The 2nd International Conference on Multidisciplinary Engineering (2nd ICOMDEN 2024)

The 2nd International Conference on Multidisciplinary Engineering: 00019 (2024) https://doi.org/10.29103/icomden.v2.xxxx
Volume 2, 2024
eISSN: xxxx-xxxx
Research Original Article

Comparison of the Results of Double Exponential Smoothing Method with Triple Exponential Smoothing for Predicting Chili Prices

Nadia Saphira✉[1] **Munirul Ula**[2] **Sujacka Retno**[3]
[1]Student in Department of Informatics, Faculty of Engineering, Universitas Malikussaleh, Bukit Indah, Lhokseumawe, 24353, Indonesia, nadia.200170023@mhs.unimal.ac.id
[2]Department of Information Technology, Faculty of Engineering, Universitas Malikussaleh, Bukit Indah, Lhokseumawe, 24353, Indonesia, munirulula@unimal.ac.id
[3]Department of Information Technology, Faculty of Engineering, Universitas Malikussaleh, Bukit Indah, Lhokseumawe, 24353, Indonesia, sujacka@unimal.ac.id
✉Corresponding Author: **nadia.200170023@mhs.unimal.ac.id** | **Phone: +6285322825394**

Abstract
Double Exponential Smoothing (DES) is a forecasting method that combines two components level and trend, used for data with a trend pattern that tends to increase or decrease over time. In contrast, Triple Exponential Smoothing (TES) incorporates three components: level, trend, and seasonality, making it suitable for data with trend and seasonal patterns. This study uses historical chili price data from 2020 to 2023, obtained from the Bank Indonesia website, managed by the National Strategic Food Price Information Center (PIHPS), to compare the effectiveness of DES and TES in predicting chili prices in Medan City. Prediction accuracy was evaluated using MAPE (Mean Absolute Percentage Error) and MAE (Mean Absolute Error). The study results show MAPE values for DES as follows: Large Red Chili 1.25%, Curly Red Chili 1.39%, Green Bird's Eye Chili 1.14%, and Red Bird's Eye Chili 1.13%. TES produced slightly lower MAPE values: Large Red Chili 1.25%, Curly Red Chili 1.38%, Green Bird's Eye Chili 1.12%, and Red Bird's Eye Chili 1.10%. The MAE values for DES are as follows: Large Red Chili 447.9, Curly Red Chili 494.83, Green Bird's Eye Chili 430.92, and Red Bird's Eye Chili 423.36. TES showed better accuracy with MAE values of Large Red Chili at 447, Curly Red Chili at 493.02, Green Bird's Eye Chili at 416.2, and Red Bird's Eye Chili at 409.36. The results conclude that Triple Exponential Smoothing performs better than Double Exponential Smoothing in predicting chili prices.
Keywords: Double Exponential Smoothing, Triple Exponential Smoothing, Price Prediction Chili, MAPE, MAE.

INTRODUCTION
Chili peppers (Capsicum Annuum L) play a significant role in Indonesia's economy due to their high economic value and essential role in fulfilling community needs for food and medicinal purposes. For the Indonesian population, chili is a crucial vegetable commodity as it is a primary ingredient in various culinary preparations [1]. At certain times, unstable chili prices can trigger economic inflation, especially during the rainy or dry seasons, or during major religious celebrations in Indonesia [2].

Food prices are a key indicator reflecting food availability for the population and are a critical element in food economics that impacts inflation. Changes in food prices can affect the welfare of both producers and consumers. Chili, in particular, is known for its highly fluctuating prices, often experiencing significant spikes or drops [3].

