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Prediction of Cooking Oil Production Amount Using the Fuzzy Time Series Ruey Chyn Tsaur Method

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Abstract. Cooking oil is used as a medium for frying foodstuffs widely consumed by the general public. Cooking oil can be produced from various raw materials, such as coconut, copra, palm oil, soybeans, corn, sunflower, olive, and others. This research aims to determine the predicted results of cooking oil production at PT. Pulau Sambu Kuala Enok and find out the results of forecasting the cooking oil production at PT. Pulau Sambu Kuala Enok in 2023. The method used in this research is Ruey Chyn Tsaur's Fuzzy Time Series. Based on the results of data processing, forecasting results were obtained for January to December 2022, and this forecast has a MAPE value of 17.25%. The research results show that the Fuzzy Time Series Ruey Chyn Tsaur method has a good level of accuracy for predicting the amount of cooking oil production.

Keywords: Fuzzy Time Series Ruey Chyn Tsaur, Cooking oil, MAPE

1 Introduction

Cooking oil is a medium for frying food widely consumed by the wider community. Cooking oil is a vegetable oil purified and can be used as a food ingredient. Cooking oil can be produced from various raw materials, such as coconut, copra, palm oil, soybeans, corn, sunflower, olive, and others. Approximately 290 million tons of oil are consumed every year. The enormous demand for fried food is evidenced by the large amount of fried food consumed by people of all ages [1].

PT. Pulau Sambu Kuala Enok is a company engaged in the integrated coconut processing industry in the Indragiri Hilir Riau area. The coconut tree plant has many used parts, so this plant is considered a multipurpose plant. PT. Pulau Sambu Kuala Enok produces crude coconut oil, cooking oil, and copra extract pellets; this company produces cooking oil according to consumer demand. As time goes by, the business world will continue to change rapidly, requiring companies to be able to analyze the business environment and predict various possibilities that will occur in the future. A reliable and accurate forecasting system is needed to make policy decisions. A policy is established for business progress so that the company will get maximum profits [2]. Solving the problem of the amount of cooking oil production can use the application of fuzzy science, namely using the fuzzy time series (FTS) method. Forecasting with FTS is forecasting by processing past data patterns and then using them to predict future data. FTS captures patterns from historical data to project future data [3].

Several divisions of fuzzy methods include the application of Fuzzy Inference Systems in research [4]-[9]. Furthermore, Fuzzy Linear Progressing is used in research [10]. Furthermore, fuzzy clustering is found in research [11] and [12]. Then, Fuzzy Analytical Hierarchy was used in research [13]. Lastly, Fuzzy Time Series is found in research [14- [20]. Further research by [19] in 2022 regarding the Analysis of Palm Oil Consumption and Production in Indonesia Using the Moving Average Method. Based on forecasting research, results showed that palm oil consumption in Indonesia 2022 will increase by 10.36% or 1.643 million tonnes compared to total palm oil consumption in 2021, which was only 15.857 million tonnes. This can be said to be good because palm oil consumption continues to increase significantly every year. Further research by [20

2022 regarding Ruey Chyn Tsaur's Fuzzy Time Series Logic Method for Predicting Upward Trend Data Patterns. Based on research results, they predicted data on the condition value of the total weight of goods via train transportation on the island of Java in the period January 2020 to July 2022 using FTS Logika Reuy Chyn Tsaur is 1017.6. Reuy Chyn Tsaur's FTS Logic method has accurate prediction results in the case of the total weight of goods via train transportation on the island of Java in the period January 2020 to July 2022. Because it has a MAPE value of 8.05%, it can be considered suitable for predicting the value of the total weight of goods via Java Island train transportation.

Further research in 2021 regarding Rainfall Forecasting at PPKS Bukit Sentang Using Ruey Chyn Tsaur's Fuzzy Time Series [21]. Based on research on forecasting results using Ruey Chyn Tsaur logic, a MAPE result of 0.05% was obtained. Because the MAPE results obtained are <10%, this forecast falls into the excellent criteria. The results of rainfall forecasting at PPKS Bukit Sentang using Ruey Chyn Tsaur logic for January 2021 amounted to 351 mm, and December 2021 amounted to 151 mm, with an average MAPE result of 0.37%, which is in the excellent category. Based on the description of the problem above and research results [19], [20], [21], The author is interested in taking the research title, namely "Prediction of Cooking Oil Production Amounts Using Ruey Chyn Tsaur's Fuzzy Time Series Method."

