Application of ARIMAX-LSTM Model in Forecasting the Price of Broiler Chicken in Central Java

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ABSTRAK

Perekonomian Jawa Tengah tumbuh 4,98% pada 2023 dengan sektor perdagangan sebagai penggerak utama, termasuk komoditas daging ayam ras yang produksinya meningkat dari 621.718,06 ton (2021) menjadi 791.997,10 ton (2023.) Namun, harga komoditas ini mengalami fluktuasi yang cukup besar, terutama dipengaruhi oleh faktor-faktor eksternal seperti permintaan yang meningkat selama periode hari libur nasional dan harga produk substitusi seperti telur ayam dan daging sapi yang dapat mempengaruhi daya beli daging ayam ras. Data harga daging ayam, harga telur ayam, dan harga daging sapi diperoleh dari *website* resmi PIHPS (Pusat Informasi Harga Pangan Strategis), sedangkan data pekan sebelum libur diperoleh menggunakan pustaka Python "*holidays*". Penelitian ini mengembangkan model Hybrid ARIMAX-LSTM untuk memprediksi harga daging ayam secara lebih akurat. Model ARIMAX digunakan untuk menangkap pola linier dari harga ayam telur dengan mempertimbangkan variabel eksternal (harga telur, daging sapi, dan pekan libur nasional) sementara LSTM menangkap pola non-linier residual yang tidak dapat dijelaskan oleh model ARIMAX. Hasilnya menunjukkan bahwa model Hybrid menghasilkan MAPE 1,19%, lebih akurat dibandingkan ARIMAX tunggal (MAPE 1,38%). Prediksi harga Januari 2025 berkisar Rp35.300 – Rp35.900/kg, menunjukkan stabilitas tanpa fluktuasi ekstrem. Penelitian ini memberikan solusi prediktif yang dapat digunakan oleh pemerintah dan pelaku usaha dalam pengendalian harga serta stabilisasi pasar.
Kata kunci: ARIMAX, Harga Daging Ayam Ras, Hybrid, LSTM., Prediksi Harga

ABSTRACT

Central Java's economy grew 4.98% in 2023 with the trade sector as the main driver, including the broiler chicken meat commodity whose production increased from 621,718.06 tons (2021) to 791,997.10 tons (2023). However, the price of this commodity experiences considerable fluctuations, mainly influenced by external factors such as increased demand during the national holiday period and the price of substitute products such as chicken eggs and beef that can affect the purchasing power of broiler chicken meat. Data on chicken meat prices, chicken egg prices, and beef prices were obtained from the official website of PIHPS (Strategic Food Price Information Center), while data for the week before the holiday was obtained using the Python library "holidays". This research develops a Hybrid ARIMAX-LSTM model to predict chicken meat prices more accurately. The ARIMAX model is used to capture the linear pattern of chicken egg prices by considering external variables (egg prices, beef, and national holidays), while the LSTM captures non-linear residual patterns that cannot be explained by the ARIMAX model. The results show that the Hybrid model produces a MAPE of 1.19%, which is more accurate than the single ARIMAX (MAPE 1.38%). The predicted January 2025 price ranges from IDR 35,300 - IDR 35,900/kg, showing stability without extreme fluctuations. This research provides a predictive solution that can be used by the government and businesses in price control and market stabilization.
Keywords: *ARIMAX, Broiler Chicken Price, Hybrid, LSTM, Price Prediction*

INTRODUCTION

Central Java's economy grew by 4.98% in 2023 with GRDP reaching Rp1,696.79 trillion, where trade became the main sector due to its role as a distribution center for goods and services [1]. In this case, broiler chicken meat is one of the livestock commodities traded at fluctuating prices and is the most widely produced livestock. On Badan Pusat Statistik website, in 2021 the province of Central Java produced 621,718.06 tons of broiler chicken meat, then continued to increase to 791,997.10 tons in 2023 exceeding the province's needs by 446,700.34 tons, thus experiencing a surplus between supply and demand [2], [3]. On the website of Pusat Informasi Harga Pangan Strategis Nasional (PIHPS), the average price of broiler chicken meat in Central Java province before fasting was Rp.35,802/kg, but during the fasting month until before Eid the price of broiler chicken meat rose to Rp.38,810/kg [4]. Then on April 16, 2024 the price of chicken meat jumped to Rp.40,200/kg and decreased to Rp.35,700/kg on May 01, 2024 [4]. With the imbalance between the amount of production and the need for broiler chicken meat, making it one of the commodities that often experience price fluctuations. Fluctuating prices will cause the value of profit or loss to fluctuate and become inconsistent [5].

