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| RESEARCH ARTICLE

Prediction of Tempe Raw Material Needs for Home Industry Using Tsukamoto Fuzzy Logic Algorithm

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| ABSTRACT
The home tempeh industry is faced with the challenge of accurately predicting raw material needs. Implementing an effective prediction system can help estimate the amount of tempeh production in the future, so as to avoid stock shortages of raw materials. In addition, when tempeh producers have accurate predictions, they can manage soybean stocks better, especially when there is a stock shortage, so that production is not affected by rising soybean prices. This research aims to develop a Tsukamoto Fuzzy Logic based prediction system to overcome this problem. Research methods include collecting historical production data, designing fuzzy models, and system testing. Interim results show that the developed system is able to increase prediction accuracy by up to 95%, which in turn can reduce production costs and minimize waste of raw materials.

| KEYWORDS

Fuzzy Logic Tsukamoto, Tempe Industry, Prediction

| ARTICLE INFORMATION

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1. Introduction

Tempeh, a legendary Indonesian dish made from fermented grains, has become an integral part of the nation's culture and nutrition. However, the tempeh industry faces complex challenges in maintaining the availability of raw materials. Wise in managing raw material stocks is not easy. Sometimes you have to be ready to face where the demand for soybeans increases dramatically.

Based on BPS data in 2024, local soybean production is only able to meet 15% of national needs, while the rest (85%) must be met through imports. The need for soybeans in Indonesia is estimated to reach 2.67 million tons / year, while domestic soybean production only reaches 346,821 tons, so the soybean needs that must still be met through imports are 2.323 million tons. This condition will affect the domestic tempeh market, because soybean prices are expensive, and Indonesia is currently still dependent on soybeans imported from America.

Expensive imported soybeans cause raw material costs to increase, which is bad news for the tempeh industry as a whole. Tempeh producers must predict their raw material inventory well in advance of the production date due to increased material costs. Previously, tempeh producers were often overwhelmed when managing soybean stocks in the warehouse in case of a shortage. The scarcity of soybeans can cause prices to soar, so it is important for tempeh producers to have the ability to predict future soybean needs so that production continues to run smoothly. This makes them vulnerable to miscalculations that can affect production. With better stock management, tempeh producers can plan the use of raw materials efficiently and maintain business continuity in the midst of uncertain market conditions.

Various previous studies have analyzed the prediction of soybean raw material requirements for tempeh. The first study by Cahyadi, using the Economic Order Quantity (EOQ) method to optimize soybean inventory focuses on the quality aspects of optimal raw material ordering, with the result that the use of this method can minimize raw material inventory expenditures [Cahyadi, 2024]. However, the EOQ method is considered less flexible due to assumptions regarding the stability of demand, which does not always reflect real conditions. The second research by Nugroho applied the Fuzzy Tsukamoto method to predict the pre-production needs of tempeh processing, where data was collected for one month and recorded weekly [Nugroho, 2023]. Nugroho's research resulted in a prediction of the amount of tempeh production per bean, but did not include the results of MAPE accuracy. The third study by Weka also used the Fuzzy Tsukamoto method to optimize the amount of tempeh production, with data collection for one year. The variable data used in Weka's research includes delivery, production, and demand, which shows that this method can produce good optimization. Weka's research results recorded an error calculated using Mean Absolute Percentage Error (MAPE) of 9.01%, which shows a very good level of prediction accuracy [Weka, 2024].

In contrast to previous studies, in this study the author proposes the application of the Fuzzy Tsukamoto method to predict the need for tempeh raw materials in the home tempeh industry. The data in this study will be taken for eight months, from January to August 2024, focusing on the calculation of monthly tempeh production predictions. This method is expected to provide tolerance for data variations and allow more accurate predictions so that the accuracy produced by the system is higher than previous research on soybean stocks. Factors affecting raw material inventory, such as inventory quantity and demand, will be comprehensively analyzed. Thus, this research aims to provide innovative solutions in managing the availability of soybean raw materials, so that the tempeh industry can adapt to market dynamics and improve production efficiency.

With the increasing demand for tempeh and the challenge of maintaining the availability of raw materials, this research aims to provide an innovative solution through the application of the Fuzzy Tsukamoto method. through this approach, it is hoped that the home-based tempeh industry can adapt to market dynamics and ensure optimal availability of raw materials and tempeh producers can know how much tempeh to produce in the future. this can reduce the risk of stock shortages and overstocks of soybeans in the warehouse.

