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Implementation of Fuzzy Logic in Determining the Acceptance Status of Fresh Milk Based on pH and Density

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Abstract

Fuzzy logic, known as fuzzy set theory, has become widely used to deal with uncertainty in research data processing. Fuzzy logic methods are known for their ease of implementation in machine language environments and their effectiveness in combining machine language representations with human language with an emphasis on meaning or importance. Fuzzy logic maps input space to output space, and this concept is closely related to dealing with uncertainty in data. In applying fuzzy logic in this study, the variables pH and density of milk are considered inputs whose value ranges are divided into low, medium, and high categories. The result of the fuzzy system is the acceptability state of fresh milk. By applying this method using MATLAB software, the simulation results show that at a milk pH of 6.2 and a specific gravity of 1.0320, the acceptability state of fresh milk is 30. After the defuzzification process and manual calculation, the final result is 29.30~30. From these results, fuzzy logic provides high accuracy to support progressive decision-making. This allows the system to consider the complexity of milk quality criteria that cannot always be measured in a binary way (e.g., good or bad), resulting in more precise and accurate decisions.

Keywords: Acceptance Status, Density, Fuzzy Logic, Matlab, pH

INTRODUCTION

The use of technology today is increasingly widespread in various aspects and plays an important role in various work activities, where automation is one of the right things to implement. Artificial intelligence *(*AI) is defined as the intelligence possessed by an artificial entity. Fuzzy logic is a fuzzy or partial truth, with a basic logic that states between yes or no (Setia & Ramadhan, 2019). The Fuzzy Mamdani method has been widely applied in various fields, such as intelligent control systems, decision-making, and modeling systems with uncertainty. Its main advantage lies in its ability to handle problems that cannot be explained by traditional logic, which is only binary (Narulita & Ahmad, 2024).

Using a computerized system can be faster, more precise and accurate, and provide alternative solutions in dealing with problems and preventing losses due to product damage which can have a domino effect on product users and companies. One of the advances in computerization is the *Implementation of Fuzzy Logic in Determining the Acceptance Status of Fresh Milk Based on pH and Density*. This system's progress is to determine the level of acceptance based on the pH and density of milk, as well as support in assessing the quality of dairy products, whether the product is suitable for consumption or circulation, and accelerate handling when there is a failure or discrepancy in product quality (Sumiati & Hadyanto, 2017).

Dairy products have a high nutritional content but are susceptible to spoilage. Its nutrients include fat, carbohydrates, potassium, protein, and vitamins (Nisa, Abdy, & Zaki, 2020). The level of knowledge regarding the processing of dairy products needs to be optimized for quality and durability to avoid the occurrence of raw material mismatches that cause failure in the production process. Milk quality assessment can be determined based on pH and milk density. Therefore, to overcome the failure in the production process caused by the quality of milk that does not follow predetermined standards, fuzzy logic control can be implemented to determine the level of acceptance based on the pH and density of milk according to standard standards. Fuzzy logic can be used to translate a quantity, which is then expressed using language (linguistics) (Septiani & Djatna, 2015). This makes it easier for researchers to make decisions regarding the acceptance of fresh milk.

The purpose of writing the journal *Implementation of Fuzzy Logic in Determining the Acceptance Status of Fresh Milk Based on pH and Density* is to apply fuzzy logic to increase accuracy and avoid failures in the production and distribution process using the parameters of milk pH and density.

METHODS

Fuzzy Inference System (FIS) is a calculation framework process based on the concept of fuzzy set theory that can be used in making data decisions. The ability to link the input space appropriately to the output is a feature possessed by fuzzy logic (Pardede, 2020; Wicaksana, Hastono, & Solikhah, 2024). In developing human knowledge, a qualitative model approach can be used to estimate capabilities without using precise quantitative calculations. Fuzzy inference systems can use fuzzy logic for the process of formulating mappings from given inputs to outputs to assist in making decisions. Basically, inference is the process of combining several rules based on the available data, and a fuzzy relation will be connected to each rule in the fuzzy knowledge base (Anggun, Marisa, & Dharma, 2016). This includes membership function parameters, logical operations, and rules (Ciptaningrum et al., 2022). In this case, the type of fuzzy method used is the Mamdani fuzzy method, often also called the Max-Min method. The method introduced by Ebrahim Mamdani in 1975 is the most commonly used because it was first developed and successfully applied to the design of control systems using fuzzy set theory (Ikhwan, Badri, Andriani, & Saragih, 2019).