In Medan City, chili prices fluctuate daily, making them difficult to predict accurately [4]. According to data from the National Strategic Food Price Information Center (PIHPS), the price of large red chili in Medan City once reached IDR 109,500 per kilogram (PIHPS, 2022), curly red chili reached IDR 102,500 per kilogram (PIHPS, 2022), green bird's eye chili reached IDR 105,500 per kilogram (PIHPS, 2022), and red bird's eye chili reached IDR 107,500 per kilogram (PIHPS, 2022). The most significant price change occurred between July 10-11, 2022, with a difference of IDR 37,000, rising from IDR 70,500 to IDR 107,500. This volatility has prompted the government's concern about maintaining stable chili prices to control inflation in Medan City.

The purpose of this study is to track chili price trends. Predicting chili prices may provide a benchmark for the Medan city government to mitigate price fluctuations, maintaining market price stability so that inflation does not negatively impact consumers and sellers alike. This study also compares the Double Exponential Smoothing and Triple

Exponential Smoothing methods to forecast chili prices. These methods are used to evaluate effectiveness and accuracy in chili price prediction, aiming to identify the most optimal method. The results of this comparison will form the foundation for developing a web-based forecasting information system capable of predicting chili prices more accurately and efficiently.

LITERATURE REVIEW

1. Data Mining

Data mining is a technique for analyzing trends and characteristics within data sets and uncovering previously unidentified information in large databases. Data mining uses statistical, mathematical, and machine-learning techniques to explore meaning and patterns within data [5]. Leveraging distributed information systems is essential in handling the vast amount of data. Every day, data fluctuates between current and historical data, resulting in a massive volume of information. Data mining algorithms are designed to analyze large-scale data effectively and efficiently

2. Forecasting

Forecasting is analyzing the current state by comparing it with previous conditions. In a forecasting system, historical data analysis is the final source for historical trends. This means that research is always needed to predict what will happen. Forecasting holds an important responsibility in various fields, including economics, health, technology, natural disasters, and agriculture [6].

3. Double Exponential Smoothing

Double Exponential Smoothing is a method that predicts future values by providing forecasts based on several previous periods or observations. The Double Exponential Smoothing method in this chart is a linear model that uses two parameters (α and β) to simulate a trend with different parameters from the original data [7]. The following equations can be used to determine the formula for Holt's Double Exponential Smoothing method:

$$S_t = aX_t + (1-a)\,(S_{t-1} + T_t - 1) \quad (1)$$

$$T_t = \beta(S_t - S_t\text{-}\,1) + (1 - \beta)\,T_t - 1 \quad (2)$$

$$F_{t+m} = S_t + Tt_m \quad (3)$$

Description:

S_t = Smoothed value at time t
X_t = Actual data at time t
α, β, γ = Exponential parameters with values between 0-1
$F_{(t+m)}$ = Forecast result
m = Future period
T_t = Trend value at period t
l_t = Seasonal factor

4. Triple Exponential Smoothing

The Triple Exponential Smoothing method is an extension of the exponential smoothing method that uses three exponential smoothing constants: level, trend, and seasonality [8]. This method produces three weights in the prediction process: α, β, and γ. The equations are as follows:

$$S_t = a\frac{X_t}{it-L} + (1-a)(S_{t-1} + T_{t-1}) \quad (4)$$

$$Tt = \beta(S_t + S_{t-1}) + (1 - \beta)T_{t-1} \quad (5)$$

$$SNt = y(\frac{Xt}{St}) + (1-y)l_t - L \quad (6)$$

$$Ft = (S_{t-1} + T_{t-1}) \text{ x } SNt - 1 \quad (7)$$

Description:

S_t = Overall smoothing value
X_t = Actual data at time t
T_t = Seasonal smoothing
a, β, y = Parameters with values between 0 and 1
SNt = Trend smoothing
$F_{(t-m)}$ = Forecast value

MATERIALS & METHODS

1. Data Collection

This research uses data sourced from the Bank Indonesia website, specifically the National Strategic Food Price Information Center (PIHPS). The chili price data utilized spans the period from 2020 to 2023. The research focuses on Large Red Chili, Curly Red Chili, Green Bird's Eye Chili, and Red Bird's Eye Chili as the study objects. The dataset contains a total of 5,838 records.

