winter's Üstel Düzgünleştirme yöntemleri ile modellenmesi ve bu modellerin öngörüleriyle Türkiye'de çiğ süt üretimi ve süt sektörünün geleceği açısından analizi amaçlanmıştır. Yapılan analizlar sonucunda Winter's Üstel Düzgünleştirme modelinin sanayiye aktarılan süt miktarının karar verme kriteri ve geleceğe yönelik kestirim değeri bakımından Box-Jenkins modelinden daha tutarlı sonuç vereceği belirlenmiştir.

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1. Introduction

In Turkey, the dairy industry is one of the most dynamic branches of production among the sub-sectors of the farming industry (1). A total of 20,699,894 tons of milk was produced in 2017. 90.64% of the milk produced is cow milk, 6.49% sheep milk, 2.53% goat milk and 0.34% water buffalo milk (2). A significant portion of the milk produced in Turkey is cow milk. Research has shown that 52.2% of the cow milk produced in Turkey is subjected to industrial processes, 21.5% is used by individuals to produce dairy products, 10.5% is directly sold to non-industrial buyers, 8.2% is consumed as milk by individuals, 5.0% is used to feed animals, 2.2% is delivered free of charge and 0.4% is used for other purposes (3).

The amount of milk supplied to the industry in developed countries is high, as the informal economy is low and production has a more sustainable pattern, unlike the case in Turkey (1).

In this context, various market intervention methods were resorted to in an attempt to keep the milk supply and prices at the desired level in the developed countries. For instance, quota system was used to reduce the milk supply to a level sufficient to meet the demand in the EU, and was employed to increase the income of raw milk producers that did not have a sufficient level of income to the desired level in Canada (4).

The dairy industry in Turkey has some problems due to the fact that the milk supply varies by regions and seasons and that the dairy industry and cattle breeding enterprises have a distributed structure (5).

Furthermore, the marketing network in Turkey is quite different and is generally based on intermediaries. While this marketing chain results in increases in the price of final products, it also leads to decreased efficiency in the procurement of milk by industrialists. Particularly, a sustainable production requires a dairy industry integrated with an effectively functioning production sector (6).

Milk-processing companies face an uncertain production pattern in planning their production processes. This uncertainty results in huge economic losses if it is not taken into account when planning the production (7).

The quantity of milk supplied to the industry is as important as the quantity of raw milk produced for the production planning of such enterprises. Therefore, the projections based on the number of livestock, the quantity of milk as well as the recorded quantity of raw milk supplied to the industry will allow us to make clearer inferences and predictions for the future of the dairy industry. For this purpose, there is need for creation of a proper database and time series analysis methods that enable modelling of such data (8).

While the studies conducted in recent years have focused on prediction of milk production, time series analyses have found wide use in predicting the procurement of milk by milk cooperatives and the production of milk in the future (9, 10, 11), the milk production by the dairy industry in the future (12, 13), the procurement of milk by milk-processing companies (14), analysis of market prices of milk and forecast for the future (15).

The purpose of the present research is to model the time series data of the quantity of raw milk supplied to the dairy industry in Turkey between 2013/01 and 2018/03 using Box-Jenkins and Winters' Exponential Smoothing methods, and to appraise the models in terms of the production of raw milk and the future of the dairy industry in Turkey.

2. Material and Methods

Data set:

The data of the research are the monthly quantities of raw milk supplied to the dairy industry between 2013/01 and 2018/03. The data on raw milk supplied to the dairy industry were obtained from relevant industrial organisations. Table 1 shows the time series data on the quantity of cow milk supplied to the dairy industry.

