Time series modelling for goat and cow milk price index forecasting by trend analysis and Holt's method

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Keywords
Time series
Forecasting
Price index
Trend analysis
Holt's method

Abstract
Goat and cow milk is a fundamental agricultural product. Multiple factors can affect the price of milk over time such as production conditions, consumption demand, financial crisis and inflation. Dynamics of the milk price data should be considered to determine trend, cycle, or seasonality in the milk market so each pattern may affect the forecasting method should be used and the estimation results. Hence, the aim of this study is finding the pattern of the milk price time series data and estimation for the next 3 monthly periods. Historical data of Goat Milk and Cow Milk was used from the Agricultural Products Producer Price Index data between January 2016 to March 2022 published by Turkish Statistical Institute. Considering the trend pattern, trend analysis and Holt's method (double exponential smoothing) were used. The results demonstrated that the trend pattern may continue in near future, indicating that the procedures used were reasonable.

Introduction

Forecasting is required for many fields including business, industry, government, economics, environmental sciences, medicine, social science, politics, and finance and so on. Forecasting is critical since it gives input to the majority of decision-making and planning concerns. Forecasting problems could be classified as short, medium and long term. Short- and medium-term forecasting is typically based on identifying, modeling, and extrapolating the patterns found in historical data. Time series data is observed in many forecasting situations based on historical data. Collection. A time series is a chronological or time-oriented collection of observations on a dependent variable [1]. Many variables are assessed sequentially across time in most quantitative academic topics, as well as in business and commerce [2]. Time series data analysis for forecasting is one of the most important aspects of the practical usage. In the present study, the patterns are analyzed for goat milk and cow milk and then, regarding to the results, trend analysis and holt's methods are decided as appropriate methodologies to estimate price for 3 monthly period.

Material and Method

In time series plots, data could represent one or more possible patterns, trend, cycle, seasonality and randomness. Moving Average or Single Exponential Smoothing could be used if dataset does not have a trend component or a seasonality. To apply a general trend model to time series data and produce forecasts, trend analysis can be used. The linear, quadratic, exponential growth or decay, and S-curve trend models are all options. When the time series data has a steady trend and no seasonality, trend analysis could be used to fit a trend. Holt's method is a type of double exponential smoothing technique designed to track time series with linear trend. If there is an exact linear trend, Holt's Method is appropriate for forecasting. When the data has a trend and a seasonality component, and these two components are additive or multiplicative, Winters' Method could be applied. This method generates dynamic estimates for three variables: level, trend, and seasonality [3].
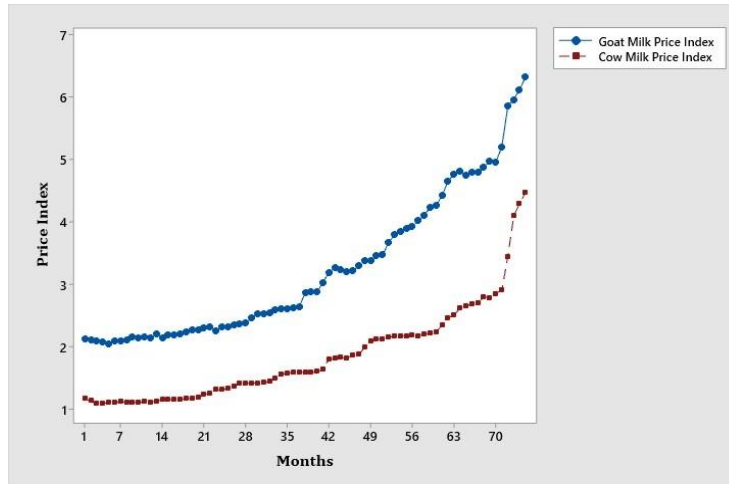
Figure 1. Time Series Plot of of Goat Milk (a) and Cow Milk (b) Price Index between Jan. 2016 to March 2022

In this study, the historical data of goat and cow milk price index was gathered from The Turkish Statistical Institute's Agricultural Products Producer Price Index between January 2016 to March 2022 (75 months). At first step, time series plots were examined to gain a clear understand of patterns (Fig 1.). Trend pattern was observed in the time series graph of goat milk data and cow milk data. Trend analysis [4] and Holt's method [5] is selected as appropriate methods. When a trend analysis demonstrated a linear trend, the linear trend model is:

$$Y_t = \beta_0 + \beta_1 t + e_t \tag{1}$$

β_0 is the constant, β_1 is the average change from one period to the next, t is the value of the time unit and e_t is the error term.