Table 1. Actual Data of All Chili

No	Date	Type of Chili	Chili Price
1	01/01/2020	Large Red Chili Peppers	Rp. 31214
2	02/01/2020	Curly Red Chili Peppers	Rp. 30800
3	03/01/2020	Green Bird's Eye Chili Peppers	Rp. 39800
4	04/01/2020	Red Bird's Eye Chili Peppers	Rp. 38900
…	…	…	…
5838	31/12/2023	Red Bird's Eye Chili Peppers	Rp. 44300

2. Methods

Below is the system scheme from the research conducted.

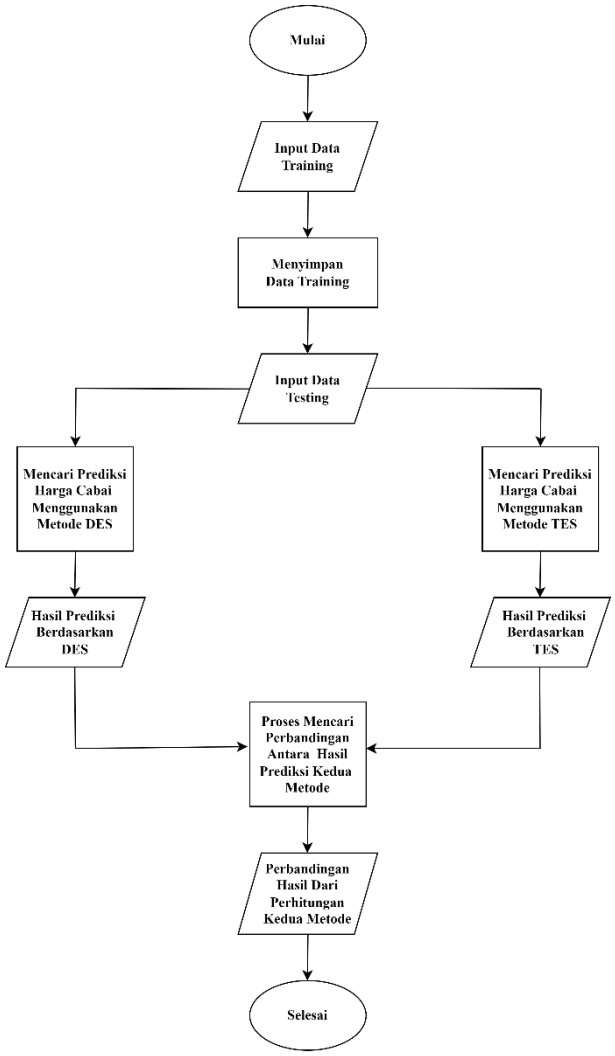

Figure 1. System Schema

The following process flow of the system scheme will be explained through the following points:

1. Start: The initial step of the process, where the system begins.
2. Input Training Data: In this step, historical data or training data for the forecasting model is entered into the system. This data is used to train the model in both forecasting methods, Double Exponential Smoothing and Triple Exponential Smoothing.
3. Store Training Data: After the training data is entered, the system saves this data for use in calculations and model training.

4. Input Testing Data: This step involves entering testing data, which will be used to evaluate the performance of the forecasting model that has been trained using the training data. The testing data is used to predict chili prices using both methods, Double Exponential Smoothing and Triple Exponential Smoothing.
5. Calculation Process for Double Exponential Smoothing and Triple Exponential Smoothing: In this step, two calculation processes occur for Double Exponential Smoothing and Triple Exponential Smoothing. In both processes, the system calculates the level, trend, and seasonal components (if using Triple Exponential Smoothing) based on the training data.
6. Output of Prediction Results: After the calculations are complete, both methods will produce predictions for chili prices for the upcoming period based on the testing data. The output from both methods is the predicted chili prices.
7. Comparing Prediction Results: This step involves comparing the prediction results from both methods, DES and TES. The system will compare the two prediction results to evaluate the relative performance of both methods.
8. Output of Prediction Results from Both Methods: After the comparison is complete, the output of the prediction results from both methods is provided. This can be in the form of predicted values or graphs showing the comparison between the predictions of DES and TES.
9. Finish: The final step of the process, where all steps have been completed and the system has finished running. At this point, the prediction results from both methods have been evaluated and presented, End.

