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Estimation of Poultry Meat Production in Turkey Using GM (1,1) with Second Parameter Fitting-Markov Model

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Abstract: Considering that poultry meat is an economical and stable food source and its place in a balanced diet, it is an indispensable food item for today as well as tomorrow. It is the most produced poultry meat in the world among other meat types since 2015. Turkey ranks 10th in the world in chicken meat production. Chicken farming and backyard poultry farming, which was mostly family-run until the 1980s, has left its place to giant facilities today. There are over 15,000 broiler breeding farms in Turkey and the annual turnover of the sector, which provides a livelihood for approximately 3 million people with all its stakeholders, has reached 5.5 billion USD. It is currently the biggest alternative to red meat. Today, white meat is preferred all over the world in terms of protein source and the per capita consumption of poultry meat is increasing every year in the world. Our per capita consumption of poultry meat has reached 21 kg/year. Accurate estimation of poultry meat production in Turkey is important for establishing short, medium and long-term policies that will balance supply and demand. In this study, GM (1, 1) with second parameter fitting-Markov model, which is a combination of the Markov chain method and the GM (1, 1) model with the second parameter fitting, which can be used to predict future data with very limited data and information, was used in the estimation of poultry meat production. The obtained results show that GM (1, 1) with second parameter fitting-Markov model used has high predictive precision and applicability.

Keywords: Grey estimation model, Markov chain, Poultry meat production

Introduction

Poultry meat has a remarkable position in meeting the need for animal protein, which is one of the cornerstones of a healthy diet, because it is economical. In other words, poultry meat is an important and strategic food source in proper and healthy nutrition because it is not only "beneficial for health" but also "low cost" compared to some other protein sources. In Turkey, the animal protein deficit resulting from the gradual decline in red meat production due to cost problems and crises has been balanced by the increase in chicken and turkey meat production. The world consumption of chicken meat shows an increasing trend due to its low fat, high protein value, rich in vitamins and minerals, and low price compared to red meat (Hekimoglu & Altındeger, 2009).

In Turkey, industrialization efforts in the white meat sector started after 1960, and integrated institutions related to broiler production and egg production were put into operation in the 1970s. After 1980, with the increase in exports to the sector and the implementation of Resource Utilization Support Fund in 1985, a large number of poultry farms with projects and modern structures were established and the sector developed rapidly (Kenanoglu et al., 1999) .

Today, this sector has reached the desired level in terms of production amount and technology; however, the most important problem in the sector today is that the products have to be sold below the cost in the country due to the narrowing of export opportunities. This situation brings about an intense competition with the red meat sector.

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The fact that the poultry meat sector in Turkey has been identified as one of the few sub-sectors in the food sector that can compete with the EU; the fact that the sector creates a large workforce employment and is one of the best organized food sub-sectors reveals the importance of the poultry meat sector for Turkey (Hekimoglu & Altındeger, 2009). Since chicken and turkey meat constitute almost all of Turkey's poultry meat production, only chicken and turkey meat were included in the scope of this study.

Method

In this study, the situation of Turkey's poultry meat production in the following years was tried to be estimated by using the GM(1,1) with Second Parameter Fitting-Markov Model.

GM(1,1) with Second Parameter Fitting-Markov Model

The grey system theory developed Ju Long (1982). In research in the field of condition analysis, forecasting and decision making, it focuses on uncertainty and lack of information to analyse and understand systems (Ju Long, 1982). Grey system theory, which is an interdisciplinary approach, is an alternative method for quantifying uncertainty. The basic idea in its emergence is to predict the behaviour of uncertain systems, which cannot be overcome by stochastic or fuzzy methods, with the help of a limited number of data.

The main feature that distinguishes the grey prediction method, which is one of the main fields of work of grey system theory, from traditional prediction methods is that it needs a limited number of data to predict the behaviour of uncertain systems. Unlike traditional prediction methods, the main feature of the grey prediction method is that it does not need strict assumptions about the data set and can be successfully applied in the analysis of systems with limited data. The grey prediction method has been developed to make predictions about the future with the help of the grey model GM(1,1) using the available data. GM(1,1) is a time series forecasting model that contains a set of differentiable equations. The GM(1,1) notation is used to express the grey model with first-order differentiable equations with a single variable. Wang et al. (2018), put forward a grey Markov forecasting model to predict mine gas emissions by combining grey system theory and Markov chain theory. In order to eliminate the error and improve the prediction accuracy of the model, secondary parameter fitting was performed based on the GM (1, 1) model. GM(1,1) with second parameter fitting-Markov model consists of the basic steps described in detail below.