2 Literature Review and Research Methods

2.1 Fuzzy Time Series

Fuzzy time series (FTS) is a data forecasting method that uses fuzzy as its fundamental principle. In this method, forecasting uses a system of lifting data patterns from historical data that will be used to interpret future data. A fuzzy set is a class without boundaries [15].

The fuzzy time series method [19] is the completion of the prediction as follows:

a. Determining the Universal Set
This stage is to determine the universal set, but before that, determine the smallest and largest values from historical data first. So the following equation can be used:

$$U = [D_{minimal}; D_{maximal}] \quad (1)$$

Information:
$D_{minimal}$ = minimum value
$D_{maximal}$ = maximum value
Where and are two exact positive numbers. Determination of values is carried out by researchers and taken randomly; the purpose of taking values is to make it easier to divide intervals.D_1D_2 $D_1D_2D_1D_2$

b. Calculating the Number of Classes
The number of good classes is determined so that all data is included. Determine the number of classes by calculating the number of partitions in the universal set by dividing it into several intervals with the same range of values. To determine this, use the term Sturges' Rule. The Sturges rule formula is:

$$K = 1 + 3.22logN \quad (2)$$

Where is the number of classes, is the amount of data while 1 and 3.22 are constant. KN

c. Determining Class Intervals
Interval is the difference between the upper limit and the lower limit. Then, to determine the class interval, the linguistic value of a fuzzy set is formed in the intervals formed from the universal set (U).

$$U = \{u_1, u_2, \ldots, u_n\} \quad (3)$$

Where,
$U =$ universe set
To determine the length of the interval, use the following equation:

$$l = \frac{U_{max} - U_{min}}{\text{number of class}}$$
$$l = \frac{(D_{max} + D_2) - (D_{min} - D_1)}{\text{number of class}} \quad (4)$$

The next interval can be obtained as follows:

$$\begin{aligned} U_1 &= [D_{min} - D_1; D_{min} - D_1 + l] \\ U_2 &= [D_{min} - D_1 + l; D_{min} - D_1 + nI] \\ &\vdots \\ U_n &= [D_{min} - D_1 + (n-1)I; D_{min} - D_1 + nI] \end{aligned} \quad (5)$$

Where n is the number of partitions or classes obtained. Then, after getting the class intervals, continue by calculating the mean value for each interval using the following equation:$l = 1,2,3, \dots, n$

$$m_i = \frac{\text{lower limit} + \text{upper limit}}{2} \quad (6)$$

d. Determining Fuzzy Sets

A fuzzy set can be a set where each member has a degree of membership. To make it easier to determine fuzzy sets, each fuzzy set is. Where n is the number of intervals, namely, the fuzzy set is defined as follows:$A_i, i = 1, 2, 3, \dots, n$. $u_1 = [d_1 : d_2], u_2 = [d_2 : d_3], \dots, u_n = [d_n : d_n - 1]$.

$$A_j = \sum_{i=1}^{n} \frac{\mu_j(u_i)}{u_i} \quad (7)$$

Where μ_j is the degree of membership of the fuzzy set A_j in the elements of the set u_i, with $i = 1, 2, 3, \dots, n$ and $0 < \mu_j < 1$. The degree of membership has three conditions with 3 data types, namely true (1), vague (0.5), and not true (0). With the following Equation:

$$\mu_j(u_i) = \begin{cases} 1, & j = i \\ 0.5, & j = i - 1 \text{ or } j = 1 + i \\ 0, & \text{others} \end{cases} \quad (8)$$

Rule 1 If it exists $\mu_j(u_i)$ with $j = i$, then $\mu_j(u_i) = 1$

Rule 2 If there is $\mu_j(u_i)$ with $j = i - 1$ or $j = i + 1$, then $\mu_j(u_i) = 0.5$