Table 1: Quantity of milk supplied to the dairy industry (tons)

Tablo 1: *Süt sanayine aktarılan süt miktarı (Ton)*

	2013	2014	2015	2016	2017	2018
January	610.403,56	675.713,86	683.819,45	714.131,76	734.834,39	803.544,05
February	593.031,43	654.907,21	664.967,96	722.488,61	711.651,39	775.895,14
March	691.122,72	761.814,20	776.788,47	818.214,00	835.971,63	889.907,97
April	717.892,77	782.557,32	798.960,40	818.148,07	834.345,08	
May	756.972,33	814.708,71	861.918,48	849.338,25	868.350,38	
June	715.380,99	746.764,72	790.440,37	770.543,06	796.465,07	
July	653.514,61	715.180,42	743.506,00	725.436,34	777.953,52	
August	608.758,67	669.141,67	698.885,00	706.024,87	748.471,50	
September	573.025,57	618.715,92	648.267,00	653.904,24	700.513,19	
October	578.777,69	614.828,66	663.146,00	678.526,63	717.421,54	
November	581.183,37	603.411,09	648.520,00	660.111,99	701.531,53	
December	622.900,22	652.510,37	692.961,00	695.722,70	759.149,83	

Analysis method:

In this research appraise the estimate made employing the methods of “Autoregressive Integrated Moving Average” (ARIMA) and “Winters' Exponential Smoothing” in a time series analysis. SPSS 25.0 version was used for the analysis.

Developing an appropriate model by using statistical methods and making predictions for the future may be possible with time series. The time series is a series of observations made at periodic time intervals (16). The predictions for the success of these series are related to the fact that the past values are stable. The margin of error of the estimates of series showing descent-output values is very high compared to stationary series (17). The stagnation can be defined as the "probabilistic process whose mean and variance do not change over time and whose common variance between two periods depends on the distance between the two periods, not the period on which this common variance is calculated." (18, 19). The most common tests used to investigate stagnation are; series “Autoregressive Correlation Function” (ACF), “Partial Autocorrelation Function” (PACF) graphs and “augmented Dickey-Fuller” (ADF) unit root test (20).

Box-Jenkins Method (ARIMA):

This method is in two different processes (21). The autoregressive model (AR) and the the moving average (MA) model. Box-Jenkins method, which is a combination of two models, is expressed with ARMA model. However, Box-Jenkins method is required to be stationary series.

In order to perform the series constant, d difference of the cow milk supplied to the dairy industry series is taken. After, it is included in the ARMA model to acquire the ARIMA model. In time series estimate, this model is commonly used because of its statistical characteristics as well as its structure (22).

Depending on the nature of the data available, an ARIMA model with the most convenient but limited number of parameters is selected among the various model options. Such non-seasonal models are indicate by ARIMA (p,d,q). In an ARIMA model;

p: the degree of the autoregressive model (AR),

q: the degree of the moving average model (MA),
d: the degree of the non-seasonal differences taken. The ARMA model is as given in equation [1] (21).

$$Y_t = \sum_{i=1}^{q} \beta_i \, \varepsilon_{t-i} + \sum_{i=1}^{p} \alpha_i \, Y_{t-i} + \varepsilon_t \qquad [1]$$

Equation [2] is acquire when the first difference of the non-stationary time series X_t is taken.

$$\nabla X_t = X_t - X_{t-1} = X_t' \qquad [2]$$

If the time series $X_t{}'$ is still not stationary, its second difference (d=2) is taken.

$$\nabla^2 X_t = \nabla(X_t') = X_t' - X_{t-1}' = X_t - 2X_{t-1} + X_{t-2} \qquad [3]$$

If the series is still not stationary, the differencing is repeated until it becomes stationary. Thus, the ARIMA(p,d,q) model is obtained (23).

$$X_t = \nabla^d Y_t = (1-B)^d Y_t \qquad [4]$$

Seasonal Box-Jenkins models are usually denoted by ARIMA[p,d,q) (P,D,Q)s.
P: the degree of the seasonal autoregression (SAR) model,
D: the number of seasonal differences taken,
Q: the degree of the seasonal moving average (SMA) model,
s: the period (18).

$$(1-\phi_1 B - \phi_2 B^2 - \cdots . -\phi_p B^p)(1-\phi_1 B^s - \phi_2 B^{2s} - \cdots . -\phi_p B^{ps})(1-B)^d (1-B^s)^D Z_t = (1-\theta_1 B - \theta_2 B^2 - \cdots . -\theta_q B^q)(1-\Theta_1 B^s - \Theta_2 B^{2s} - \cdots . -\Theta_Q B^{Qs})\varepsilon_t \qquad [5]$$

Winters' Exponential Smoothing Method

This method is used where there is both trend and seasonality in the data series at hand. Seasonality is seen in real data and this method can be additive or multiplicative. The additive and multiplicative model equations are given in equality [6] and equality [10] (24).