Fluctuations in the price of broiler chicken meat are influenced by the demand for broiler chicken meat which tends to increase ahead of holidays or national holidays, the uneven supply of broiler chicken meat in various markets, and price comparisons of substitute products such as the price of eggs and beef [6], [7]. When the price of chicken meat rises high enough, some consumers will switch to other animal products as a more affordable alternative. Inappropriate price control can trigger wider economic impacts, so price prediction is important to help manage the risk of price fluctuations in the market. Methods such as ARIMA (Autoregressive Integrated Moving Average) are often used for short-term predictions by looking at past trends, but have the disadvantage of ignoring external variables as supporting factors [8]. Based on this, the ARIMA model continues to evolve into ARIMAX (Autoregressive Integrated Moving Average with Exogenous Variables) to improve accuracy, but is still limited to linear patterns [9]. Therefore, a method that can capture linear and non-linear patterns is needed, namely using a Hybrid model [10].

For a model that can capture non-linear patterns well is the LSTM (Long Short Term Memory) model, which is a recurrent neural network specifically designed to understand complex patterns in sequential data [11]. LSTM has three gates (input, output, forget) that filter relevant information, making it more adaptive to dynamic fluctuations than linear models [12]. Therefore, the Hybrid ARIMAX-LSTM approach was developed by reprocessing the residual results from the linear model into a non-linear model to improve the prediction accuracy over the base model [13]. The main advantage of this model lies in the ability of LSTM to recognize residual patterns that are not captured by ARIMAX, while utilizing exogenous variables. Until now, there are still few studies that focus on broiler price forecasting by considering external variables (prices of substitute products and the approach of national holidays). So this research aims to achieve better and more accurate accuracy in forecasting the price of broiler chicken by considering external variables with the Hybrid ARIMAX-LSTM model.

In previous research that compared ARIMA, ARIMAX, and Hybrid ARIMAX-LSTM models to predict the value of Indonesia's oil and gas imports by considering the factors of world crude oil prices, currency exchange rates, and inflation. The results show that the Hybrid ARIMAX-

LSTM (0,1,2) model with crude oil price and inflation variables gets the best evaluation with a MAPE value of 8.01% on test data and 9.58% on training data, compared to other models [14]. Based on the results of the above research, this research proposes a new approach in predicting the price of broiler chicken meat by considering external variables (prices of substitute products and ahead of national holidays) from January 2019 to December 2024 using the ARIMAX model combined (Hybrid) with the LSTM model which will be evaluated by Mean Absolute Percentage Error (MAPE). This research also forecasts the price of broiler chicken meat in January 2025 on weekdays (Monday to Friday) using known values of exogenous variables.

METHOD

In this research, the price data for broiler chicken meat, eggs, and beef are sourced from Pusat Informasi Harga Pangan Strategis (PIHPS) website [4]. Meanwhile, the week before public holidays variable was created using the Python holidays library, which is also used to identify the days leading up to public holidays. The data period of this research is from January 2019 to December 2024 on weekdays (Monday - Friday) with a total of 1566 rows. The following is the flow of analysis in this research:

a. The data that has been collected is combined and data preprocessing is carried out by overcoming missing values and checking outliers so that it becomes a form of time series data which is divided into 1556 rows of training data and 10 testing data
b. In the training data, stationarity testing is carried out using the Augmented Dickey Fuller (ADF) method followed by a differencing process on variables that are not stationary, then the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots are carried out to determine the optimum lag until ARIMAX modeling is carried out using the best order.
c. Forecasting results from ARIMAX modeling on training data and test data, residual calculations are carried out and residual assumption tests are carried out using the Autocorrelation (White Noise) test with L-jung Box. If the assumption test is not met, proceed to the LSTM modeling process on the residual data.
d. The residual data is divided into training data and test data, and will be converted into a temporal format by forming time steps whose number is adjusted to the data division in ARIMAX modeling.
e. LSTM modeling that has been built on the training data is performed to produce new residual forecasts
f. Forecasting test data using the best LSTM model to produce new residual forecasts
g. The residual data forecasting results from the LSTM model are combined with the forecasting results from the ARIMAX model or called the Hybrid process
h. Forecasting for January 2025 with the Hybrid ARIMAX-LSTM model that has been built with known exogenous variable data.