Rule 3 If it does not fall within the two conditions above, then $\mu_j(u_i) = 0$

Based on equation (8) we get

$$\begin{aligned} A_1 &= \frac{1}{u_1} + \frac{0.5}{u_2} + \frac{0}{u_3} + \cdots + \frac{0}{u_i} \\ A_2 &= \frac{0.5}{u_1} + \frac{1}{u_2} + \frac{0.5}{u_3} + \cdots + \frac{0}{u_i} \\ A_3 &= \frac{0}{u_1} + \frac{0.5}{u_2} + \frac{1}{u_3} + \cdots + \frac{0}{u_i} \\ A_4 &= \frac{0}{u_1} + \frac{0}{u_2} + \frac{0.5}{u_3} + \cdots + \frac{0}{u_i} \\ &\vdots \\ A_j &= \frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \cdots + \frac{0.5}{u_{i-1}} + \frac{1}{u_i} \end{aligned} \quad (9)$$

e. Fuzzification

Fuzzification is a stage that aims to change numerical variables into fuzzy variables in interval form. To convert numerical variables into linguistic variables by grouping data into vague sets.

f. Determining Fuzzy Logical Relations (FLR)

FLR is a relationship between data and subsequent data in the form of a fuzzy set A. If it is A_i, then the FLR relationship is written as $A_i \rightarrow A_i$. With A_i as the current state or current condition and A_j as the next state or next event. $F(t-1)F(t) = A_j$

g. Define Fuzzy Logic Relation Group (FLRG)

FLRGs are formed from FLR groupings. FLRG is formed based on the fixed relationship with the current state or the left side of the FLR.

h. Defuzzification

In the defuzzification process to produce forecasts, the defuzzification process is carried out using Tsaur's rules; the steps are as follows:

1) If the FLRG group at A_i is empty ($A_i \rightarrow \emptyset$), then the forecasting results are obtained using the equation $F_t = m_j$. Where mj is the middle value of u_j.
2) If the FLRG on A_i is a one-to-one relationship ($A_i \rightarrow A_k$) then the forecast obtained is the middle value of u_k
3) If the FLRG on A_i is a one-to-many relationship ($A_i \rightarrow A_1, A_2, \dots, A_j$) then the forecasting results are carried out using the following equation:

$$F_t = \frac{m_1 + m_2 + \cdots + m_j}{j} \tag{10}$$

2.2 Ruey Chyn Tsaur Method

The Ruey Chyn Tsaur method is a method that combines the fuzzy time series method and the Ruey Chyn Tsaur method. A new concept is carried out to analyze the accuracy of prediction calculations on the value of the Taiwan currency with the US dollar. The results of this research can provide good accuracy compared to the fuzzy time series method [21]. Here are Ruey Chyn Tsaur's steps:

a. Determining Fuzzy Logical Relation Group (FLRG)

A fuzzy Logical Relation Group (FLRG) is a state-to-state relationship.

b. Determining the Transition Probability Matrix

In this process, we can use FLRG

c. Defuzzification
1) Calculating Initial Forecasts

In this process, the results can be based on FLR, FLRG, and the transition probability matrix obtained previously. Initial forecasting (F_t) with $t = 1, 2, 3, \dots, N$ can be used as follows:

i. If the fuzzy logic relation group of Ai is an empty set $(A_i \rightarrow \emptyset)$, then the forecast $F(t)$ is m_i, m_i is the midpoint of the interval ui. With the following Equation:

$$F(t) = m_i \tag{11}$$

ii. If the fuzzy logic relation group of Ai is a one-to-one relation (for example $A_i \rightarrow A_k$ where $P_{ik} = 1$ and $P_{ij} = 0, j \neq k$) and mk is the middle value of uk with the following equation:

$$F(t) = m_i P_{jl} = ml \tag{12}$$

iii. If the fuzzy logic relationship group is a one to many relationships (for example $A_i \rightarrow A_1, A_2, \ldots, A_j$) with Y_{t-1} is the actual data $(t-1)$, then the forecasting results are carried out using the following equation:

$$F(t) = m_1 P_{i1} + m_2 P_{i2} + \cdots + m_{i-1} P_{i(i-1)} + Y_{(t-1)} P_i + m_{i+1} P_{i(i+1)} + \ldots + m_n P_{jl} \tag{13}$$