Additive model

$$Y_{t+h} = \mu_t + b_t t + S_{t-p+h} + e_t \qquad [6]$$

The updated average equation is given in equation [7].

$$\mu_t = \alpha(Y_t - S_{t-p}) + (1-\alpha)(\mu_{t-1} + b_{t-1}) \qquad [7]$$

The equation of the updated trend component is given in equation [8].

$$b_t = \Upsilon(\mu_t - \mu_{t-1}) + (1-\Upsilon) b_{t-1} \qquad [8]$$

The equation of the updated seasonality component is given in equation [9].

$$S_t = \delta(Y_t - \mu_t) + (1-\delta) S_{t-p} \qquad [9]$$

Multiplicative Winters' model has a linear trend and seasonality with multiplicative parameters, and is as follows:

$$\hat{Y}_t = (\mu_t + b_t t) S_{t-p+h} + e_t \qquad [10]$$

The updated average equation is given in equation [11].

$$\mu_t = \alpha\left(\frac{Y_t}{S_{t-p}}\right) + (1-\alpha)(\mu_{t-1} + b_{t-1}) \qquad [11]$$

The equation of the updated trend component is given in equation [12].

$$b_t = \Upsilon(\mu_t - \mu_{t-1}) + (1-\Upsilon) b_{t-1} \qquad [12]$$

The equation of the updated seasonality component is given in equation [13].

$$S_t = \delta(Y_t / u_t) + (1-\delta) S_{t-p} \qquad [13]$$

3. Results

In order to forecast the amount of milk supplied to the dairy industry, time series analysis of the data on the amount of raw milk supplied to the dairy industry between 2013/01 and 2018/03 was conducted. The time series graph of the amount of raw milk supplied to the dairy industry and the graph of the differenced series are given in Fig1.

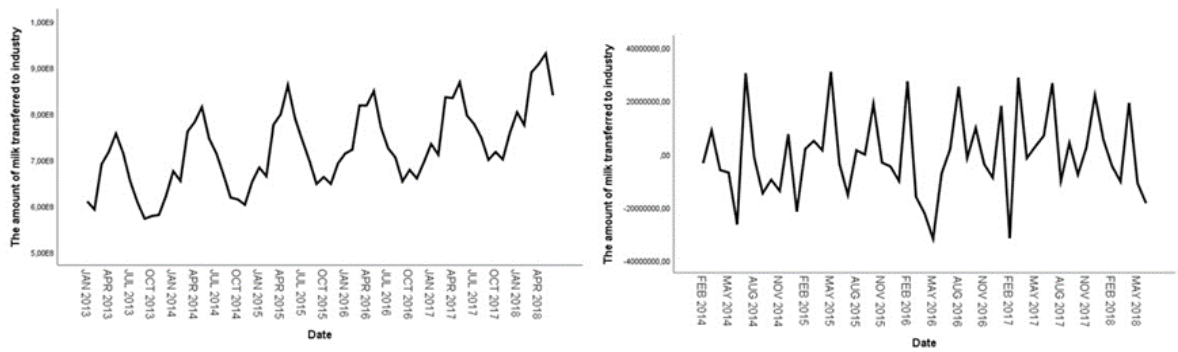

Figure 1: Quantity of milk supplied to the dairy industry (tons) and first differenced and seasonally differenced time series graph

Şekil 1: *Süt sanayine aktarılan süt miktarı (ton) ve 1. Derece fark ve sezonsal farkı alınmış serilere ait zaman serisi grafiği*