For the workflow of this research is shown in Figure 1.

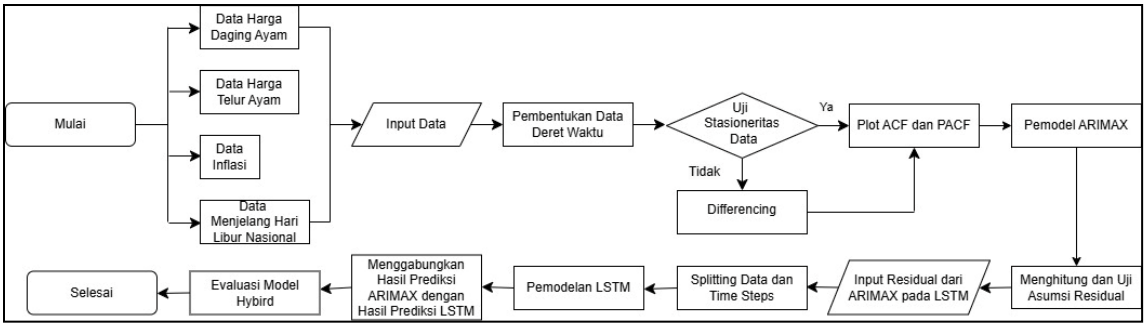

Figure 1. Research Workflow

Hybrid ARIMAX-LSTM

Hybrid method was first published by Zhang (2003), which combines ARIMA model with Neural Network to forecast time series data [15]. Time series data is composed of autocorrelation patterns that have linear and non-linear components. In this research, the linear component will be handled by the ARIMAX model, which is tasked with recognizing the linear pattern of the data as well as the influence of external variables. Meanwhile, the non-linear component will be handled by the LSTM model, which is able to capture complex patterns and non-linear relationships remaining in the residuals of the ARIMAX model. In general, time series data is expressed by equation (1).

$$y_t = L_t + N_t \quad (1)$$

Where L_t represents the linear component predicted by ARIMAX, and N_t represents the non-linear component predicted by LSTM from the residuals of the linear component. The final result of this Hybrid method is the sum of the linear and non-linear predictions, resulting in more accurate forecasting. The general form of the Hybrid method result is expressed in equation (2).

$$y'_t = L'_t + N'_t \quad (2)$$

Mean Absolute Percentage Error (MAPE)

To assess whether the model is accurate or not in forecasting chicken meat prices by considering external variables can be done using MAPE evaluation. MAPE is used to measure the error rate between the original data and the prediction results in the form of a percentage [16], [17]. The general form of MAPE is stated in equation (3).

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{X_t - F_t}{X_t}\right| \times 100\% \quad (3)$$

If the MAPE percentage result is smaller or less than 10%, the prediction results are very accurate, whereas if the MAPE percentage result is above 50%, the prediction results are not accurate [18].

RESULT AND DISCUSSION

Initial Data Exploration

Before entering into the data preparation process, the data is divided into two parts: training data or in sample data 1,556 rows (period January 01, 2019 to December 21, 2024), and test data or out sample data 10 rows (period December 22, 2024 to December 31, 2024). This division is done sequentially based on time (time-series split), so the test data is out-of-sample forecasting data

that is never seen by the model during the training process. Furthermore, missing value and outlier checks were carried out on the training data and test data. From the check, in the training data there were 48 missing data in the columns "Price_Meat_Chicken", 'Price_Egg', and "Price_Meat_Cow", while in the test data there were no missing values. The missing data is resolved by interpolating the data based on time [19][20], where the missing data is filled in by estimating the values before and after based on time. Then, for the results of checking outliers in the training data, there are 14 outlier data in the "Price_Meat_Chicken" column, while in the test data there is 1 outlier data in the 'Price_Eggs' column and there are 4 outlier data in the "Price_Cow Meat" column. The outlier data is not addressed because the price data describes real events as a result of external factors [14]. Figure 2 shows the distribution of chicken meat prices in the training data. The graph highlights several periods of significant price increases, such as in 2020 when the price rose from Rp 28,000/kg to Rp 42,000/kg. The graph also shows a random pattern and no seasonal pattern.

