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Article

Implementation of Sugeno Fuzzy Logic Methods for Predicting Pie Crust Raw Material Stock

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A B S T R A C T

Accurate prediction of raw material stocks is essential for cost management and effective production planning in the food industry. The Sugeno fuzzy logic method is employed to predict the stock levels of pie leather raw materials. This method aims to offer a reliable prediction system that enhances stock management, thereby minimizing the risks associated with overstocking or stock shortages. The performance of the model is evaluated using the average error percentage test, which yielded a result of 3.94%. This indicates an accuracy level of 96.06%, demonstrating a high degree of precision. The findings suggest that the Sugeno fuzzy logic method is a highly effective tool for predicting raw material requirements in the pie leather production process. The study underscores the potential of fuzzy logic methods in supply management, ensuring smooth production operations. By implementing this method, manufacturers can achieve better inventory control, leading to more efficient production planning and cost savings. The results validate the application of Sugeno fuzzy logic as a robust approach for inventory prediction, capable of significantly improving the overall management of raw material stocks in the food industry. This research highlights the practical benefits of advanced predictive models in optimizing supply chains, supporting continuous production flow, and enhancing the overall efficiency of production systems. Consequently, the use of fuzzy logic methods can play a critical role in streamlining production processes and maintaining optimal inventory levels, ultimately contributing to the success and sustainability of food manufacturing operations.

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I. INTRODUCTION

The culinary industry is a highly dynamic and competitive sector. Success in this industry is often determined by the ability of producers to respond to market demand quickly and efficiently [1]–[3]. One critical aspect of food production management is the management of raw material stock [4], [5]. Inventory refers to the stock of goods or raw materials provided to support smooth production so that consumer needs can be met [6], [7]. Well-implemented inventory management can result in good and timely production performance to maintain the optimal quantity of goods. Inventory requires control to maintain the quality and quantity of these raw materials [8], [9]. One way to control raw material inventory is through prediction.

The procurement of pie crust raw materials is done in Packages, each consisting of several main components ready for use. Each Package contains a mix of flour, butter, and eggs. This flour mix is a pre-formulated blend, so the user only needs to add butter and eggs according to the instructions to produce the perfect pie crust dough. Using these Packages simplifies the pie-making process, saves time, and ensures consistent taste and texture of the pie crust with every production.

With this rapid development, the Medan pie crust production house faces challenges such as sales fluctuations. Having too much stock of pie crust ingredients can lead to financial inefficiencies, such as unproductive expenses, while having too few raw materials can result in inefficient operational costs and lost sales opportunities [10]. Therefore, a prediction process is necessary to achieve the best results or maximize efficiency [11].

From these issues, an appropriate solution is required to address the problem of purchasing pie raw material stocks. In the research titled "Application of the Sugeno Fuzzy Method for Raw Material Inventory Prediction" conducted by Warmansyah & Hilpiah, it was proven that the Sugeno fuzzy logic method can be used efficiently in determining stock purchases and achieved a MAPE value of 38% [12]. Therefore, pie raw material stock predictions can be made using the Sugeno fuzzy logic to determine future pie raw material stock purchases according to needs [13].

The predictions from this research show that applying the Sugeno Fuzzy Logic Method in optimizing the monthly purchase of pie crust raw materials can provide significant benefits for pie producers. By considering various factors such as initial stock quantity, raw material intake, and production, the resulting strategy can minimize the amount of surplus stock and increase the number of sold stocks, thereby maximizing profits. The use of fuzzy logic allows for more dynamic and adaptive evaluations of changes in demand and stock availability, aiding producers in making more accurate and timely decisions [14]. Besides reducing losses due to excess stock, this research also contributes to stock management optimization in business, demonstrating great potential in more efficient and effective raw material stock management, and providing new insights for research and practice in stock management and business decision-making.

With fuzzy logic, issues that have unclear values are no longer an obstacle because computers not only understand Boolean logic with definite and clear values (crisp), but also recognize logic with ambiguous or uncertain values. In fuzzy logic, data can be both true and false simultaneously, but the degree of truth or falsity depends on the weight it carries [15].