When Fig1 is analysed, it can be said that there are fluctuations in the series and an upward trend with a trend. The main reasons that prevent the series from being stationary are the presence of seasonality and trend. The ACF and PACF graphs of the series are given in Fig2 and Fig3 for the study of stability. When the graphs are examined, it can be said that the series is not stable because more than one delay is outside the confidence limits. Since the series is not stationary, the logarithm was first taken and the differences between the values of the series were reduced and partially stabilized. However, this process was applied until the series was stationary. Once the difference was taken, it was concluded that the series stagnated for trend and seasonality. ACF and PACF graphs are shown in Fig2 and Fig3.

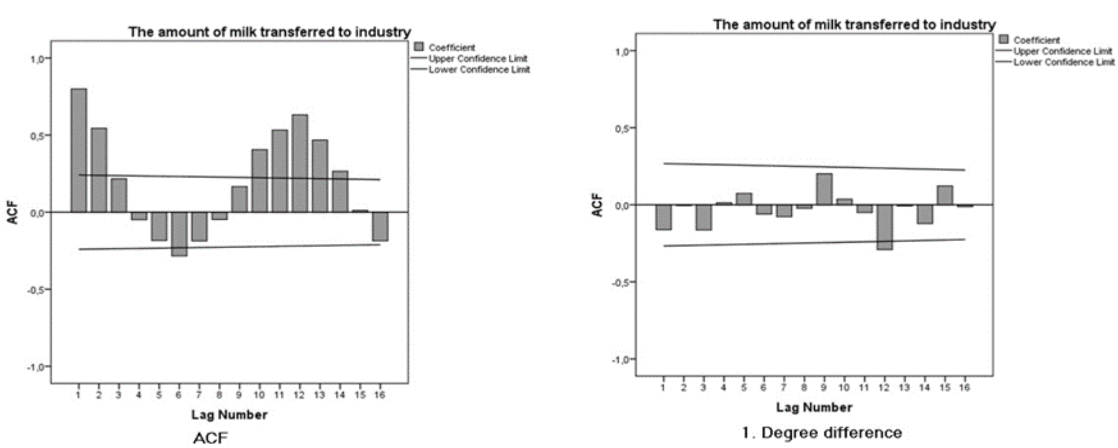

Figure 2: ACF and first differenced ACF graph of the time series data on the quantity of milk supplied to the dairy industry

Şekil 2: *Süt sanayine aktarılan süt miktarına ait serinin ACF ve 1. Derece farkı alınmış ACF grafiği*

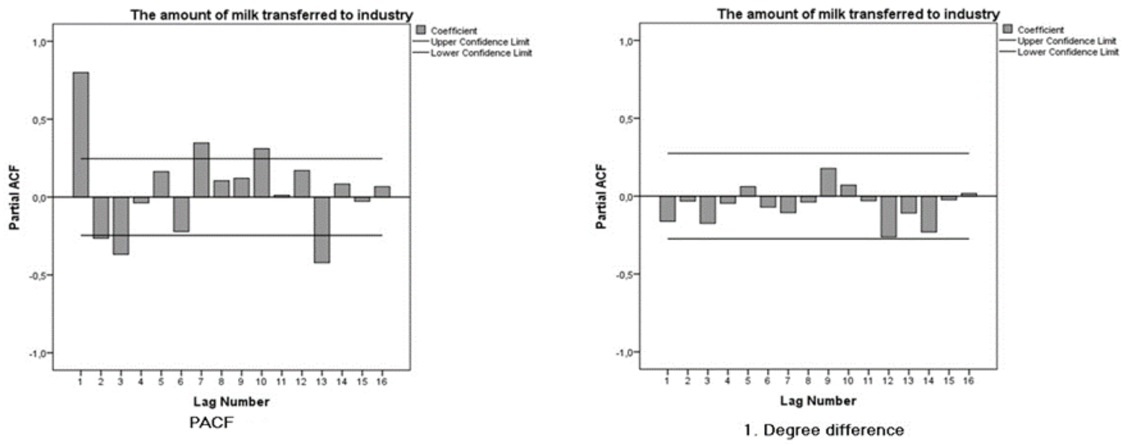

Figure 3: PACF and first differenced PACF graph of the time series data on the quantity of milk supplied to the dairy industry