Step-1: Let $X^{(0)}$ be the raw time series sequence with a single variable valence n magnitude that forms the time series.

$$X^{(0)} = (x^{(0)}(1), x^{(0)}(2), x^{(0)}(3),\ldots, x^{(0)}(n)) \; ; n \geq 4 \tag{1}$$

$X^{(1)}$ is constructed using the first-order aggregate production operator.

$$x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i),\ (i = 1,2,3,\ldots\ldots, n) \tag{2}$$

$$X(1) = (x^{(1)}(1), x^{(1)}(2), x^{(1)}(3),\ldots, x^{(1)}(n)) \; ; n \geq 4 \tag{3}$$

Step-2: Determination of Coefficients: $x^{(0)}(k)+ax^{(1)}(k)=b$ represents the original form of the model G(1,1). k is the time points; a is the coefficient of improvement; b represents the driver coefficient. $Z^{(1)}$ is generated using the first-order mean value generation operator.

$$z^{(1)}(k)=0{,}5x^{(1)}(k)+0{,}5x^{(1)}(k-1) \tag{4}$$

$$Z^{(1)} = (z^{(1)}(1), z^{(1)}(2), z^{(1)}(3),\ldots, z^{(1)}(n)) \tag{5}$$

The basic form of the G(1,1) model is written as $x^{(0)}(k)+az^{(1)}(k)=b$ in which the $Z^{(1)}$ series is used. The least squares method is used in estimating the a and b parameters. If the equation is written in matrix form, Y=Bã equality can be obtained. Here, Y, B and ã represent the matrices.

$$B = \begin{bmatrix} -z^{(1)}(2) & \cdots & 1 \\ \vdots & \ddots & \vdots \\ -z^{(1)}(n) & \cdots & 1 \end{bmatrix} \tag{6}$$

$$Y = \begin{bmatrix} x^{(0)}(2) \\ . \\ . \\ . \\ x^{(0)}(n) \end{bmatrix} \tag{7}$$

$$\tilde{a} = \begin{bmatrix} a \\ b \end{bmatrix} \tag{8}$$

In order to obtain the vector ã, the following operations must be performed in order.

$$Y=B\tilde{a} \tag{9}$$

$$B^TY=B^TB\tilde{a} \tag{10}$$

$$\tilde{a}=(B^TB)^{-1}B^TY \tag{11}$$

Step-3: Obtaining the GE equation. The prediction model is obtained by solving the differential equation 12.

$$\frac{dx^{(1)}(k)}{dk} + ax^{(1)}(k) = b \tag{12}$$

$$\hat{x}^{(1)}(k+1) = \left[x^{(1)}(0) - \frac{b}{a}\right] e^{-ak} + \frac{b}{a} \tag{13}$$

Since the original data is made into a cumulative series for the GM (1,1) model to work, in order to obtain the forecast results, a backward cumulative series should be created using equation 14.

$$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) \tag{14}$$

Step-4: Second Parameter Fitting Method of GM (1, 1) Model. Equation (13) is the time response of GM (1, 1) model equation. There are large amount of data proved that original data will produce error if we use Equation (13) to fit. To improve the fitting precision and prediction precision, we do secondary parameter fitting to Equation (13) and change it into,

$$\hat{x}^{(1)}(k+1) = \alpha e^{-ak} + \beta \tag{15}$$

According to the first estimate of a value a and estimation of original series $X^{(1)}$ to α and β

$x^{(1)}(0+1) = \alpha e^{-a0} + \beta$
$\mathrm{x}^{(1)}(1+1) = \alpha e^{-a1} + \beta$
$\mathrm{x}^{(1)}(2+1) = \alpha e^{-a2} + \beta$
.
.
.
$x^{(1)}\big((n-1)+1\big) = \alpha e^{-a(n-1)} + \beta$

written in matrix form is

$$\mathrm{X}^{(1)} = G\begin{pmatrix} \alpha \\ \beta \end{pmatrix} \tag{16}$$

In which,

$$\mathrm{X}^{(1)} = \left[\mathrm{x}^{(1)}(1), \mathrm{x}^{(1)}(2), \mathrm{x}^{(1)}(3), \dots, \mathrm{x}^{(1)}(\mathrm{n})\right]^T$$

$$G = \begin{bmatrix} e^{-a(1-1)} & \cdots & 1 \\ \vdots & \ddots & \vdots \\ e^{-a(n-1)} & \cdots & 1 \end{bmatrix}$$

According to the least square method,

$$\binom{\alpha}{\beta} = (G^T G)^{-1} G^T \mathrm{X}^{(1)} \tag{17}$$

At last, second parameter fitting of GM (1, 1) model was got, combined Equation (17) with Equation (15) (Wang et al., 2018).