II. LITERATURES REVIEW

In the research titled "Application of Sugeno Fuzzy Logic for Coffee Bean Stock Optimization at Rooster Cafe" conducted by Hafiz & Sriani, it was also proven that the Sugeno fuzzy logic method can be used as a method to determine the production amount using input variables (Initial Stock, Sold Stock, Additions) and output variables in the form of the final stock amount. This study also obtained a MAPE value of 19.81%, equivalent to an accuracy rate of 80.19% [16]. The difference between this research and previous research is the utilization of the Sugeno fuzzy logic method to predict pie crust raw material stocks. The main objective of this study is to model a system that can predict pie crust raw material stocks and calculate the accuracy of the Sugeno fuzzy logic method in modeling a system that can predict pie crust raw material stocks.

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Fuzzy Sugeno Fuzzy Logic is an approach within logic theory that enables the handling of uncertainty and lack of information[17], [18]. The concept of fuzzy logic was introduced by Lotfi A. Zadeh in 1965. Fuzzy logic allows membership values in a set to range between 0 and 1, representing the degree of membership of an element in a set [19], [20]. In fuzzy logic, the truth value of a statement ranges from completely true to completely false. With fuzzy set theory, an object can belong to multiple sets with different degrees of membership in each set [21], [22].
The Sugeno method is similar to the Mamdani method, but the difference lies in its output. In Sugeno fuzzy logic, the output is a constant rather than a fuzzy set. The membership function in the Sugeno fuzzy method is often called a singleton function, which is a membership function that has a value of 1 at one actual value and 0 at other actual values. The defuzzification process in the Sugeno method is more efficient compared to the Mamdani method [23], [24], [25]. This is because the Sugeno fuzzy method calculates the output function of each rule and produces the output as a weighted average. Meanwhile, the Mamdani method has to calculate the area under the membership function curve of the output variable. The advantage of Sugeno fuzzy logic is that with zero-order, it is often more suitable for various modeling needs.

The definition of prediction is the process of estimating or forecasting future needs, in this context, specifically to determine the quantity of raw material stock purchases required. The aim of this prediction is to achieve optimal efficiency in inventory management, thereby avoiding excess or shortage of stock that could affect operational costs and sales opportunities [26].

III. FRAMEWORK

In this famework, the author will undertake several stages to design a model for predicting raw material stocks using Sugeno fuzzy logic. These stages are crucial to ensure the smooth progress and accuracy of the research.

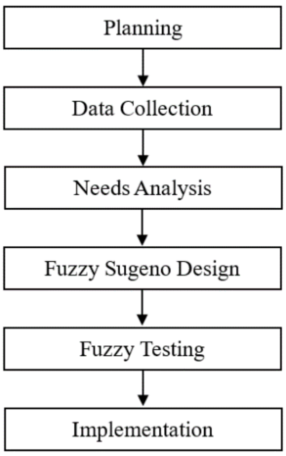

Figure 1. Research Framework

IV. METHODOLOGY

Planning

Planning is necessary to design the stages that will be completed in a research study. To arrange the steps that will be followed in the research process, planning is an essential phase. Researchers may make sure the study is carried out methodically, successfully, and economically by using this planning. The phrasing of the problem, the variables, and the suitable measurements are determined by researchers. It should be possible to determine addiction levels with the intended results with careful planning.

Data Collection

The data obtained in this study is time series data, which consists of a series of data collected and recorded at regular intervals . The data was sourced from a production house vendor in Medan

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and includes initial stock, production, incoming goods, and final stock. This data spans from April 2023 to May 2024 and is presented in Table 2.

Needs Analysis

In this study, identifying input and output variables is part of the needs analysis. The input variables consist of initial stock, production, and incoming goods, all of which contribute to the amount of goods available at the beginning and during a certain period. The output variable is the final stock, which indicates the amount of goods available after considering all other variables.