Şekil 3: *Süt sanayine aktarılan süt miktarına ait serinin PACF ve 1. Derece farkı alınmış PACF grafiği*

It is seen in Fig2 and Fig3 that ACF and PACF graphs are observed when two delays exceed the confidence limit and the other two delays are close to the confidence limit. According to the results, these values can be neglected and it can be said that the series is still stationary. Stability analysis of the series was also performed using the extended ADF unit root test. According to the ADF test before the difference, the series is said to be non-stationary ($t = -0.254$; $p = 0.954$) and after the difference, the series is said to be stationary ($t = -14.258$; $p = 0.001$). While trying to form an appropriate model by making use of these processes, several different models have been tried and the most suitable model for the amount of raw milk transferred to the dairy industry is SARIMA (0,1,0) (0,1,1).

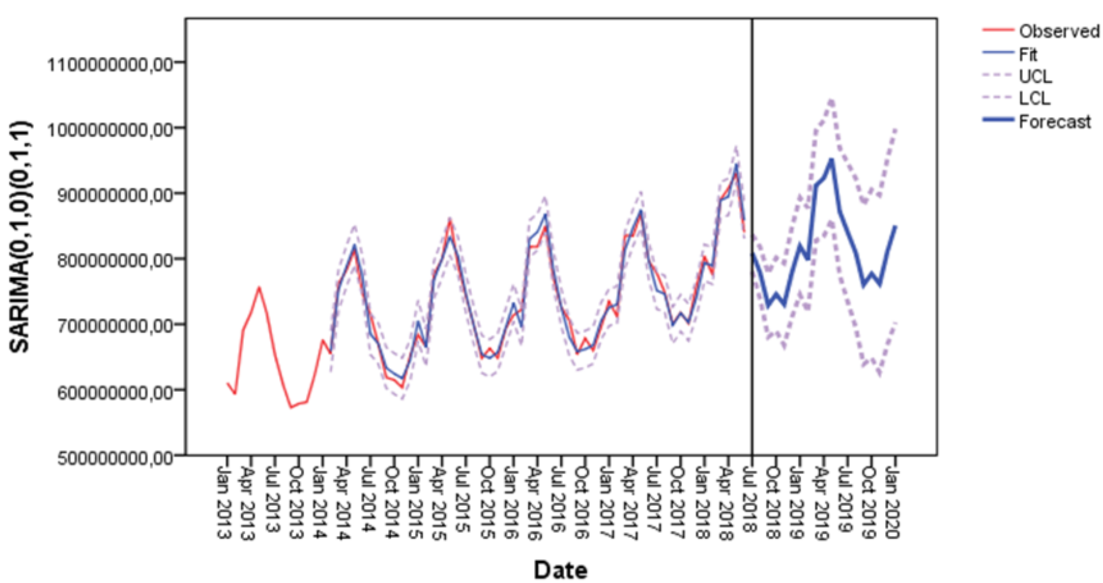

Figure 4: Forecast of the quantity of milk supplied to the dairy industry by the Box-Jenkins model

Şekil 4: *Yıllara göre süt sanayine aktarılan süt miktarı Box Jenkins modeli öngörü grafiği*

Table 2: Forecast values of the quantity of milk supplied to the dairy industry in the Box-Jenkins models (tons)

Tablo 2: *Box Jenkins modellerine göre süt sanayine aktarılan süt miktarı öngörü değerleri (ton)*