3. Evaluation

Mean Absolute Percentage Error (MAPE) is a calculation used to determine the average percentage of absolute error. MAPE is useful for measuring the accuracy of the forecasting methods used. By calculating MAPE, one can see the extent of the estimation error as a percentage of the actual values (10). Below is the formula for calculating the MAPE value:

$$\text{MAPE} = \frac{1}{n}\sum_{i-1}^{n}\left|\frac{\tilde{y}i - yi}{yi}\right| x\ 100 \quad (8)$$

Description:

n = Number of data points
$\tilde{y}i$ = Predicted value at index i
yi = Actual value at index i

MAPE Value	Criteria
<10%	Very Good Forecasting
10-20%	Good Forecasting
20-50%	Fair Forecasting
>50%	Poor Forecasting

Table 2. MAPE Range Value

RESULTS AND DISCUSSION

In this study, the author discusses the results of implementing prediction methods using Double Exponential Smoothing and Triple Exponential Smoothing. The data used includes prices for large red chili peppers, curly red chili peppers, green bird's eye chili peppers, and red bird's eye chili peppers, with predictions focused on January 2024.

1. Prediction Results Using the DES Method

At this stage, the author will present the results of chili price predictions using the Double Exponential Smoothing method.

A. Large Red Chili Peppers

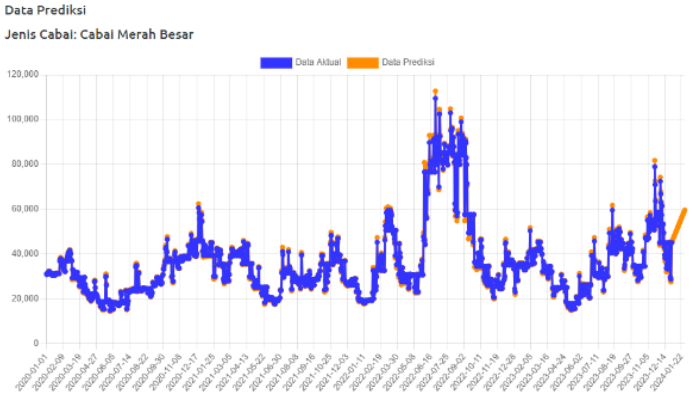

Figure 2. Large Red Chili Peppers DES Graph

The image above shows the predicted price data for large red chili peppers using the Double Exponential Smoothing (DES) method. The blue line represents the actual chili prices from 2020 to mid-2023, while the orange line indicates the

predicted chili prices for the upcoming period. It can be observed that the DES method provides fairly stable predictions until the end of the actual data period.