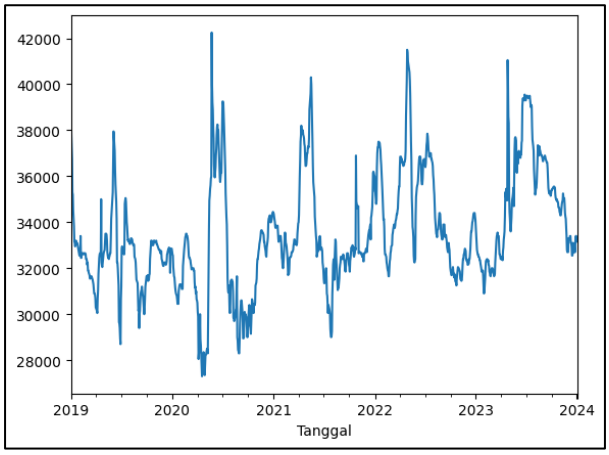

Figure 2. Distribution of Breast Chicken Price Data

In the training data, stationarity testing is carried out, as a condition for forecasting with the ARIMAX model in the "Chicken_Meat_Price" column. To test stationarity in mean or trend using the ADF (Augmented Dickey-Fuller) test method. For the ADF method with the hypothesis:

H_0 : Chicken Meat Price Data is Not Stationary

H_1 : Chicken Meat Price Data is Stationary

Significance value: α= 5%

Test criteria: H_0 is rejected if p-value < 5%

The results of stationarity testing with the ADF test on each variable are shown in Table 1 as follows:

Table 1. ADF Test Results of Chicken Meat Price

Variable	Test Statistic	p-value	Result
Chicken_Meat_Price	-5.449	0.000003	Stationary

Based on the stationarity test results in Table 1, it shows that the "Chicken_Meat_Price" column is stationary, so that the variable does not need to be transformed or differenced and can proceed to the next process. for the value of D (d) = 0.

Furthermore, identifying the order of the model based on the analysis of ACF and PACF plots on the training data to assist in determining the optimum lag and finding a combination of orders as ARIMAX parameters. To display ACF and PACF plots, the Python library statsmodels.graphics.tsaplots can be used. The results of the ACF plot on the variable "Price_Daging_Ayam" show an exponential decline pattern, which indicates there is no significant relationship between lags, resulting in the value of MA(q) = 0. Meanwhile, the results of the PACF plot on the same variable show a cut-off after the 1st, 2nd, and 3rd lags, so the possible AR(p) values are 1, 2, or 3. The ACF and PACF plots of the variable "Chicken_Meat_Price" are shown in Figure 3 for the order results of the plot can be a benchmark in determining the order combination, but to produce the best ARIMAX model that is significant in all parameters, another combination experiment can be done by trying other order combinations.

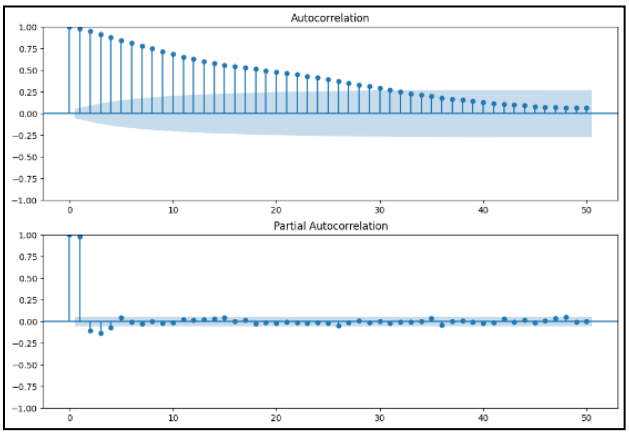

Figure 3. ACF and PACF Plot of Chicken Meat Price

ARIMAX Modeling

In the training data and test data, division is made into target variables (y) and external variables (x). The target variable is the price of chicken meat and the external variables are the price of eggs, the price of beef, and the week before the holiday. So that this process will produce "y_train", "x_train", 'y_test', and "x_test" to forecast the price of broiler chicken based on external variables. The ARIMAX model is then built to predict the price of broiler chicken meat in "y_train" by considering the variables in "x_train", using the best order combination, which is [0,0,3]. This combination means that the model does not use an autoregressive (AR) component, does not perform differencing because the data is stationary, and only involves three lags in the moving average (MA) to account for 3 lag errors to correct noise. For ARIMAX modeling results, it is expressed in equation (4).