2) Calculating the Final Results of Forecasting

The final forecasting process combines the fuzzy time series method with the Markov chain. The equations are as follows:

$$F' = F_t + D \tag{14}$$

Where,

F'= final forecasting result

F_t= Initial forecasting results

D= forecasting tendency value

2.3 Measurement of Prediction Error

Forecasting error (error) is a way to measure how well the performance of a forecasting model used is by comparing actual data with forecasting results.[18]. If the error rate obtained is small, then the forecasting results will be closer to the actual data. Accuracy in forecasting is used as a rejection criterion in selecting a method. To determine the accuracy of a method, we can use several measures, namely the MAPE (Mean Absolute Percentage Error) value [15]. To calculate MAPE, use the following equation:

$$MAPE = \frac{1}{n} \sum_{t-1}^{n} \frac{\left| Y(t) - F'(t) \right|}{Y(t)} \times 100 \tag{15}$$

Where,

$MAPE$= error value

$Y(t)$= actual data

$F'(t)$= value of forecasting results

n= number of aircraft passenger data

The MAPE forecasting error calculation criteria are in Table 1 [15].

Table 1. MAPE Error Forecast Calculation Criteria

Forecasting Criteria	MAPE Percentage
Very good	MAPE < 10%
Good	MAPE 10% - 20%
Pretty good	MAPE 20% - 50%
Not accurate	MAPE > 50%

Thus, the accuracy of forecasting results can be calculated using the following formula:

$$\text{The accuracy of forecasting or predictions} = 100\% - MAPE \tag{16}$$

2.4 Research Methodology

This research will be carried out by referring to literature studies. The following are the steps taken:

a. Data collection

Data collection was carried out at PT.PulauSambu Kuala Enok and the data collected was recap data on retail production results provided by PT. Pulau Sambu Kuala Enok from January-December 2022.

b. Data processing

This research used the Ruey Chyn Tsaur Fuzzy Time Series method to process existing data. The Ruey Chyn Tsaur Fuzzy Time Series method is a method that combines the fuzzy time series method and the Ruey Chyn Tsaur method. The forecasting steps using Ruey Chyn Tsaur Logic in steps 1 to 6 are steps in the fuzzy time series, and the next step is a step in Ruey Chyn Tsaur. The following are Ruey Chyn Tsaur's Fuzzy Time Series method steps.

1) Forming a Universal Set of actual data using equation (1)
2) Calculating the number of classes using equation (2)
3) Forming Intervals using Equations (3),(4),(5),(6)
4) Determining Fuzzy Sets using equations (7),(8),(9)
5) Determining Fuzzification
6) Determining Fuzzy Logic Relations (FLR)
7) Determining Fuzzy Logic Relations Group (FLRG)
8) Calculating the Transition Probability Matrix
9) Defuzzify (10),(11),(12),(13),(14)

c. Measurement of forecasting error

At this stage, the researcher will first calculate the MAPE value using equation (15). After obtaining the MAPE value, the next step is to find the accuracy of the prediction results using Equation (16).

3 Results and Discussion

3.1 Actual Data

The data in Table 2 is data taken from PT. Pulau Sambu Kuala Enok. The data will be processed on retail production of cooking oil in January-December 2022.

Table 2. Cooking Oil Production Data PT. Pulau Sambu Kuala Enok

No	Month	Actual Data (Tons)
1	January	252.95
2	February	332.15
3	March	599.24
4	April	440.90
5	May	293.14
6	June	238.59
7	July	119.90
8	August	211.79
9	September	206.04
10	October	236.08
11	November	255.51
12	December	310.27

Source: PT. Pulau Sambu Kuala Enok (2022)

3.2 Ruey Chyn Tsaur's Fuzzy Time Series Application

Ruey Chyn Tsaur's fuzzy time series method is the following solution:

a. Determining the Universal Set

Determining the Universal Set is done by Equation (1). Based on Table 2, the universe set is obtained:

$U = [D_{min}; D_{max}] = [119.90; 599.24]$

b. Determining Intervals

Division of the universe set into several partitions of intervals (n) using the Sturges formula in equation (2)

$n = 1 + 3.22logN = 1 + 3.22\log(12) = 4.47 \approx 4$

Each partition has the same interval length, which is found using equation (4).