Holt's method uses two weights, also called smoothing parameters to update the components at each period. The equations are as follows:

$$L_t = \alpha Y_t + (1 - \alpha) [L_{t-1} + T_{t-1}] \tag{2}$$
$$T_t = \gamma [L_t - L_{t-1}] + (1 - \gamma) T_{t-1} \tag{3}$$
$$\hat{Y}_t = L_{t-1} + T_{t-1} \tag{4}$$

L_t is level at time t. α is weight for the level. T_t is trend at time t. γ is weight for the trend. Y_t is data value at time *t*. $\hat{Y}_t$ is fitted value, or one-step-ahead forecast, at time *t*. The forecast for *m* periods ahead from a point at time *t* is as follows:

$$\hat{Y}_t = L_t + mT_t \tag{5}$$

Results and Discussion

As a result of trend pattern that is observed in the time series graph of goat and cow milk data, it can be concluded there is a linear increasing tendency at price index data between January 2016 and March 2022 (Fig.2). A significant indicator of the existence for linear trendline pattern is R-squared (R^2) values for goat and cow milk of 0.81 and 0.88, respectively. These values could be provided by the Regression analysis [6].
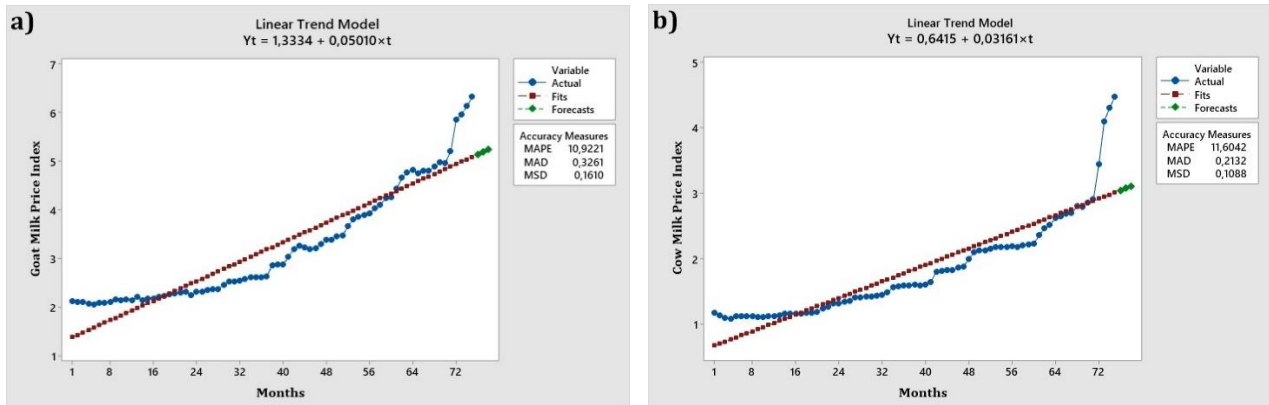

Figure 2. Trend Analysis of Goat Milk (a) and Cow Milk (b) Price Index and Forecasting Results

Based on trend analysis, 76nd, 77nd, and 78rd month price predictions for goat milk is gathered by the equation given below;

$$Y_t = 0,0501t + 1,3334 \tag{6}$$

Estimation of 76nd, 77nd, and 78rd month price for goat milk is gathered as 5.140, 5.191, 5.242, respectively (Table 1).