$$Y_t = 0.1395(Harga\_Telur_t) + 0.2487(Harga\_Daging\_Sapi_t) + 490.47(Pekan\_Sebelum\_Libur_t) + e_t + 1.3760 \times e_{t-1} + 1.2143 \times e_{t-2} + 0.6255 \times e_{t-3} \quad (4)$$

The results of the ARIMAX modeling analysis are shown in

Table ***2*** as follows:

Table 2. ARIMAX Modeling Results

Variable	Coefficient	p-value	Result
Harga_Telur	0.1395	0.000	Significant
Harga_Daging_Sapi	0.2487	0.000	Significant
Pekan_Sebelum_Libur	490.47	0.000	Significant
MA (1)	1.3760	0.000	Significant
MA (2)	1.2143	0.000	Significant
MA (3)	0.6255	0.000	Significant

Based on the results of the ARIMAX analysis on the model parameters shown in Table 2, the variables of egg prices, beef prices, and the week before the holiday $p - value < 0.5$, indicating that the three variables are statistically significant and have a direct effect on the demand for broiler chicken meat that causes an increase or decrease in prices. Then, a Rp1 increase in the price of eggs and beef is estimated to increase the price of chicken meat by Rp0.14 and Rp0.25, respectively. Meanwhile, the week before the national holiday had the biggest impact, with chicken meat prices increasing by around Rp490.47 compared to a normal day.

Residual Assumption Test

After the forecasting results of the ARIMAX model are obtained, Ljung-Box testing is then carried out on the ARIMAX residuals to determine whether the data meets white noise (no autocorrelation) or not (has autocorrelation). The L-jung Box test uses the hypothesis:

H_0 : Residuals meets white noise

H_1 : Residuals does not meet white noise

Significance value: α= 5%

Test criteria: H_0 is rejected if p-value < 5%

The results of the white noise test with the L-jung Box test on the residual data are shown in Table 3 as follows:

Table 3. Residual Assumption Test Results

Test L-jung Box	p-value	Result
167.74	0.000	Residuals does not meet white noise

Based on Table 3 L-Jung Box testing shows the test statistic value is very large and the p-value is much smaller than the significant value, then reject H_0. The conclusion of the test shows strong evidence that the residuals are not random or still have a pattern. Since the residual data has not met the white noise assumption test, the residual data will be further processed into LSTM modeling to handle non-linear patterns.

LSTM Modeling

Before entering into LSTM modeling, preprocessing is carried out by converting residual data into 2 dimensions. Furthermore, the residual data is normalized / scaling the residual data using the MinMaxScaler method. Then, the residual data will be divided into 2 parts, namely, training data and test data with data division of 1,546 and 10 data. The time steps in this research are 5, because chicken meat prices have complex patterns and are influenced by historical movements within a certain period of time and can reflect relevant trends and fluctuations. Furthermore, the

data will be converted into 3 dimensions (number of samples, number of time steps in each sample, and number of features) to adjust the format of the LSTM model.

The basic LSTM model used in this research has 3 LSTM layers, 3 Dropout layers, and 2 Dense layers. In the model training process, EarlyStopping is added to stop training automatically if there is no improvement in the validation loss value after several consecutive epochs, so as to prevent overfitting and speed up training time. The following LSTM model structure is shown in Table 4 which is used to train and test data.

Table 4. Structure Model LSTM

Model LSTM	
LSTM	128, Return Sequences =True
Dropout	0,2
LSTM	64, Return Sequences =True
Dropout	0,1
LSTM	32, Return Sequences =False
Dropout	0,1
Dense	16, Activation='RELU'
Dense	1
Optimizer	Adam
Epoch	7
Batch Size	32

Hybrid ARIMAX-LSTM Modeling

The forecasting results on the test data are then combined with the forecasting results from the ARIMAX model, forming a hybrid approach. This process is known as Hybrid ARIMAX-LSTM modeling. Evaluation of the Hybrid forecasting results was carried out using the MAPE metric, which resulted in a value of 1.19%. When compared to the MAPE value of the ARIMAX (1.38%) model separately, the Hybrid model shows better performance. This shows that the Hybrid approach is able to improve accuracy in forecasting the price of broiler chicken meat in Central Java. Figure 4 shows a comparison of the original data, ARIMAX prediction results, and ARIMAX-LSTM prediction results.