2. Methodology

2.1 Research Stages

In this study, there are six stages of research used to facilitate research activities, which can be seen as in Figure 1.

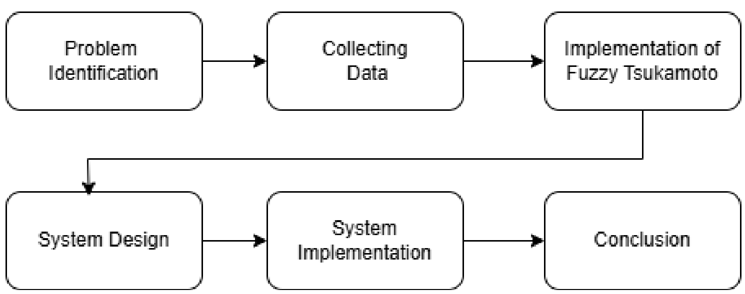

Figure 2.1 **Research Stages**

Description:

a. Problem Identification: At this stage, the actual problem point is implemented and what elements are needed for problem-solving in the home tempeh industry.
b. Collectiong Data: Data collection is done by observing and interviewing the owner of the home tempe industry owned by Mrs. Sulasmi to get the necessary data. Research data collection was carried out from January 2024 to August 2024, the researcher asked Mrs. Sulasmi to provide the necessary data, such as sales records, raw material stocks, and tempeh production during that period.
c. Implementation of Fuzzy Tsukamoto: To solve the problem of predicting future tempeh raw materials.
d. System Design: In this phase design the system with UML, database and interface.
e. System Implementation: As a tool for home tempe industry owners to make it easier to predict the need for raw materials and the amount of tempeh that must be produced in the future.
f. Conclusion: This final phase is to make conclusions based on the results of calculations by applying the Fuzzy Tsukamoto method.

2.2 Fuzzy Tsukamoto
In this research, the analysis method used is Tsukamoto Fuzzy logic, Tsukamoto Fuzzy was discovered by Lotfi A. Zadeh in 1978, then named after the name of a Japanese educational figure, Yukio Tsukamoto, who at that time was a professor at Kyushu University, Japan. Tsukamoto fuzzy maps input values into fuzzy sets which are then operated with fuzzy rules. Then, the output value is generated from the aggregation result of the entire set [Burhanuddin, 2023].

In classical logic, it is stated that everything is binary, which means that it only has two possibilities, "Yes or No", so it has a membership value of 0 or 1. However, in fuzzy logic, the possibility of membership values is between 0 and 1. That is, a situation can have two values "Yes and No", "True and False", "Good and Bad" simultaneously, but the value depends on the membership weight it has [Adha, 2022].

The stages in the Fuzzy Tsukamoto method are according to [Pujiarso Nugroho, 2019] as follows:

a. Fuzzyfication
b. Form a fuzzy knowledge base (Rule in the form of IF....THEN)
c. Inference, with the MIN implication function to get the α-predicate value of each rule (α1, α2, α3, ... αn) Then this α-predicate value is used to calculate the output of the inference results firmly (crisp) into the rule (z1, z2, z3, ... zn).
d. Defuzzification
   Using (Average) z*= (∑ aizi)/(∑ ai)........(1)
   Description:
   Z= Output variable
   αi = Predicate α value
   zi = Output variable value

   The MIN implementation function and the defuzzification process are carried out by finding the average of the values.

2.3 Mean Absolute Percentage Error
Mean Absolute Percentage Error (MAPE) calculation to analyze the percentage of method accuracy or prediction error. By using the actual value of the data. A forecasting method can be said to be accurate if the percentage error value in the MAPE calculation is close to zero. In the MAPE calculation, there is a value limit that indicates whether the MAPE value is feasible or not to use [Fadillah & Tyaswati, 2024].

Tabel 2. 1 Standard MAPE Calculation Value

MAPE Value	Description
0-10%	The ability of the forecasting method is very good
10-20%	Good forecasting method capability
20-50%	The ability of the forecasting method is feasible
>50%	The ability of the forecasting method cannot be used

2.4 Prediction
Prediction is the result of forecasting or estimating future values using past data. This prediction activity is very useful for determining how much stock of goods is needed in the next period. The prediction of the amount is also influenced by the stock inventory in the storage area so that there is no accumulation which can later cause damage to the goods because they are stored for a long time in the storage area or in the warehouse [Nisa & Harefa, 2023].