Fuzzy Sugeno Design

This design includes identifying relevant variables, formulating fuzzy rules based on domain knowledge, and setting up fuzzy sets for input and output variables. This design process will form the basis of the raw material stock prediction model. In this research series, fuzzy logic will be implemented through three steps: Fuzzification, Inference, and Defuzzification.

1) Fuzzification

This is the first step in a fuzzy logic system where crisp (precise) input values are converted into fuzzy values. It involves mapping input values to the appropriate fuzzy sets using membership functions. This step allows the system to handle uncertain or imprecise data.

2) Inference

The inference engine is the heart of the system, which evaluates fuzzy rules based on the fuzzy values of the input variables. Different methods can be used, such as the Mamdani or Sugeno methods. The inference engine combines the fuzzy rules and produces a fuzzy output value. Here is an example of a zero-order Sugeno Fuzzy inference rule:

$$\text{IF } (\text{x1 is A1})\ and\ (x2\ is\ A2)\ and\ (x3\ is\ A3),\ THEN\ z = k \quad (1)$$

A1 is the first fuzzy set as the antecedent, and k is the constant as the output. In this study, there are 27 possible combinations to form different fuzzy rules. Table 4 below provides a detailed breakdown of the fuzzy rules.

3) Deffuzification

This is the final step where the fuzzy output set from the inference process is converted back into a crisp output value. This involves using a defuzzification method, such as the centroid method, to obtain a single precise output from the fuzzy set. This step provides a tangible result from the fuzzy logic system that can be used for decision-making or control purposes.

$$WA = \frac{a_1 z_1 + a_2 z_2 + a_3 z_3 + \cdots + a_n z_n}{a_1 + a_2 + a_3 + \cdots + a_n} \quad (2)$$

WA is the weighted average value, αn is the degree of membership of the nth rule, and zn is the nth output value (constant) index.

Fuzzy Testing

The Mean Absolute Percentage Error (MAPE) can be used in fuzzy system testing to assess how accurate the predictions made by the fuzzy model are [27]. The average absolute percentage error between the predicted and actual values is determined using the MAPE method [28]. In order to conduct this test, the actual observed data is compared with the forecast results of the fuzzy system.

$$MAPE = \frac{\sum Xi - Fi}{n} \times 100\ \% \quad (3)$$

Where Xi represents the actual value, Fi represents the fuzzy calculation result, and n is the number of data points. MAPE provides a measure of how accurate the model is in making predictions, with a lower MAPE value indicating better model performance.

Table 1. MAPE Accuracy Level

MAPE Value	Accuracy
< 10%	Very High
10% - 20%	High
20% -50%	Moderate
>50%	Low

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Implementation

After the Sugeno fuzzy logic model was tested and proven effective in predicting pie crust raw material stock, this research model can be implemented. This model will serve as a tool for pie crust production vendors in Medan to manage their pie crust raw material inventory efficiently and economically. Implementing this model will bring practical benefits in enhancing efficiency in determining pie crust raw material stock. One tool that can be used to implement this model is MATLAB.

MATLAB, short for "MATrix LABoratory," is a programming environment and numerical computing platform that is highly popular in the fields of science, engineering, and industry. Developed by MathWorks, MATLAB offers a variety of features that support data analysis, visualization, modeling, and numerical computations with a user-friendly interface [29], [30]. One significant application of MATLAB is in the research of raw material stock prediction using fuzzy logic.

V. DISCUSSION AND RESULT

Data Collection

Table 2. Pie Crust Production Data April 2023 – May 2024

Months	Initial Stock	Production	Incoming Goods	Final Stock
April 2023	1000	300	310	1010
Mei 2023	1010	598	620	1032
Juni 2023	1032	799	920	1153
Juli 2023	1153	861	730	1022
Agustus 2023	1022	670	674	1026
September 2023	1026	1108	1140	1058
Oktober 2023	1058	1579	1535	1014
November 2023	1014	1090	1095	1019
Desember 2023	1019	659	730	1090
Januari 2024	1090	672	650	1068
Februari 2024	1068	1195	1145	1018
Maret 2024	1018	1200	1178	996
April 2024	996	1220	1250	1026
Mei 2024	1026	1100	1115	1041

Needs Analysis

1. Input Variable

There are 3 input variables: Initial Stock, Production, Incoming Goods. These input variables contain ranges of values that will be used to determine fuzzy sets.