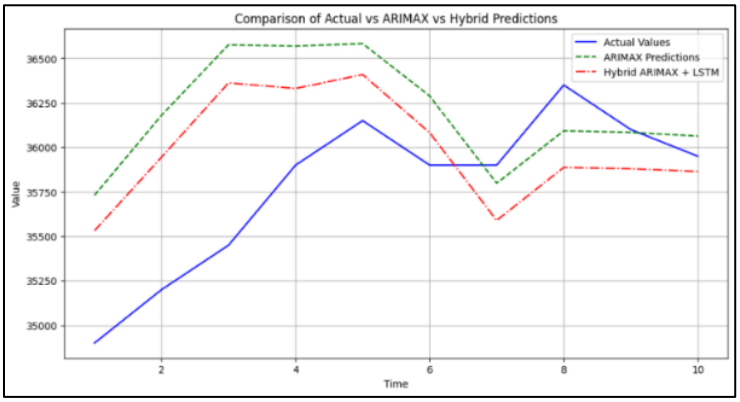

Figure 4. Comparison Chart of Original Data, ARIMAX, ARIMAX-LSTM

Forecasting January 2025

Furthermore, from the ARIMAX and LSTM models that have been built and the Hybrid ARIMAX -LSTM process is carried out, to forecast the price of broiler eggs for January 2025. This model utilizes historical egg price data from January 2019 to December 2024, as well as known exogenous variables in January 2025. The resulting price prediction for January 2025 shows price variations that are still within a reasonable range, without unfounded extreme spikes, indicating that the model can produce stable, accurate and reliable output. Forecast results for January 2025 are shown in Table 5.

Table 5. Forecasting Results for January 2025

Tanggal	Harga_ Telur	Harga_ Daging_Sapi	Pekan_Sebelum_ Libur	Prediksi_Harga_ Daging_Ayam
01/01/2025	30100	127400	1	35.372
02/01/2025	30100	128050	0	35.518
03/01/2025	29950	128150	0	35.966
06/01/2025	29950	128150	0	35.928
07/01/2025	29000	128200	0	35.760
08/01/2025	28800	128100	0	35.685
09/01/2025	28600	128200	0	35.692
10/01/2025	28400	128200	0	35.665
13/01/2025	27550	128250	0	35.551
14/01/2025	27350	128250	0	35.515
15/01/2025	27200	128250	0	35.492
16/01/2025	27050	128250	0	35.472
17/01/2025	26850	128250	0	35.442
20/01/2025	26350	128250	1	35.861
21/01/2025	26200	128250	1	35.839
22/01/2025	25900	128250	1	35.797
23/01/2025	25750	128250	1	35.776
24/01/2025	25700	128250	1	35.768
27/01/2025	25500	127300	1	35.504
28/01/2025	25500	127300	1	35.503
29/01/2025	25500	127300	1	35.503
30/01/2025	26050	128250	0	35.326
31/01/2025	25950	128250	0	35.311

CONCLUSION

In the research of predicting the price of broiler chicken meat in Central Java by considering external variables in the period January 2019 to December 2024 on weekdays using Hybrid ARIMAX-LSTM modeling, it can be concluded that

1) The ARIMAX (0,0,3) model can be used to capture linear patterns by considering exogenous variables (egg prices, beef, and holidays) well, but the residual assumption test results show

that the residual results do not meet white noise. Therefore, a hybrid process is performed with another model

2) The LSTM model is used to capture non-linear patterns of ARIMAX residuals that can improve prediction accuracy.
3) Hybrid ARIMAX-LSTM results provide better accuracy (MAPE 1.19%) than a single ARIMAX model (MAPE 1.38%).
4) The Hybrid model successfully predicts the price of broiler chicken meat influenced by external variables for January 2025 with a range of Rp35,300 - Rp35,900/kg, showing stability without extreme spikes.

Thus, the development of the Hybrid ARIMAX-LSTM model is proven to be able to provide potential price estimates to be used as a basis for decision making by market players and policy makers in dealing with future food price dynamics.

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