B. Curly Red Chili Peppers

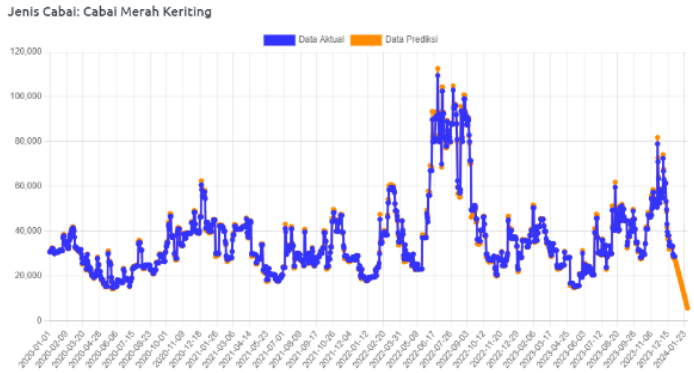

Figure 3. Curly Red Chili Peppers DES Graph

The image above displays the predicted price data for curly red chili peppers using the Double Exponential Smoothing (DES) method. This image shows the comparison between actual data and predicted data, where the actual data is represented by the blue line, while the predicted data is indicated by the orange line. From this graph, it can be observed that the predicted data closely follows the trend of the actual data until around the beginning of 2024. However, the prediction shows a significant decline after that period. This may indicate an unexpected change in pricing patterns or limitations in the prediction model used.

C. Green Bird's Eye Chili Peppers

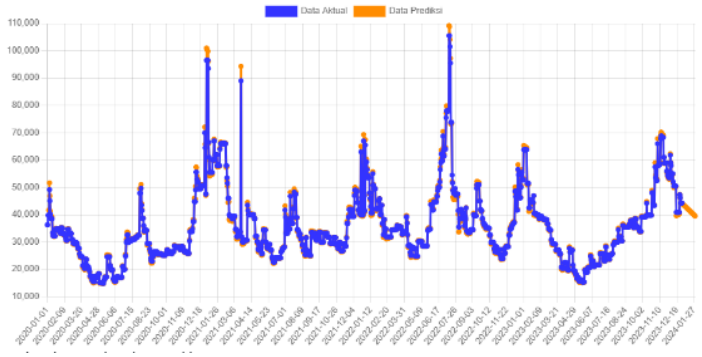

Figure 4. Green Bird's Eye Chili Peppers DES Graph

The image above displays the predicted price data for green bird's eye chili peppers using the Double Exponential Smoothing (DES) method. The blue line represents the actual prices of green bird's eye chili peppers from 2020 to mid-2023, while the orange line indicates the predicted prices for the upcoming period. It can be seen that the DES method provides fairly accurate predictions until the end of the actual data period, but the future predictions show a sharp downward trend in prices. This may indicate that the DES model is less capable of capturing seasonal patterns or more dynamic trend changes in the price data of green bird's eye chili peppers.

D. Red Bird's Eye Chili Peppers

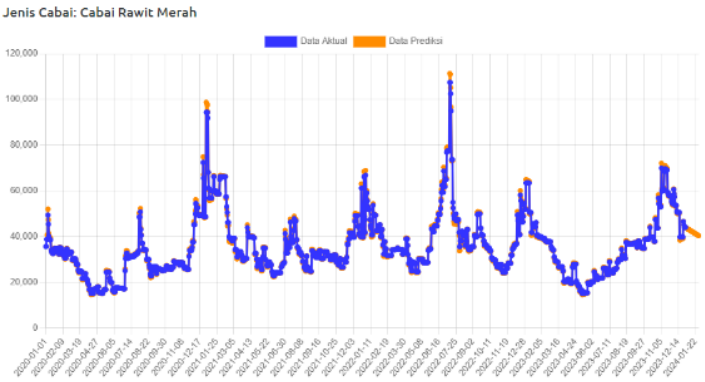

Figure 5. Red Bird's Eye Chili Peppers DES Graph

The image above shows the comparison between the actual data and the predicted prices of curly red chili peppers from the beginning of 2020 to the end of 2024. The actual data is represented by the blue line, while the predicted data is displayed by the orange line. From the graph, it is evident that the prediction model is quite accurate in following the price trend of curly red chili peppers until early 2024. However, the predictions indicate a drastic decline after that period, which may suggest limitations of the model in predicting unexpected changes in the price patterns of red bird's eye chili peppers.

2. Prediction Results Using the TES Method

At this stage, the author will present the results of chili price predictions using the Triple Exponential Smoothing method.