Table 3. Input Variable

Function	Variable	Fuzzy Set	Universe of Discourse	Domain
Input	Initial Stock	Few	996-1153	[996 - 1075]
		Moderate		[996 - 1075 - 1153]
		Many		[1075 - 1153]
	Production	Few	300-1579	[300 - 940]
		Moderate		[300 - 940 - 1579]
		Many		[940 - 1579]
	Incoming Goods	Few	310-1535	[310 - 923]
		Moderate		[310 - 923 - 1535]
		Many		[923 - 1535]

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2. Output Variable

Based on the data obtained, the output variable in this study is “Final Stock”. This output variable has 3 fuzzy sets: "few," "moderate," and "many." Table 3 shows the domain of the Final Stock variable.

Table 4. Output Variable

Fuction	Variable	Fuzzy Set	Domain
Output	Final Stock	Few	[996]
		Moderate	[1075]
		Many	[1153]

Fuzzy Sugeno Design

1. Initial Stock Variable

Based on pie crust production data obtained from a pie production house vendor in Medan for the period from April 2023 to May 2024, it is known that the minimum initial stock amount is 996 packages and the maximum reaches 1153 packages, with an average initial stock of 1038. The universe of discourse for the initial stock variable covers the range from 996 to 1153 packages.

$$\mu Few[x_1] = \begin{cases} 1 & ; x \leq 996 \\ \frac{1075 - x}{1075 - 996} & ; 996 \leq x \leq 1075 \\ 0 & ; x \geq 1075 \end{cases} \quad (4)$$

$$\mu Moderate[x_1] = \begin{cases} 0 & ; \quad x \leq 996 \; or \; x \geq 1153 \\ \frac{x - 996}{1075 - 996} & ; \quad 996 \leq x \leq 1075 \\ \frac{1153 - x}{1153 - 1075} & ; \quad 1075 \leq x \leq 1153 \end{cases} \quad (5)$$

$$\mu Many[x_1] = \begin{cases} 0 & ; x \leq 1075 \\ \frac{x - 1075}{1153 - 1075} & ; 1075 \leq x \leq 1153 \\ 1 & ; x \geq 1153 \end{cases} \quad (6)$$

Membership functions are used to transform crisp data into fuzzy set data. In this prediction, a triangular membership function is used. This function acts as a curve that maps input data points into membership values, which range from 0 to 1. For the variable "Initial Stock", a triangular membership function can be created based on the domain obtained from the table 2.

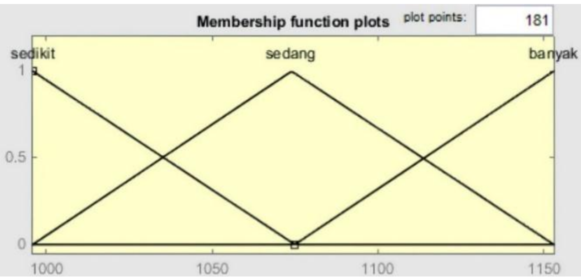

Figure 2. Membership Function for the Initial Stock Variable.

This curve shows how the initial stock values are categorized into three fuzzy sets: Low, Medium, and High. Each membership function curve represents the rising and falling representation of the initial stock values, which are evenly distributed across the universal range from 0 to 1153.

2. Production Variable

Based on pie crust production data obtained from a pie production house vendor in Medan for the period from April 2023 to May 2024, it is known that the minimum production amount is 300 packages and the maximum reaches 1579 packages, with an average initial stock of 932.214286 packages. The universe of discourse for the initial stock variable covers the range from 0 to 1579 packages.