	Forecast	UCL	LCL
July_2018	808.627,91	780.665,63	836.590,19
August_2018	777.991,90	738.447,26	817.536,54
September_2018	729.020,93	680.588,83	777.453,02
October_2018	745.730,25	689.805,68	801.654,81
November_2018	730.466,73	667.941,16	792.992,29
December_2018	779.613,15	711.119,82	848.106,47
January_2019	819.240,99	745.259,74	893.222,24
February_2019	798.139,60	719.052,60	877.226,60
March_2019	911.766,49	827.883,94	995.649,04
April_2019	922.917,65	834.499,27	1.011.336,04
May_2019	952.824,51	860.091,89	1.045.557,13
June_2019	871.503,06	774.648,18	968.357,94
July_2019	839.932,90	734.274,07	945.591,74
August_2019	809.296,89	695.513,27	923.080,51
September_2019	760.325,92	638.960,21	881.691,63
October_2019	777.035,24	648.534,04	905.536,44
November_2019	761.771,72	626.510,93	897.032,51
December_2019	810.918,14	669.219,86	952.616,42
January_2020	850.545,99	702.690,23	998.401,75

Table 2 and Table 4 show the forecast values of the amount of milk to be supplied to the dairy industry until 2020. The amount of milk supplied to the dairy industry has an increasing trend.

Table 3: Model fit criteria for the Box-Jenkins model

Tablo 3: *Box jenkins modeli model uyum kriterleri tablosu*

Model	Model Fit statistics								Ljung-Box Q(18)		
	Stationary R-squared	R-squared	RMSE	MAPE	MAE	MaxAPE	MaxAE	Normalized BIC	Statistics	DF	Sig.
Amount of milk transferred to dairy industry-model	0,136	0,967	14379055,290	1,527	11398801,623	4,234	30282092,160	33,037	16,363	17	0,498

The goodness of fit criteria of the models are evaluated in a comparative manner. R^2 is a well-known measure and a measure of goodness of fit for the linear model, frequently referred to as the coefficient of determination. It ranges from 0 -1, and small values show that the model does not fit well into the data. The stationary R^2 is a measure comparing the stationary part of the model with the basic model. It is preferred where there is a trend or a seasonal pattern. RMSE is the square root of the mean of the error squares. It is used to express how different the dependent series is from the level predicted by the model. Smaller values indicate better model estimates. MAPE shows the mean absolute percentage error and is independent of the units of the series, so it can be used to compare different series. The MAE represents the mean absolute error and is expressed in units of the series itself. MaxAPE is the highest absolute percent error measure. It represents the highest error that occurs among the estimated values, expressed as a percentage and is therefore unit independent. Estimates are a measure that can be used for worst-case applications. MaxAE indicates the highest absolute error and is expressed in the same unit as the slave series. The BIC, the normalized "Bayesian Information Criterion", is a general measure of the total fit of the model. This measure is used to compare between different models in the same series, and lower values indicate a better model (25).

Looking at Table 3, it is clear that the quantity of raw milk supplied to the dairy industry is statistically significant is the Box-Jenkins model ($p<0.05$). MAPE value indicates that the series have quite usable forecasts.

Then, the quantity of raw milk supplied to the dairy industry was predicted using Winters' Exponential Smoothing Method, one of the exponential smoothing methods. Table 4 and Table 5 illustrate the forecast values until 2020. It is clear that the quantity of milk supplied to the dairy industry has an increasing trend.