A. Large Red Chili Peppers

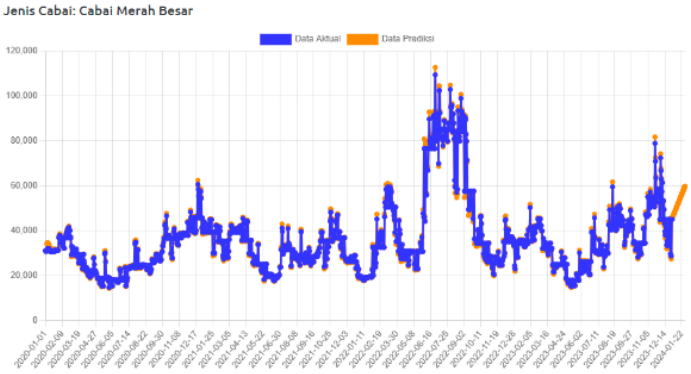

Figure 6. Large Red Chili Peppers TES Graph

The predictions made with TES indicate a significant upward trend in prices at the end of the period, which is much sharper compared to the historical data. This may suggest that TES tends to provide more aggressive predictions in detecting upward trends in the prices of large red chili peppers.

B. Curly Red Chili Peppers

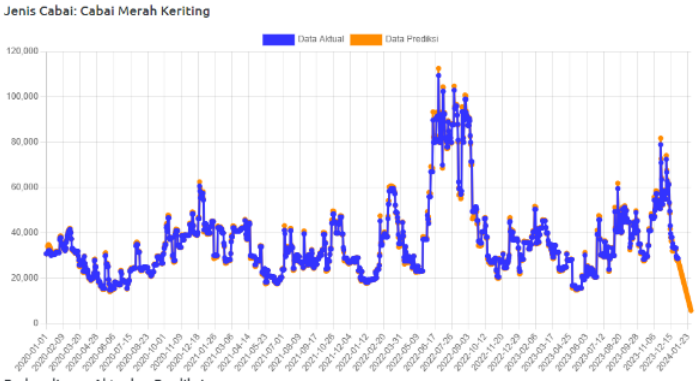

Figure 7. Curly Red Chili Peppers TES Graph

It can be observed that the TES method provides fairly stable predictions until the end of the actual data period, but the future predictions indicate a very sharp decline in prices. This may suggest that the TES model struggles to capture seasonal patterns or more complex trends in the price data of curly red chili peppers.

C. Green Bird's Eye Chili Peppers

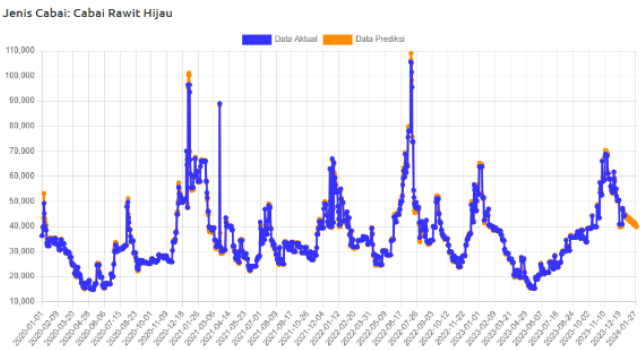

Figure 8. Green Bird's Eye Chili Peppers TES Graph

The image above shows the predicted price data for green bird's eye chili peppers generated using the Triple Exponential Smoothing (TES) method. It can be observed that the TES method provides fairly stable predictions until the end of the actual data period.