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$$\mu Few[x_2] = \begin{cases} 1 & ;\ x \le 300 \\ \frac{940 - x}{940 - 300} & ;\ 300 \le x \le 940 \\ 0 & ;\ x \ge 940 \end{cases} \quad (7)$$

$$\mu Moderate[x_2] = \begin{cases} 0 & ;\ x \le 300\ or\ x \ge 1579 \\ \frac{x - 300}{940 - 300} & ;\ 300 \le x \le 940 \\ \frac{1579 - x}{1579 - 940} & ;\ 940 \le x \le 1579 \end{cases} \quad (8)$$

$$\mu Many[x_2] = \begin{cases} 0 & ;\ x \le 940 \\ \frac{x - 940}{1579 - 940} & ;\ 940 \le x \le 1579 \\ 1 & ;\ x \ge 1579 \end{cases} \quad (9)$$

Membership functions are used to transform crisp data into fuzzy set data. In this prediction, a triangular membership function is used. This function acts as a curve that maps input data points into membership values, which range from 0 to 1. For the variable "Production", a triangular membership function can be created based on the domain obtained from the table 2.

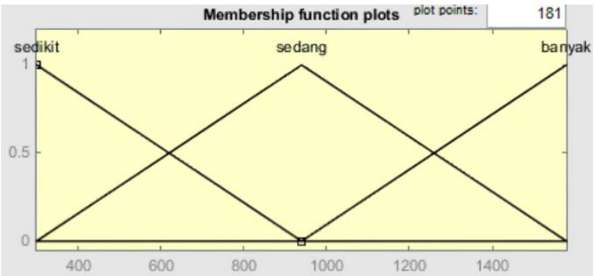

Figure 3. Membership Function for the production

This curve shows how the initial stock values are categorized into three fuzzy sets: Low, Medium, and High. Each membership function curve represents the rising and falling representation of the production values, which are evenly distributed across the universal range from 0 to 1579.

3. Incoming Goods Variable

Based on pie crust production data obtained from a pie production house vendor in Medan for the period from April 2023 to May 2024, it is known that the minimum incoming goods amount is 310 packages and the maximum reaches 1535 packages, with an average initial stock of 935.1428571 packages. The universe of discourse for the initial stock variable covers the range from 0 to 1535 packages.

$$\mu Few[x_3] = \begin{cases} 1 & ;\ x \le 310 \\ \frac{923 - x}{923 - 310} & ;\ 310 \le x \le 923 \\ 0 & ;\ x \ge 923 \end{cases} \quad (10)$$

$$\mu Moderate[x_3] = \begin{cases} 0 & ;\ x \le 310\ or\ x \ge 1535 \\ \frac{x - 310}{923 - 310} & ;\ 310 \le x \le 923 \\ \frac{1535 - x}{1535 - 923} & ;\ 923 \le x \le 1535 \end{cases} \quad (11)$$

$$\mu Many[x_3] = \begin{cases} 0 & ;\ x \le 923 \\ \frac{x - 923}{1535 - 923} & ;\ 923 \le x \le 1535 \\ 1 & ;\ x \ge 1535 \end{cases} \quad (12)$$

Membership functions are used to transform crisp data into fuzzy set data. In this prediction, a triangular membership function is used. This function acts as a curve that maps input data points into membership values, which range from 0 to 1. For the variable "Incoming Goods", a triangular membership function can be created based on the domain obtained from Table 2.

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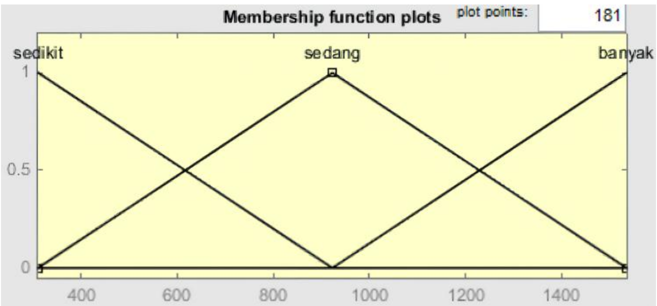

Figure 4. Membership Function for the incoming goods

This curve shows how the initial stock values are categorized into three fuzzy sets: Low, Medium, and High. Each membership function curve represents the rising and falling representation of the production values, which are evenly distributed across the universal range from 0 to 1535.