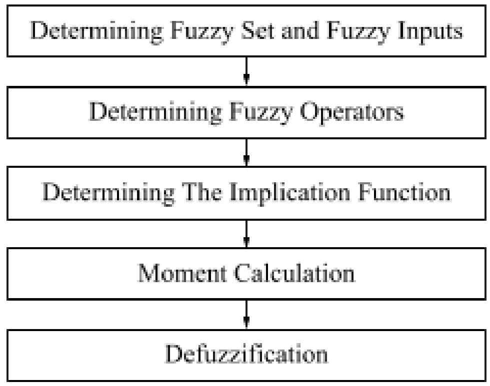

Figure 1. Flowchart of the Stages of Using the Fuzzy Inference System (FIS) Application

Literature Study

The references used are based on literature studies from scientific journals and previous research that can be used as supporting references related to and relevant to the research being conducted. This stage is used to understand all the methods that will be used and to provide an overview during the work.

Membership Functions

A membership function is a curve that states the mapping of input data points entered into its membership value (membership degree), with an interval ranging from 0 to 1. There are two types of membership functions: triangular and trapezoidal.

Triangular and Trapezoidal Membership Function

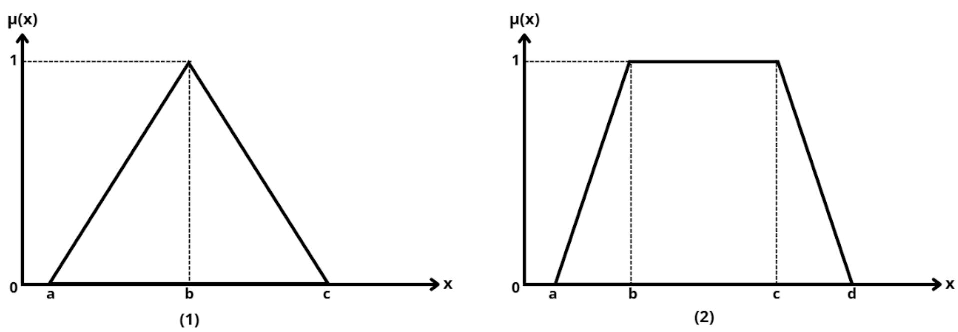

Figure 2. (1) Triangular Membership Function and (2) Trapezoidal Membership Function

Triangular membership function is a triangular curve-shaped membership graph that combines two linear lines with a membership function of 3 (three) key parameters: minimum, maximum, and peak (Sofia & Juhari, 2021). According to (Siskandar et al., 2023), the triangular membership set graph is used to determine variables that have membership to the distance from the peak value. The closer the input value is to the peak value, the higher the membership. The membership set for the Triangular Membership Function graph μF (a, b, c). This graph can be used if the data variable is evenly distributed around the center value. *A trapezoidal membership function* is a trapezoidal curve-shaped membership graph with more than one degree of the highest membership value. The membership set in the trapezoidal membership function graph is μF (a, b, c, d). This graph can be used when the variable has a clear and well-defined range of values (Siskandar et al., 2023).

RESULTS AND DISCUSSION

The quality assessment of fresh milk is determined by the acceptance status based on pH and density. Generally, two decisions can determine the acceptance decision: acceptance and rejection. Accepted milk generally meets the acceptance decision based on organoleptic parameters. The organoleptic assessment determines whether the milk to be consumed or processed is suitable for consumption and fresh. The evaluation is based on several indicators such as color, taste, texture and aroma of the milk, which are closely related to quality. However, milk that does not meet the organoleptic standards set by the company is usually returned to the supplier or stopped at the next processing stage. In this case, quality assessment becomes critical to pay attention to, because decisions in the selection of raw materials will greatly affect the quality of the final product produced, quality control can also affect the increase in milk prices and ensure that the milk avoids damage and deviations from the standards set by the company (T. Wicaksana & Sunaryanto, 2021).