2.5 JavaScript
JavaScript is a client-based programming language that is executed by the browser, allowing web-safety to perform additional tasks that ordinary HTML scripts cannot [Noviantoro, et al., 2022]. JavaScript is primarily used for client-side programming

implemented as part of a web browser to allow developers a better way to implement user interfaces and dynamic features in web pages [Lewenusa, 2023].

2.6 MySQL

MySQL is a database server program that can receive and send data quickly using SQL commands. MySQL is a relational database that stores data in separate tables, instead of storing data in a large storage space [Ery Hartati, 2022]. MySQL provides various security features to protect data, including user authentication and access authorization [Zein, et al., 2023].

2.7 UML

Unified Model Language (UML) diagram is a use case diagram to describe an interaction between one or more actors with the information system to be built, and describe the functions that exist in an information system [Nistrina & Sahidah, 2022]. UML does not only describe software system models, but can model object-oriented systems [Zein, et al., 2023].

3. Results and Discussion

Needs Analysis :

a. The system can perform the login process.
b. The system can make changes to user data and passwords.
c. The system can perform the logout process.
d. The system can display membership degrees.
e. The system is able to perform fuzzification, inference, defuzzification using the Tsukamoto fuzzy method.
f. The system can display and save calculation results.
g. The system can manage prediction result reports

3.1 Usecase Diagram

Use case diagram is a modeling of the information system to be created. Use cases describe an interaction between one or more actors with the information system to be created. to find out what functions are in a system and who has the right to use these functions. The following is a use case designed to create this system:

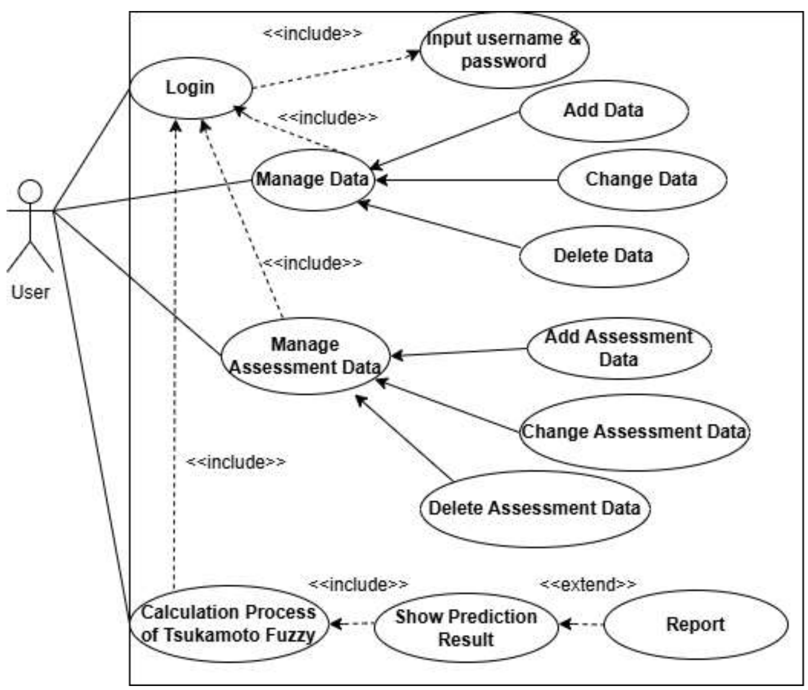

Figure 3. 1 System Usecase Diagram

3.2 System Flowchart

Flowchart is a chart showing the flow in a program or system procedure logically. Flowchart is an illustration in the form of a flow chart of algorithms in a program, which states the flow direction of the program [Yulianeu & Oktamala, 2022]. The flowchart of the prediction system with the tsukamoto fuzzy method is shown in the following figure:

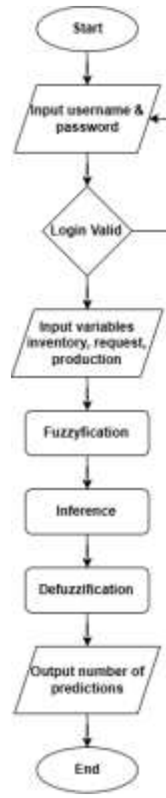

Figure 3. 2 System Flowchart

3.3 Implementation of Tsukamoto Fuzzy Algorithm

Table 3.1 Value of Each Alternative

Alternative Name	Inventory	Request	Production
January	300	700	690
February	235	680	670
March	105	650	620
April	105	720	690
May	285	680	600
June	230	670	690
July	100	580	580
August	280	670	600

Based on the reasoning in fuzzy inference, 20 rules are formed. The following is explained in the table below.