$l = \frac{U_{max} - U_{min}}{n} = \frac{599.24 - 119.90}{4} = 119.83$

After that, we look for the definition of the partition u_1, u_2, u_3, u_4, of the universal set U with equation (5).

$U_n = [d_n + d_{n+1}]$

$u_1 = [119.90; 239.73], u_2 = [239.73; 359.56]$

$u_3 = [359.56; 473.39], u_4 = [473.39; 599.22]$

Then the middle value (m) of each universe set U is calculated using equation (6).

$m_n = \frac{[d_n + d_{n+1}]}{2}$

$m_1 = 179.81; m_2 = 299.64; m_3 = 416.47; m_4 = 536.30$

c. Determining fuzzy sets

Determining the fuzzy set or fuzzy set A is done using equation (9) as follows:

$A_1 = \frac{1}{u_1} + \frac{0.5}{u_2} + \frac{0}{u_3} + \frac{0}{u_4}$

$A_2 = \frac{0.5}{u_1} + \frac{1}{u_2} + \frac{0.5}{u_3} + \frac{0}{u_4}$

$A_3 = \frac{0}{u_1} + \frac{0.5}{u_2} + \frac{1}{u_3} + \frac{0.5}{u_4}$

$A_4 = \frac{0}{u_1} + \frac{0}{u_2} + \frac{0.5}{u_3} + \frac{1}{u_4}$

d. Fuzzification and Fuzzy Logic Relations (FLR)

The fuzzification stage is determined based on linguistic values based on previously determined fuzzy sets, and the Fuzzy Logical Relationship (FLR) is searched using fuzzification data. Below are the fuzzification and FLR data from the data above, which are presented in Table 3.

e. Determining Fuzzy Logic Relations Group (FLRG)

The FLRG value is determined based on the relationship between the current state and the next state, which is then grouped, where the current state or current event is fixed. In Table 5 below, FLRG data is presented.

Table 3. Data Fuzzification and FLR

No	Month	Actual Data (Tons)	Fuzzification	FLR
1	January	252.95	A_2	-
2	February	332.15	A_2	$A_2 \rightarrow A_2$
3	March	599.24	A_4	$A_2 \rightarrow A_4$
4	April	440.90	A_3	$A_4 \rightarrow A_3$
5	May	293.14	A_2	$A_3 \rightarrow A_2$
6	June	238.59	A_1	$A_2 \rightarrow A_1$
7	July	119.90	A_1	$A_1 \rightarrow A_1$
8	August	211.79	A_1	$A_1 \rightarrow A_1$
9	September	206.04	A_1	$A_1 \rightarrow A_1$
10	October	236.08	A_1	$A_1 \rightarrow A_1$
11	November	255.51	A_2	$A_1 \rightarrow A_2$
12	December	310.27	A_2	$A_2 \rightarrow A_2$

Table 4. FLRG results

Current Stage	Next Stage	FLRG
A_1	$4A_1, A_2$	$A_1 \rightarrow 4A_1, A_2$
A_2	$A_1, 2A_2, A_4$	$A_1 \rightarrow A_1, 2A_2, A_4$
A_3	A_2	$A_3 \rightarrow A_2$
A_4	A_3	$A_4 \rightarrow A_3$

f. Calculating the Transition Probability Matrix

The transition probability matrix is determined based on fuzzification data up to FLRG for each data. The transition probability matrix on data is of order 4 × 4 based on the previous interval.

$$\begin{bmatrix} 4/5 & 1/5 & 0 & 0 \\ 1/4 & 2/4 & 0 & 1/4 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

g. Defuzzification

The initial forecast based on probability values can be seen in the transition probability matrix.