4. Rules

Based on the Determination of Fuzzy Sugeno Rules in predicting pie crust raw materials using fuzzy logic to handle uncertainties in production. Fuzzy logic enables decision-making based on if-then rules that reflect the relationships between input variables such as Initial Stock, Production, Incoming Goods, and the output variable, namely final stock. Each rule has a membership function and an implication function to map the input to the output. There are 27 possibilities to form different fuzzy rules.

Table 5. Fuzzy Rules

No	*Input*			*Output*
	Initial Stock (x1)	Incoming Goods (x2)	Production (x3)	Final Stock
1	Few	Few	Few	Few
2	Few	Few	Moderate	Moderate
3	Few	Few	Many	Many
4	Few	Moderate	Few	Few
5	Few	Moderate	Moderate	Few
6	Few	Moderate	Many	Moderate
7	Few	Many	Few	Few
8	Few	Many	Moderate	Few
9	Few	Many	Many	Moderate
10	Moderate	Few	Few	Moderate
11	Moderate	Few	Moderate	Moderate
12	Moderate	Few	Many	Many
13	Moderate	Moderate	Few	Few
14	Moderate	Moderate	Moderate	Moderate
15	Moderate	Moderate	Many	Many
16	Moderate	Many	Few	Few
17	Moderate	Many	Moderate	Moderate
18	Moderate	Many	Many	Many
19	Many	Few	Few	Moderate
20	Many	Few	Moderate	Moderate
21	Many	Few	Many	Many
22	Many	Moderate	Few	Moderate
23	Many	Moderate	Moderate	Moderate
24	Many	Moderate	Many	Many
25	Many	Many	Few	Few
26	Many	Many	Moderate	Many
27	Many	Many	Many	Many

5. Data Representation

In this chapter, the researcher will proceed to explain the calculations of the Sugeno fuzzy logic for one particular month, namely October, with the aim of understanding how this method can be applied in relevant data analysis.

Table 6. Data Representation For The Month Of October

Month	Initial Stock	Produksi	Barang Masuk	Stok Akhir

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	(Packages)	(Packages)	(Packages)	(Packages)
October 2023	1058	1579	1535	1014

a. Initial Stock (X1 = 1058)

Membership fiction used:

$$\mu Few[x_1] = \begin{cases} 1 & ; x \leq 996 \\ \frac{1075 - x}{1075 - 996} & ; 996 \leq x \leq 1075, \\ 0 & ; x \geq 1075 \end{cases} \qquad \mu Moderate[x_1] = \begin{cases} 0 & ; x \leq 996 \ or\ x \geq 1153 \\ \frac{x - 996}{1075 - 996} & ; 996 \leq x \leq 1075 \\ \frac{1153 - x}{1153 - 1075} & ; 1075 \leq x \leq 1153 \end{cases}$$

What is the value of μ when the Initial Stock is 1058 packages?

Thus:

$$\mu Few[1058] = \frac{1075 - 1058}{1075 - 996} = 0{,}215189873, \qquad \mu Moderate[1058] = \frac{1058 - 996}{1075 - 996} = 0{,}784810127$$

b. Production (X2 = 1579)

Membership function used:

$$\mu Moderate[x_2] = \begin{cases} 0 & ; x \leq 300 \ or\ x \geq 1579 \\ \frac{x - 300}{940 - 300} & ; 300 \leq x \leq 940 \\ \frac{1579 - x}{1579 - 940} & ; 940 \leq x \leq 1579 \end{cases} \qquad \mu Many[x_2] = \begin{cases} 0 & ; x \leq 940 \\ \frac{x - 940}{1579 - 940} & ; 940 \leq x \leq 1579 \\ 1 & ; x \geq 1579 \end{cases}$$

What is the value of μ when the production is 1579 packages?