Tabel 3. 2 Rule Value of Each Data

Rule	Inventory	Request	Production	Description
01	High	High	High	High
02	High	Low	High	High
03	High	Low	High	Low
04	Low	High	High	High
05	Low	Low	High	Low
06	Low	Low	High	High
07	High	Low	Low	High
08	High	High	Low	Low
09	Low	High	High	Low
10	Low	High	Low	High
11	High	Low	High	Low
12	Low	High	High	High
13	High	Low	High	High
14	High	High	Low	High
15	High	High	High	High
16	High	High	High	High
17	Low	Low	Low	Low
18	Low	Low	Low	Low
19	High	Low	Low	Low
20	Low	High	Low	Low

The categories and weight values to be used in the selection process are as follows:

Tabel 3. 3 Minimum and Maximum Values Category

No	Category Value	Value Interval	Variables
1.	Min Inventory	200	Low
2.	Max inventory	300	High
3.	Min Request	550	Low
4	Max Request	700	High
5	Min Production	500	Low
6	Max Production	650	High

From the example of category value table data, one of the data to be tested is January data to calculate the predicted value using the Fuzzy Tsukamoto method with the following data conditions:

a. Inventory: 300
b. Request: 700
c. Production: 690

The fuzzification process is carried out to obtain the crisp value of the membership function for each criterion which is calculated using the following formula:

0; x ≤ a
μ[x]= (x - a)/(b - a); a ≤ x ≤ b ....(2)
1; x = b

Description:
μ : Fuzzy Membership Crips Value
x: data variable
a : Minimum
Value
b : Maximum Value

a. Then the value for Inventory [300] in January data:

$$\mu\text{Low [300]} = \frac{b-x}{b-a} = \frac{600-300}{600-200} = \frac{300}{400} = 0{,}75$$

$$\mu\text{Height [300]} = \frac{x-a}{b-a} = \frac{300-200}{600-200} = \frac{100}{400} = 0{,}25$$

b. Then the value for Request [700] in January data:

$$\mu\text{Low [700]} = \frac{b-x}{b-a} = \frac{700-700}{700-550} = \frac{0}{1{,}4} = 0$$

$$\mu\text{Height [700]} = \frac{x-a}{b-a} = \frac{700-550}{700-550} = \frac{150}{150} = 1$$

c. Then the value for Production [690] in January data:

$$\mu R\text{Low [690]} = \frac{b-x}{b-a} = \frac{650-690}{650-500} = \frac{-40}{150} = -0{,}3$$

$$\mu\text{Height [690]} = \frac{x-a}{b-a} = \frac{690-500}{650-500} = \frac{190}{150} = 1{,}26$$

Next calculate the inference rule. The inference function must know the rules used in the system to get the value that will be used in the defuzzification process. An explanation of the inference process is below:

- Rule 1: If Inventory is High and Demand is High and Production is High then fuzzification (z)
  [α-predicate1 = μHigh∩μHigh ∩μHigh = min(μHigh [690]∩μHigh [300]∩μHigh [700]) = min(0.25; 1; 1.26)
  α-predicate1 = 0.25
  z1 = zMax – α-predicate1 * (zMax – zMin)
  = 700 - 0,25 * (700 - 200)
  = 700 - (0,25 * 500)
  = 575
- Rule 2: If Inventory is High and Demand is Low and Production is High then fuzzify (z)
  [α-predicate2 = μHigh∩μLow∩μHigh = min(μHigh [300]∩μLow [550]∩μHigh [650]) = min(0.25; 0; -0.3)
  α-predicate 2 = 0

  z2 = zMax – α-predicate2 * (zMax – zMin)
  = 700 – 1 * (700- 200)
  = 700 - (1 * 500)
  = 200
  z3 = zMax – α-predicate3 * (zMax – zMin)
  = 700 – (0.3 * (700- 200)
  = 700 - (0.3* 500)
  = 70
  z4 = zMax – α-predicate4 * (zMax – zMin)