Step-5: In forecasting time series, the high volatility of the series usually reduces the forecasting performance. This can be overcome by modifying the results or combining different techniques. In this study, the GM (1,1) model is combined with a Markov chain (He & Huang, 2005).

$\mathcal{E}^{(0)}(k) = (\mathrm{x}^{(0)}(k) - \hat{x}^{(0)}(k))/x^{(0)}(k)$, k=1,2,3,4,...n ;

obtained from the GM (1,1) model. Let the sequence of errors be expressed as $(\mathcal{E}^{(0)} = (\mathcal{E}^{(0)}(1), \mathcal{E}^{(0)}(2), \mathcal{E}^{(0)}(3), \ldots\ldots\ldots\ \mathcal{E}^{(0)}(k))$. In this case, we can divide the errors from the prediction model into S different states, and this new process is a Markov process. The intervals for the states are determined by considering the relative error values.

$$S_{i-} = \mathrm{A}_i, \quad S_{i+} = B_i, \tag{18}$$

Here, when it is expressed as S_{1i} and $S_{2i,}$ any s state within these states can be expressed as $S_{\mathrm{I}} = [S_{1i}, S_{2\mathrm{i}}]$. In obtaining the transition probabilities matrix $P_{ij}(a)$, a indicates the number of steps, G_{ij} is probability of transition from state Si to state Sj; and G_i is the number of observations in the S_i state.

$$p_{ij}(a) = \frac{G_{ij}(a)}{Gi} \quad (\text{ i,j =1,...s}) \tag{19}$$

a-step transition probability matrix is;

$$P_{ij}(a) = \begin{pmatrix} p_{11}(a) & \cdots & p_{1j}(a) \\ \vdots & \ddots & \vdots \\ p_{i1}(a) & \cdots & p_{ij}(a) \end{pmatrix} \qquad (\text{ i,j =1,...s}) \qquad \textstyle\sum_{i=1}^{s} p_{ij}(a) = 1 \tag{20}$$

The transition probabilities matrix is used to predict the state of the next observation. Suppose that the Markov chain under consideration is currently in state Si. Then when the line i elements in matrix $P_{ij}(1)$ are examined, $max_j\left(\ p_{ij}(1)\right) = \ p_{i3}(1)$ the equality is satisfied, the Markov chain is predicted to transition to state S_3 in the next step. Finally, the modified forecasting data can be calculated:

$$\tilde{x}^{(0)}(k) = \hat{x}^{(0)}(k)[1 + 0.5(A_i + B_i)] \tag{21}$$

It is seen that other grey-Markov chain models are frequently used in all fields in the literature. The grey Markov chain model has been used to forecast annual maximum water levels at hydrological stations (Dong et al., 2012), to forecast fire accidents (Mao & Sun, 2011), to forecast financial crises for an enterprise (Chen & Guo, 2011) and to forecast the need for electrical energy in China (He & Huang, 2005). Duan et al. (2017), used a grey Markov chain model enhanced with Taylor approximation for forecasting urban medical services demand in China. In their study, Hu et al. (2017), presented a novel grey prediction model combining Markov chain with functional-link net and applied it to foreign tourist forecasting.

Ye et al. (2018), presented a grey-Markov prediction model based on background value optimization and a central point triangular whitenization weight function. Yu et al. (2015) and Zhang & Chen (2021) used the grey Markov chain model in tax forecasting. Jia et al. (2020), presented a study based on the grey-Markov chain model for forecasting coal consumption in Gansu Province. Song et al. (2020), used grey model theory to perform load forecasting of medium and long term power system and the accuracy of the model in load forecasting is tested using the posterior difference method. Liu (2022), conducted an empirical analysis of the relationship between renewable energy consumption and economic growth based on the grey Markov model.

Results and Discussion

In this study, Grey-Markov chain model is used to predict the poultry meat production in Turkey in the coming years. The annual data from TURKSTAT in Table 1 below constituted the data set of the study. Data on chicken and turkey meat were evaluated. In the grey Markov chain model, the forecast data obtained by using the second parameter fitting method of the GM (1, 1) Model were used.