Table 5. Results of Initial Forecasting and Final Forecasting

No	Month	Actual Data (Tons)	Initial Forecasting F(t) (Tons)	Final Forecasting F'(T) (Tons)
1	January	252.95	-	-
2	February	332.15	305.49	305.49
3	March	599.24	416.47	536.30
4	April	440.90	299.64	239.73
5	May	293.14	399.47	339.56
6	June	238.59	251.23	191.32
7	July	119.90	250.79	250.79
8	August	211.79	155.84	155.84
9	September	206.04	229.35	229.35
10	October	236.08	224.75	224.75
11	November	255.51	297.06	356.97
12	December	310.27	306.77	306.77

Calculations can be made for forecasting based on historical data using Equations (11), (12), and (13), and to determine the final forecasting results using equation (15), obtained from the initial forecasting stage and adjustment of forecasting results. Table 5 shows the data from the initial forecasting and final forecasting results.

Actual data for 2022 and forecasting data for Cooking Oil production at PT. From the data above, Pulau Sambu Kuala Enok in 2023 can be presented in graphical form as in Figure 1.

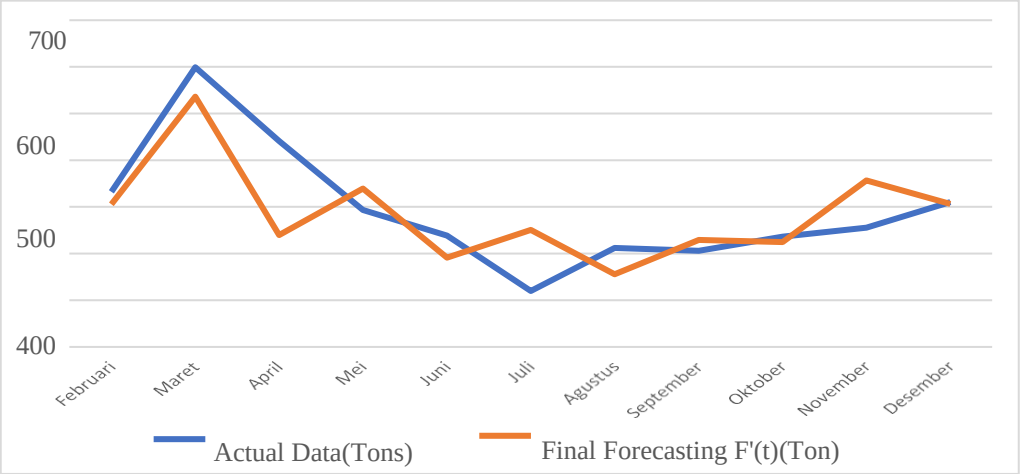

Figure 1. Actual Data for 2022 and Forecast Data for Cooking Oil Production for 2023

h. Calculating Mean Absolute Percentage Error (MAPE)

Table 6. MAPE Calculation Results

No	Month	Actual Data (Tons)	Initial Forecasting F(t) (Tons)	Error
1	January	252.95	-	-
2	February	332.15	305.49	0.08
3	March	599.24	416.47	0.10
4	April	440.90	299.64	0.45
5	May	293.14	399.47	0.15
6	June	238.59	251.23	0.19
7	July	119.90	250.79	0.29
8	August	211.79	155.84	0.26
9	September	206.04	229.35	0.11
10	October	236.08	224.75	0.04
11	November	255.51	297.06	0.39
12	December	310.27	306.77	0.01

Based on equation (15) calculations, the average MAPE is 17.25%. The average error value produced is between <20%, so the results are considered good, meaning the prediction of the amount of cooking oil production at PT. Pulau Sambu Kuala Enok is acceptable.

4 Conclusion

Based on the description, the Fuzzy Time Series Ruey Chyn Tsaur method is applied to predict the amount of cooking oil production at PT. Pulau Sambu Kuala Enok maka obtained forecasting results in 2023; in April, there was a decrease of 239.73 tons; in July, there was an increase of 250.79 tons; likewise, in November, there was

an increase of 356.97 tons—prediction of the amount of Cooking Oil production at PT. Pulau Sambu Kuala Enok has good production results by producing MAPE below 20%, namely 17.25%.

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