D. Red Bird's Eye Chili Peppers

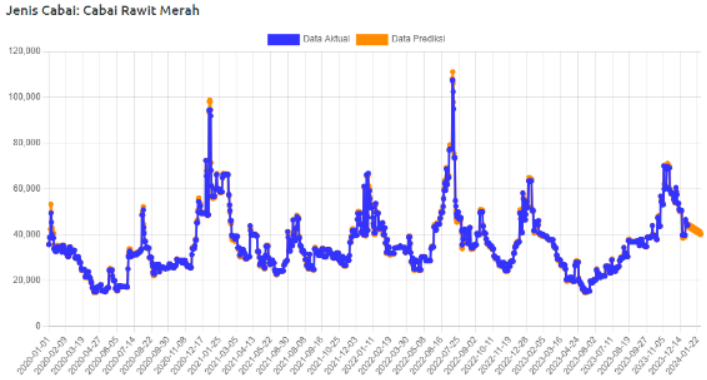

Figure 9. Red Bird's Eye Chili Peppers TES Graph

3. Comparison of Evaluation Results

In this study, the quality of prediction results is determined by evaluating the scores from the Mean Percentage Error (MAPE) and Mean Absolute Error (MAE). The evaluation results are compared to identify the most suitable algorithm for this research, considering predictions for all chili peppers. The predictions are conducted in the same way as previously. The table below compares evaluation results using the DES and TES algorithms. The evaluation results indicate that TES is superior in capturing seasonal patterns compared to DES. However, DES demonstrates a more stable performance on data without seasonal patterns. Both algorithms have strengths and weaknesses that should be considered based on the characteristics of the data used.

Table 3. Comparison of Evaluation Results

No	Type of Chili	MAE		MAPE	
		DES	TES	DES	TES
1	Cabai Merah Besar	447.9	447	1.25%	1.25%
2	Cabai Merah Keriting	494.83	493.02	1.39%	1.38%
3	Cabai Rawit Hijau	430.92	416.2	1.14%	1.12%
4	Cabai Rawit Merah	423.36	409.36	1.13%	1.1%

Based on the evaluation table, the Double Exponential Smoothing (DES) algorithm shows satisfactory results with very high accuracy for all types of chili peppers, as indicated by a MAPE value below 10%. The Triple Exponential Smoothing (TES) algorithm also provides satisfactory results with high accuracy, as its MAPE value is below 10%.

However, TES demonstrates a better fit for predicting chili prices, with lower MAE and MAPE values compared to DES. Therefore, the chili price prediction results indicate that TES provides better outcomes than DES.

CONCLUSIONS

Based on the results of the research conducted, several conclusions can be drawn as follows: the Triple Exponential Smoothing algorithm proved to be more effective in predicting various types of chili peppers in the city of Medan, as shown by the lower and more accurate MAE and MAPE values compared to Double Exponential Smoothing. Although both methods are accurate, the research results indicate that Triple Exponential Smoothing performs better in predicting chili prices than Double Exponential Smoothing. The Triple Exponential Smoothing algorithm showed very satisfactory results for various types of chili. For large red chili, the obtained MAPE accuracy was 1.25% with an MSE of 447. For curly red chili, the MAPE accuracy was 1.38% with an MSE of 493.02. Green bird's eye chili achieved a MAPE of 1.12% with an MSE of 416.2, while red bird's eye chili obtained a MAPE of 1.1% with an MSE of 409.36. On the other hand, Double Exponential Smoothing showed the following results: large red chili had a MAPE of 1.25% with an MSE of 447.9, curly red chili had a MAPE of 1.39% with an MSE of 494.83, green bird's eye chili had a MAPE of 1.14% with an MSE of 430.92, and red bird's eye chili had a MAPE of 1.13% with an MSE of 423.36. These results indicate that Triple Exponential Smoothing can predict chili prices with a very high level of accuracy, with MAPE values below 10%, thus falling into the accurate category.

ACKNOWLEDGMENTS

The author expresses their deepest gratitude to all parties who have contributed to this research. Special thanks are extended to the institution and supervisors who provided guidance and support; the author appreciates all the attention and assistance given that allowed this research to be completed. The author also thanks their family and friends for their support and encouragement throughout the research process. It is hoped that the results of this study will be beneficial for the advancement of knowledge in the field of commodity price forecasting and can serve as a reference for future research.

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