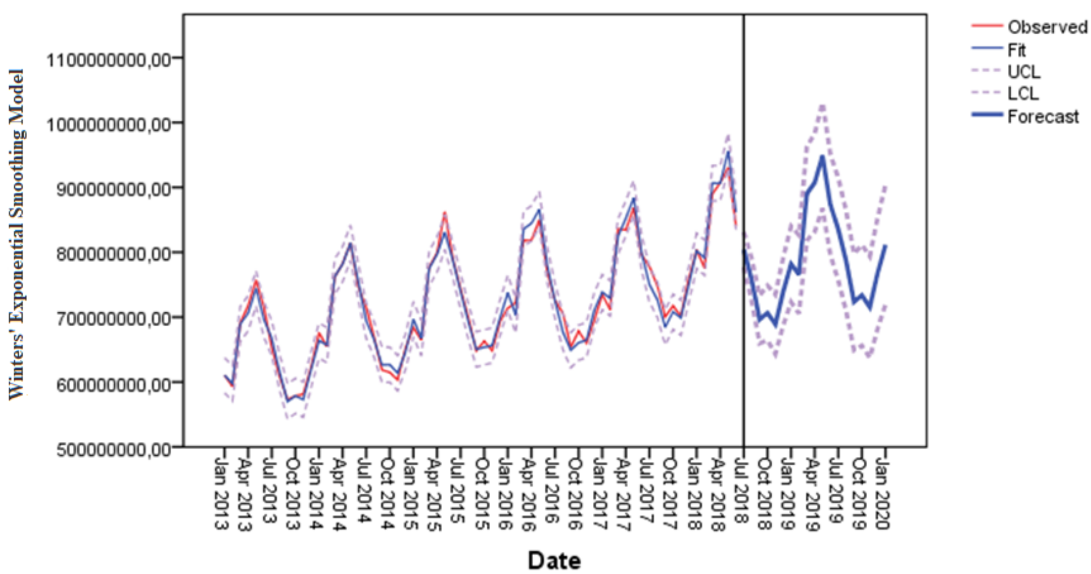

Figure 5: Forecast of the quantity of milk supplied to the dairy industry by the Winters' Exponential Smoothing model (tons)

Şekil 5: *Süt sanayine aktarılan süt miktarına ait Winter Üstel Düzgünleştirme modeli öngörü grafiği (ton)*

Table 4: Forecast values of the quantity of milk supplied to the dairy industry in the Winters' exponential smoothing models (tons)

Tablo 4: *Winter üstel düzgünleştirme modellerine göre süt sanayine aktarılan süt miktarı öngörü değerleri (ton)*

	Forecast	UCL	LCL
July_2018	804.225,56	777.161,16	831.289,97
August_2018	757.177,94	724.299,80	790.056,08
September_2018	696.474,87	659.622,69	733.327,04
October_2018	706.530,29	664.378,75	748.681,83
November_2018	689.127,27	643.370,92	734.883,62
December_2018	739.424,70	687.057,82	791.791,59
January_2019	781.704,49	723.361,53	840.047,44
February_2019	766.012,77	705.522,39	826.503,16
March_2019	890.549,36	818.475,92	962.622,79
April_2019	907.276,48	831.495,06	983.057,91
May_2019	948.971,71	867.670,96	1.030.272,46
June_2019	873.012,84	795.499,28	950.526,41
July_2019	835.532,87	756.589,90	914.475,84
August_2019	786.558,44	709.327,38	863.789,51
September_2019	723.412,82	649.134,76	797.690,88
October_2019	733.769,37	656.168,46	811.370,29
November_2019	715.610,32	637.348,50	793.872,14
December_2019	767.749,97	682.277,73	853.222,20
January_2020	811.554,08	719.715,49	903.392,68

Table 5: Model fit criteria for the Winters' exponential smoothing model
Tablo 5: *Winter üstel düzgünleştirme modeli model uyum kriterleri tablosu*

Model	Model Fit Statistics								Ljung-Box Q (18)		
	Stationary R-squared	R-squared	RMSE	MAPE	MAE	MaxAPE	MaxAE	Normalized BIC	Statistics	DF	Sig.
Amount of milk transferred to dairy industry-model	0,164	0,976	13543438,852	1,399	10337905,872	4,105	31049802,192	33,033	26,487	15	0,033

Looking at Table 5, the MAPE value is 1.399. In this case, the MAPE value of 1.527 obtained from the Box-Jenkins model (SARIMA (0,1,0) (0,1,1)), as shown in Table 5, is higher than that acquire from the Winters' Exponential Smoothing model. The results of the analyses indicate that the Winters' Exponential Smoothing model gives more consistent results than the Box-Jenkins model with respect to the decision-making criterion.