The equation below calculates the 76th, 77th, and 78th month price estimations for cow milk based on trend analysis;

$$Y_t = 0,0316t + 0,6415 \tag{7}$$

The forecasted prices for cow milk in the 76th, 77th, and 78th months are 3.043, 3.075, and 3.107, respectively (Table 1).
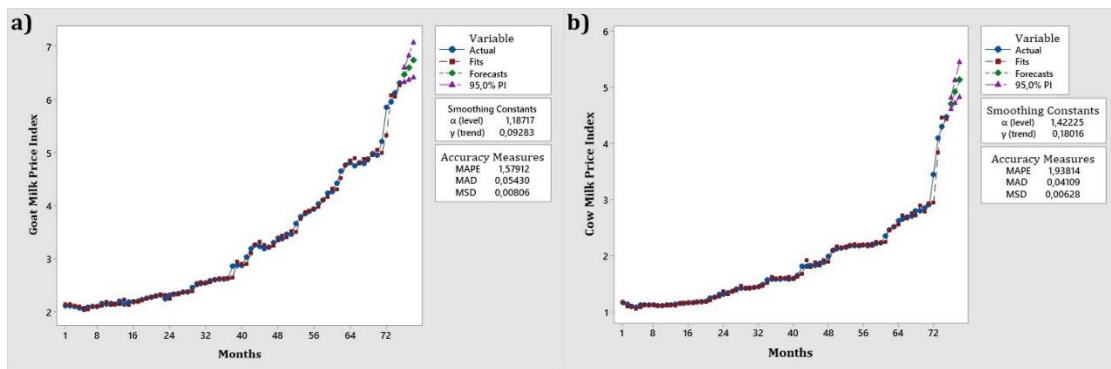

Figure 3. Holt's Method for Goat Milk Price Index (a) and Cow Milk (b) Price and Forecasting Results

Minitab was used for the application of Holt's method. As can be seen from the Minitab output shown in Fig. 3, using optimal level and trend values will minimize the sum of the squared residuals so accuracy measures represent the possible lowest values. As a result of this analysis, the 76. Month, 77. Month and 78. Month price index prediction for goat milk are 6.470, 6.608, 6. 746, respectively. The price index predictions for cow milk for the 76th, 77th, and 78th months are 4.710, 4.928, and 5.142, respectively (Table 1).

Table 1. Overall Results of Trend Analysis and Holt's Method

	Trend Analysis		Holt's Method	
	Cow Milk	Goat Milk	Cow Milk	Goat Milk
Period	Forecast	Forecast	Forecast	Forecast
76	3.04355	5.14089	4.71467	6.47046
77	3.07515	5.19099	4.92852	6.60832
78	3.10676	5.24109	5.14237	6.74618

Conclusion

The goal of this research is to determine the pattern of milk price time series data and provide predictions for the following three months. The Turkish Statistical Institute's Agricultural Products Producer Price Index data from January 2016 to March 2022 was utilized to compile historical Goat Milk and Cow Milk statistics. Trend analysis and Holt's approach were used to examine the trend pattern. The findings showed that the current trend pattern is likely to continue in near future. Results of each analysis represented different prediction values. To express which is the most appropriate method, MAD, MSE or MAPE values should be calculated. Considering MAD values for trend analysis has greater value than Holt's method for goat milk price index. Also, for cow milk price index, MAD value is greater than Holt's method. As a conclusion, Holt's method showed better performance for forecasting of goat and cow milk price index. For future study, nonlinear trend models as well as ARIMA analysis could be applied.

References

1. Montgomery. D. C. Jennings. C. L. & Kulahci. M. (2015). Introduction to time series analysis and forecasting. John Wiley & Sons.
2. Metcalfe. A. V. & Cowpertwait. P. S. (2009). Introductory time series with R (p. 2). Springer-Verlag New York.
3. Swapnarekha. H. Behera, H. S. & Nayak. J. (2021). Multiplicative Holts Winter Model for Trend Analysis and Forecasting of COVID-19 Spread in India. Sn Computer Science. 2. 416. https://doi.org/10.1007/s42979-021-00808-0
4. Mudelsee. M. (2019) Trend analysis of climate time series: A review of methods. Earth-Science Reviews. 190. 310-322. https://doi.org/10.1016/j.earscirev.2018.12.005.
5. Minitab. LLC. (2021). *Minitab*. Retrieved from https://www.minitab.com