= 700 – 0.25 * (700- 200)
=700 - (0,25* 500)
= 575
z5 = zMax – α-predicate5 * (zMax – zMin)
= 700 – 0 * (700- 200)
=700 – (0 * 500)
= 700
z6 = zMax – α-predicate6 * (zMax – zMin)
= 700 – 1,26* (700- 100)
=700 - (1,26 * 500)
= 70
Z7= zMax – α-predicate7 * (zMax – zMin)
= 700 - 0,25 * (700 - 200)
= 700 - (0,25 * 500)
= 575
Z8= zMax – α-predicate8 * (zMax – zMin)
= 700 – (0 * (700- 200)
= 700 - (0* 500)
= 700
Z9= zMax – α-predicate9 * (zMax – zMin)
= 700 – 0,3* (700- 100)
=700 - (0.3 * 500)
= 550
Z10= zMax – α-predicate10 * (zMax – zMin)
= 700 - 0,25 * (700 - 200)
= 700 - (0,25 * 500)
= 575
Z11= zMax – α-predicate11 * (zMax – zMin)
= 700 – 0 * (700- 200)
=700 – (0 * 500)
=700
Z12 = zMax – α-predicate12 * (zMax – zMin)
= 700 – 1,26* (700- 100)
=700 - (1,26 * 500)
=70
Z13 = zMax – α-predicate13 * (zMax – zMin)
= 700 - 0,25 * (700 - 200)
= 700 - (0,25 * 500)
= 575
Z14 = zMax – α-predicate14 * (zMax – zMin)
= 700 – 1 * (700- 200)
=700 – (01* 500)
=200
Z15 = zMax – α-predicate15 * (zMax – zMin)
= 700 – 1,26* (700- 100)
=700 - (1,26 * 500)
=70
Z16 = zMax – α-predicate16 * (zMax – zMin)
= 700 - 0,25 * (700 - 200)
= 700 - (0,25 * 500)
= 575
Z17 = zMax – α-predicate17 * (zMax – zMin)
= 700 – 0,75* (700- 200)
=700 – (0,75 * 500)
=325
Z18= zMax – α-predicate18 * (zMax – zMin)
= 700 – 0 * (700- 200)
=700 – (0* 500)
=700
Z19 = zMax – α-predicate19 * (zMax – zMin)
= 700 - 0,3 * (700 - 200)
= 700 - (0,3 * 500)
= 550
Z20 = zMax – α-predicate20 * (zMax – zMin)

= 700 – 0,75* (700- 100)
=700 - (0,75 * 500)
=325

The next step performs the defuzzification process. In the Fuzzy Tsukamoto method, to determine the crisp output, the centered average defuzzification is used, namely by using the equation as below:

$$Z=\frac{(predikat1 * z1)+ \ldots\ldots+(predikat\ n * zn)}{predikat1+ \ldots\ldots+predikat\ n} \ldots\ldots\ldots\ldots (3)$$

$$Z=\frac{(0,25*575)+(0*700)\ldots\ldots+(predikat\ 20 * z20)}{0,25+0+ \ldots\ldots+predikat\ 20} \ldots\ldots\ldots\ldots (4)$$

$$Z= 558,6 \ldots\ldots\ldots\ldots (5)$$

3.4 System Prediction Results

The results of this system prediction calculation can be used to determine the need for tempeh raw materials in order to forecast or predict future soybean needs. So it is expected that excess soybean stock or shortage of soybean stock in the warehouse will be minimized. The following is a table of prediction results:

Tabel 3. 4 System Prediction Results

No.	Data	Predicted Value
1.	January	558 kg
2.	February	657 kg
3.	March	624 kg
4.	April	624 kg
5.	May	581 kg
6.	June	664 kg
7.	July	602 kg
8.	August	588 kg

3.4.1 Calculation of MAPE

MAPE is a statistical measure used to measure forecasting accuracy by calculating the average error produced by a model. The following is the calculation of MAPE for this system:

Tabel 3. 5 MAPE Calculation Result

No	Pi (Production)	Pi^ (Prediction Result)	Pi - Pi^	$\frac{Pi - Pi^\wedge}{Pi}$
1	690	558	132	0,190751445
2	670	657	13	0,0193452381
3	620	624	-4	0,0064516129

4	690	624	66	0,0953757225
5	600	581	19	0,0316666667
6	690	664	26	0,0376811594
7	580	602	-22	0,0379310345
8	600	588	12	0,02
		Total		0,439202879

$$MAPE = \frac{Pi - Pi^{\wedge}}{Pi} X\ 100\% \text{ ....(6)}$$

$$= \frac{0{,}439202879}{8} X\ 100\% = 5{,}49003599 \text{..........(7)}$$

Obtained a MAPE value of 5.49003599%, with a system accuracy value of 94.50996%.The research conducted provides a comparison of research results using fuzzy logic and mean absolute perception error (MAPE) as a performance measure. MAPE is used to evaluate how accurate the forecasts produced by the tsukamoto fuzzy logic model are in predicting the amount of tempeh raw material inventory.