Table 1. Annual meat production of poultry

Year	Chicken (Ton)	Turkey (Ton)
2011	1 613 309	36 331
2012	1 723 919	41 931
2013	1 758 363	39 627
2014	1 894 669	48 662
2015	1 909 276	52 722
2016	1 879 018	46 501
2017	2 136 734	52 363
2018	2 156 671	69 536
2019	2 138 451	59 640
2020	2 136 263	58 212

Source: TURKSTAT, Poultry Production Statistics

In this study, data on chicken meat production are analysed first. First, the second parameter fitting method of the GM (1, 1) model is used to forecast future production levels. Then, the Grey-Markov chain model is used to improve the forecasting performance. Table 2 shows the results obtained for chicken meat production. Compared to real data, the Grey-Markov chain model produced more realistic results. As can be seen in the graph in Figure 1, it can be seen visually that the forecasting performance improves with the Grey-Markov model.

Table 2. Chicken meat production in Turkey actual and estimated values

Year	Actual Values (Tons)	Second Parameter Fitting Method of GM (1,1) Model	Estimated Values (Tons) with the Grey-Markov Chain Model
2011	1613309,282	1613309,28	1.622.804,1554
2012	1723918,629	1693498,10	1.731.424,0670
2013	1758362,830	1808451,09	1.759.380,4582
2014	1894668,634	1862827,97	1.904.546,0862
2015	1909276,471	1918839,87	1.898.453,4162
2016	1879017,521	1976535,94	1.890.272,4605
2017	2136734,369	2035966,83	2.115.175,6080
2018	2156671,119	2097184,70	2.144.151,2471
2019	2138450,721	2160243,29	2.137.292,0769
2020	2136262,909	2225197,93	2.128.081,9000
2021		2292105,64	2.267.753,4755
2022		2361025,15	2.452.880,2313
2023		2432016,94	2.526.633,9406
2024		2505143,32	2.602.605,2918
2025		2580468,49	2.680.860,9652
2026		2658058,55	2.717.585,8875

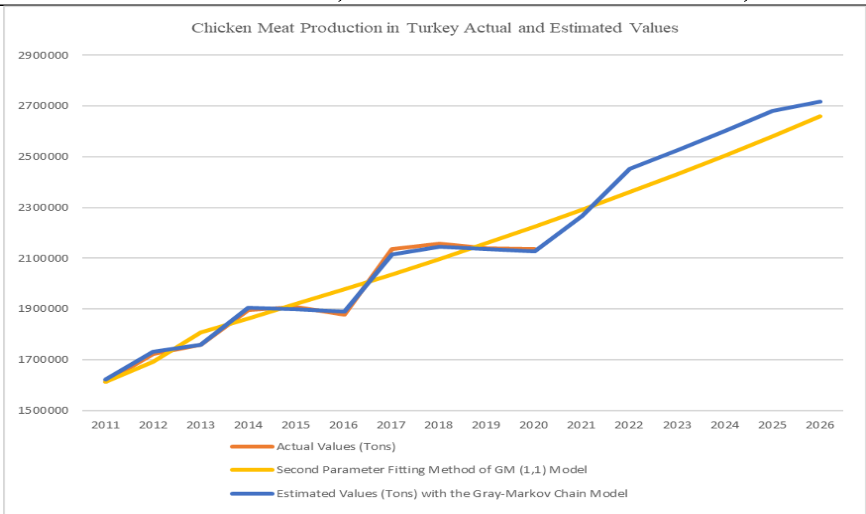

Figure 1. Chicken meat production actual and estimated value graph

Secondly, data on turkey meat production were analysed. First of all, the production levels of the next years were tried to be estimated by using the second parameter fitting method of the GM (1, 1) Model. Then, the Grey-Markov chain model is used to improve the prediction performance. Table 3 shows the results obtained for turkey meat production. Compared with real data, the Grey-Markov chain model gave more realistic results. As seen in the graph in Figure 2, it can be visually seen that the estimation performance has increased with the Grey-Markov model for turkey meat production estimations.