Thus:

$\mu Moderate[1579] = 0$, $\mu Many[1579] = 1$

c. Incoming Goods (X3 = 1535)

Membership function used:

$$\mu Moderate[x_3] = \begin{cases} 0 & ; x \leq 310 \ or\ x \geq 1535 \\ \frac{x - 310}{923 - 310} & ; 310 \leq x \leq 923 \\ \frac{1535 - x}{1535 - 923} & ; 923 \leq x \leq 1535 \end{cases} \qquad \mu Many[x_3] = \begin{cases} 0 & ; x \leq 923 \\ \frac{x - 923}{1535 - 923} & ; 923 \leq x \leq 1535 \\ 1 & ; x \geq 1535 \end{cases}$$

What is the value of μ when the incoming goods is 1535 packages?

Thus:

$\mu Moderate[1535] = 0$, $\mu Many[1535] = 1$

Based on the calculations in the fuzzification process, the values obtained are:

- Initial Stock (X_1 = 1058) : μFew = 0,215189873 dan μModerate = 0,784810127
- Productoin (X_2 = 1579) : μModerate = 0 dan μMany = 1
- Incoming goods (X_3 = 1535) : μModerate = 0 dan μMany = 1

Thus, out of 27 fuzzy rules, 8 rules are satisfied.

Table 7. Rules for the month of October

Rules	**Initial Stock (x1)**	**Incoming Goods (x2)**	**Production (x3)**	**Final Stock**
5	Few	Moderate	Moderate	Few
6	Few	Moderate	Many	Moderate
8	Few	Many	Moderate	Few
9	Few	Many	Many	Moderate
14	Moderate	Moderate	Moderate	Moderate
15	Moderate	Moderate	Many	Many
17	Moderate	Many	Moderate	Moderate
18	Moderate	Many	Many	Many

To determine the α-predicate value, linguistic variables are combined using the AND operator. Next, the MIN (smallest) value is taken from each rule resulting from the fuzzification process.

$$\alpha - [Rules\ 5] = \min(\mu Few[1058], \mu Moderate[1579], \mu Moderate[1535]) = \min\ (0{,}215189873\ ;\ 0\ ; 0) = 0$$

$$\alpha - [Rules\ 6] = \min(\mu Few[1058], \mu Moderate[1579], \mu Many[1535]) = \min\ (0{,}215189873\ ;\ 0\ ; 1) = 0$$

$\alpha - [Rules\ 8] = \min(\mu Few[1058], \mu Many[1579], \mu Moderate[1535]) = \min\ (0{,}215189873\ ; 1\ ; 0) = 0$

$\alpha - [Rules\ 9] = \min(\mu Few[1058], \mu Many[1579], \mu Many[1535]) = \min\ (0{,}215189873\ ; 1\ ; 1) = 0{,}215189873$

$\alpha - [Rules\ 14] = \min(\mu Moderate[1058], \mu Moderate[1579], \mu Moderate[1535]) = \min(0{,}784810127\ ;\ 0\ ; 0) = 0$

$\alpha - [Rules\ 15] = \min(\mu Moderate[1058], \mu Moderate[1579], \mu Many[1535]) = \min\ (0{,}784810127\ ;\ 0\ ; 1) = 0$

$\alpha - [Rules\ 17] = \min(\mu Moderate[1058], \mu Many[1579], \mu Moderate[1535]) = \min\ (0{,}784810127\ ; 1\ ; 0) = 0$

$\alpha - [Rules\ 18] = \min(\mu Moderate[1058], \mu Many[1579], \mu Many[1535]) = \min\ (0{,}784810127\ ; 1\ ; 1) = 0{,}784810127$

The predicates used are those that are not equal to 0. Thus, there are 2 predicates, rules 9 and 18. The predicate table is as follows:

Table 8. Alpha Predicates for the Month of October

Rules	alpha predikat	zn
9	0,215189873	1075
18	0,784810127	1153

After determining the alpha-predicate values and their corresponding zn values, the Weight Average (WA) formula will be used to calculate the result:

$$WA = \frac{0{,}215189873(1075)+0{,}790027701\ (1153)}{0{,}215189873+0{,}790027701} = \frac{1136{,}2152}{1} = 1136{,}2152 \text{ Packages}$$