4. Discussion and Conclusion

In an assessment of the problems of the industrial production in Turkey, it was stated that the major problem of the dairy industry was related to the market structure and the lack of organisation (26). The current problems of the industry make it impossible to supply the entire amount of milk produced to the industry.

52.2% of the milk produced in accordance with the requirements issued by the Union of Chambers of Agriculture of Turkey is used in the industry (3). The present study has found that the ratio of the milk supplied to the industry to the total amount of raw milk produced was the lowest in 2013 (42.26%) and the highest in 2016 (47.66%). Incentives and policies aimed at ensuring the produced milk is registered need to be implemented so that this ratio can be increased. Furthermore, the present study has found that the seasonal supply of milk to the industry in Turkey peaks in May and bottoms out in February. The peaking of the milk supply in May in Turkey is also consistent with the results of other studies and reports (1, 27). The sustainability of the dairy industry in Turkey is only possible if proper planning, reasonable investments and revolutionary policies that the industry needs are implemented.

In this context, there is need for creation of a proper database and time series analysis methods that enable modelling of such data so that rational policies for the livestock sector can be prospectively formulated (28). In order to achieve it, production projections for the sub-sectors of the livestock industry should be carried out and appropriate models should be developed for each product.

Various methods such as artificial neural networks (29), stochastic programming (30) and different regression models (31) have been used in predicting the milk production in the future.

As milk production was addressed, the present study used the SARIMA (0,1,0) (0,1,1) model obtained from the Box-Jenkins method and the Winters' exponential smoothing model, which is dependent on both trend and seasonality. The Winters' exponential smoothing model explains the data better, as it has a higher R^2 and lower RMSE, MAPE and MAE values than SARIMA (0,1,0) (0,1,1) model. Estimation with an MAPE rate below 10% are considered good forecasts, thus making it necessary to compare the two models in this scope (32, 33, 34, 35, 36).

The MAPE values of the SARIMA (0,1,0) (0,1,1) model and the Winters' Exponential Smoothing model were found to be 1.527 and 1.399, respectively. The MAPE values of both models suggest that their forecasting accuracy is sufficient. While both models are suitable for forecasting, Winters's exponential smoothing model can be preferred to the SARIMA model, as its MAPE value (1.399) suggests better forecasting performance.

Looking at the forecasts by both models, it is possible to say that there is an increasing trend. That is, it is predicted that the quantity of raw milk supplied to the industry in Turkey will increase within the scope of the seasonality relationship, and will reach a value between a minimum of 719,715.49 tons and a maximum of 903,392.68 tons in January 2020 according to the Winters' exponential smoothing model (Table 4). However, the recent cost-related problems and the decreasing number of dairy cows may lead to deviations in the time series data, and thus in the forecasts.

A study forecasting the future milk supply to the dairy cooperatives in the UK reports that Holt-Winters' (HW) seasonal model and seasonal autoregressive integrated moving average model (SARIMA) generate forecasts that contain less than 3% error (9).

The forecasts of the future milk supply to the milk-processing companies in Norway, based on the data between January 2001 and December 2010 were tested using HW and SARIMA models. The two time series models were compared with a model based on expert opinions and a model based on previous monthly quantities. The study underlines that the combination of the two time series models and the model based on expert opinions generates reliable forecasts for a period of two years (14).

A study conducted in India found that the optimum ARIMA model for milk production forecasts was ARIMA (1,1,0) and calculated the R^2 value to be 0.96, RMSE value 227.534 and MAPE value 4.491 (37).

It is important to implement rational policies as described below so that the problems of the dairy industry in Turkey can be overcome. In this context, the production structure of the dairy industry, most notably the costs, should be given a sustainable character in terms of marketing and quality. To that end, policy makers and the industry need to regularly carry out projections for the quantity of milk to be produced in the future and determine beforehand the quantity of milk to be produced and processed. If they do so, the dairy industry can have a sustainable structure with planned and organised production.

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