Table 3. Turkey meat production in Turkey actual and estimated values

Year	Actual Values (Tons)	Second Parameter Fitting Method of GM (1,1) Model	Estimated Values (Tons) with the Grey-Markov Chain Model
2011	36331,341	36331,34	36.080,9317
2012	41930,989	38893,17	42.442,1862
2013	39627,346	44761,90	40.060,3223
2014	48662,486	47154,19	49.143,1086
2015	52722,416	49674,34	51.769,5555
2016	46500,727	52329,18	46.832,7728
2017	52362,560	55125,90	52.040,8499
2018	69535,564	58072,10	66.220,8856
2019	59639,544	61175,76	60.754,1101
2020	58212,444	64445,29	57.676,2633
2021		67889,56	77.415,9446
2022		71517,90	64.006,0074
2023		75340,17	74.820,8965
2024		79366,71	71.030,4162
2025		83608,46	74.826,6273
2026		88076,90	91.791,8994

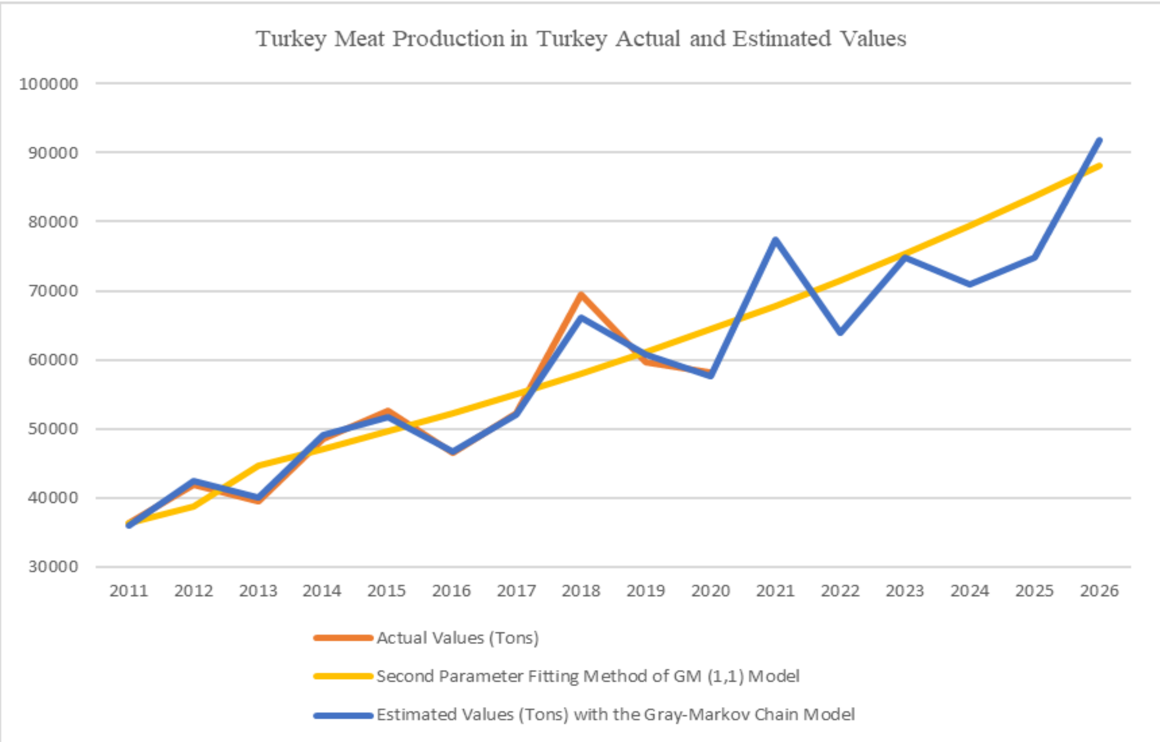

Figure 2. Turkey meat production actual and estimated value graph

Conclusion

Today, poultry meat sector has reached the desired level in terms of production amount and technology; however, the most important problem in the sector today is that the products have to be sold below their cost in the country due to the narrowing of export opportunities. This situation brings with it intense competition with the red meat sector.

In this study, the production amounts of chicken and turkey meat production until 2026 were estimated. When we look at the production estimations, it is seen that chicken meat production, which was 2.136.263 tons in 2020, will reach 2.717.585 tons in 2026, and turkey meat production will increase from 58.212 tons to 91.791 tons. The rise in red meat prices has led consumers to poultry meat, but it is important that the fluctuations in this trend are tolerable. Accurate estimation of red meat production, one of the dynamics affecting the sector, will be important in the policies to be implemented for the development of the sector in the coming years. It is important that the performance of our forecast data is high when policies are being implemented to develop the sector both in the domestic and foreign markets. In this study, it has been studied to increase the performance of this forecast data.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the author.

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