6. The Calculation Results

After obtaining the results from the manual calculation, the same calculation method was applied for the next month to obtain the raw material stock for pie crust over 14 months, presented as follows in the table 8:

Table 9. The Calculation Result

Month	Initial Stok	Production	Incoming Goods	Initial Stock (*Actual*)	Final Stock (*Fuzzy* Sugeno)
Apr-23	1000	300	310	1010	1000
May-23	1010	598	620	1032	1020
Jun-23	1032	799	920	1153	1040
Jul-23	1153	861	730	1022	1080
Aug-23	1022	670	674	1026	1030
Sep-23	1026	1108	1140	1058	1050
Oct-23	1058	1579	1535	1014	1140
Nov-23	1014	1090	1095	1019	1040
Dec-23	1019	659	730	1090	1030
Jan-24	1090	672	650	1068	1060
Feb-24	1068	1195	1145	1018	1100
Mar-24	1018	1200	1178	996	1050
Apr-24	996	1220	1250	1026	1040
May-24	1026	1100	1115	1041	1050

Fuzzy Testing (Calculation Of MAPE)

Based on the calculation results presented in Table 8, MAPE values were computed using Formula 12 to evaluate the accuracy of the Sugeno fuzzy logic model in predicting pie crust raw material stock. This involved comparing the actual final stock variable (Actual Data) with the final stock variable (Fuzzy Sugeno). The following is the MAPE calculation results presented in Table 9.

Table 10. The Calculating of MAPE

Month	Actual (Xi)	Fuzzy Sugeno (Fi)	Xi-Fi	|Xi-Fi|	Xi-Fi/Xi
Apr-23	1010	1000	10	10	0,00990099
May-23	1032	1020	12	12	0,011627907
Jun-23	1153	1040	113	113	0,098005204

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Jul-23	1022	1080	-58	58	0,056751468
Aug-23	1026	1030	-4	4	0,003898635
Sep-23	1058	1050	8	8	0,007561437
Oct-23	1014	1140	-126	126	0,124260355
Nov-23	1019	1040	-21	21	0,02060844
Dec-23	1090	1030	60	60	0,055045872
Jan-24	1068	1060	8	8	0,007490637
Feb-24	1018	1100	-82	82	0,080550098
Mar-24	996	1050	-54	54	0,054216867
Apr-24	1026	1040	-14	14	0,013645224
May-24	1041	1050	-9	9	0,008645533
				Total :	0,552208667

$$MAPE = \frac{0,552208667}{14} \times 100\ \% = 0,039443 \times 100\ \% = 3,944\ \%$$

Based on the results obtained, the MAPE value obtained is 3.94%, with an accuracy of 96.06%, categorizing it as "Very High" according to Table 4.

Implementation

To implement this model, MATLAB was used as the programming platform. Using MATLAB, this research can effectively test and validate the Sugeno fuzzy model, as well as perform sensitivity analysis to understand the impact of each input variable on the prediction results.

This research shows that the Sugeno fuzzy logic method can predict the final stock with a higher level of accuracy compared to conventional methods. These results confirm the superiority of the Sugeno fuzzy method in providing more accurate and reliable predictions, which is crucial for better decision-making in the pie crust sales business.

This research has limitations as it only uses data from a single vendor over a specific period, so the results may not reflect broader variations in different contexts. In this study, only a few variables were considered: initial stock, production, goods received, and final stock.

VI. CONCLUSION

After conducting the implementation in this research, the author concludes several points from the obtained results. This study demonstrates that the Sugeno fuzzy logic method can provide more accurate final stock predictions compared to conventional methods.

From the average percentage error testing conducted, a result of 3.944% was obtained with an accuracy rate of 96.06%, indicating a high level of accuracy. This shows the effectiveness of the method used in handling data variability and uncertainty, and gives confidence that this model can be relied upon for practical applications in stock management, especially in the pie crust sales business.

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