3.4.2 System View

3.4.2.1 Login Page

Here is a view of the login page of the Tempe raw material prediction system:

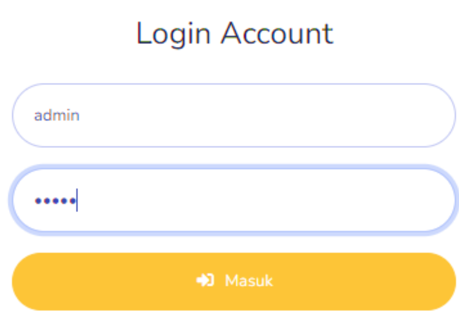

Figure 3.3 Login Page

The login page is where users can enter their user data to log into the system. This page consists of a form that asks the user to enter a username and password. Once the user fills in the form and clicks the login button, the data entered will be sent to the server for the authentication process. If an error occurs, an error notification will appear, informing the user of the problem. If the login is successful, a successful notification will be displayed, and the user will be redirected to the system home page or dashboard page.

3.4.2.2 Dashboard Page

Here is a view of the Tempe raw material prediction system dashboard page:

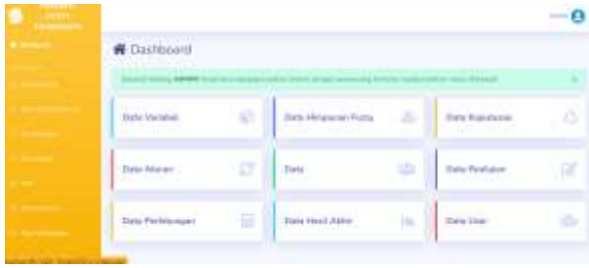

Figure 3.4 Dashboard Page

On this dashboard page there is a menu menu that is on the system.

3.4.2.3 Data Input Page

The following is a display of the Tempe raw material prediction system data input page:

Figure 3.5 Data Input Page

This page is used to input data that has been obtained from tempeh producers such as inventory data, demand and production data, on this page it is also possible to update data, delete data and add data.

3.4.2.4 Calculation Page

The following is a display of the Tempe raw material prediction system calculation page:

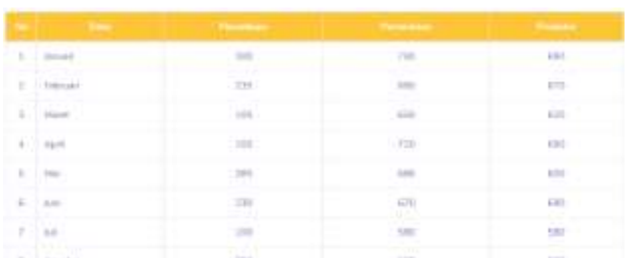

Figure 3.6 Calculation Page

On this page all calculation processes are carried out such as calculating fuzzification, inference and defuzzification.

3.4.2.5 Final Results Page

The following is a display of the final results page or prediction results on the Tempe raw material prediction system:

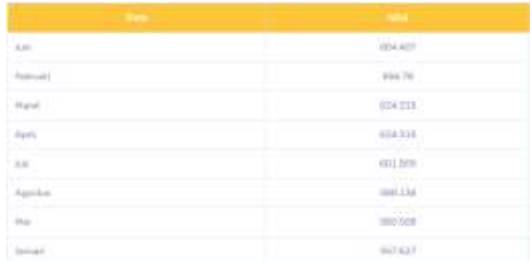

Figure 3.7 Final Results Page

On this page we can view the prediction results and download the prediction result report.

4. Conclusion

The application of the Tsukamoto Fuzzy Logic model in the tempeh industry helps predict raw material requirements more accurately, obtaining a mape value of 5.49% with a system accuracy value of 95%, indicating all system functions run according to the expected specifications. By considering variables such as market demand, production, and sales, as well as influencing factors such as seasonality and economic conditions, this model improves inventory management, The implementation of this system can predict the amount of tempeh that should be produced in the future, in order to avoid stock shortages so that it is not affected when soybean prices rise. This leads to cost savings, increased customer satisfaction, and stronger competitiveness in the market.

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