Cow's milk tends to be more perishable and contaminated than other animal products. There are several variables measured to be able to determine acceptance factors other than organoleptic, such as pH, antibiotic test, density, alcohol test to determine the protein content in milk, composition test to determine the content in milk, adulteration test to test the presence or absence of foreign objects contained in milk, and MBRT which is used to test the bacterial content in milk. The parameter variables are interconnected and bound to one another, evidenced by the fact that if there is a deviant aroma or bluish-white milk color, the milk quality decreases, and these changes also affect the pH and other parameters. The relationship needs to be proven by analysis and acceptance calculation (K. Hidayat & Anggraeni, 2023).

Analysis and calculation of fresh milk acceptance can be done using Fuzzy logic. Fuzzy logic, commonly known as fuzzy set theory, is widely used to overcome the uncertainty contained in research data (Safitri & Abadi, 2015). The use of fuzzy logic methods is easy and efficient to implement into machine language. Fuzzy logic is used as a research area that can bridge machine language with human language by emphasizing meaning or significance (Wartono, Effendi, & Rivalni, 2019). A Fuzzy Inference System (FIS) is able to map an input space into an output space. Fuzzy logic also has a relationship with uncertainty.

In using the Fuzzy Inference System (FIS) application, there are 5 stages that need to be done, namely 1) Determining Fuzzy sets and Fuzzy inputs, 2) Determining Fuzzy operators, 3) Determining the implication function, 4) Moment calculation, and 5) Defuzzification. The parameters needed to assess the quality of fresh milk are pH and milk density. Data related to pH and milk density are collected to become input variables in implementing Fuzzy logic. Fuzzy set formation consists of 2 variables, namely pH and density. Determination of the level of importance of variables is based on the company's goal to produce quality products that can meet consumer demand. Fresh milk acceptance is used as an output variable with a predetermined range.

Step 1: Determining Fuzzy Sets and Fuzzy Inputs

The input variables of pH and density assessment of fresh milk are divided into 3 fuzzy sets, namely low, medium, and high. Meanwhile, the output variable of fresh milk acceptance is divided into 3 fuzzy sets, namely rejected, withheld and accepted. Determination of the value range on both input parameters is carried out based on the quality requirements of fresh milk according to SNI 3141.1: 2011.

Table 1. Interview Data

Variable	Fuzzy Parameter	Range	Domain				Membership Function
			a	b	c	d	
pH	Low	6,0 - 6,4	6,0	6,2	6,4	-	Triangular
	Medium	6,3 - 6,6	6,3	6,4	6,5	6,6	Trapezoidal
	High	6,5 - 6,8	6,5	6,6	6,7	6,8	Trapezoidal
Density	Low	1,0000-1,0300	1,0000	1,0100	1,0200	1,0300	Trapezoidal
	Medium	1,0200-1,0400	1,0200	1,0300	1,0400	-	Triangular
	High	1,0300-1,0500	1,0300	1,0400	1,0500	-	Triangular
Acceptance Status	Rejected	10-50	10	30	50	-	Triangular
	Detained	40-60	40	50	60	-	Triangular
	Accepted	50-100	50	70	80	100	Trapezoidal

In this research, the case study used refers to the criteria of low pH with a value of **(6.2)** and high density with a value of **(1.0320)** so that the acceptance status of fresh milk will be produced as the output. The next step is to complete the case study using the Fuzzy Inference System (FIS) stages as follows:

Determine Input and Output Variables

At this stage there are input and output variables obtained from the results of the literature study. The input variables consist of pH and milk density with low, medium, and high fuzzy parameters while the output variables consist of acceptance. The range obtained is based on the Indonesian National Standard (SNI) which is attached in the table. 1. Interview Data.

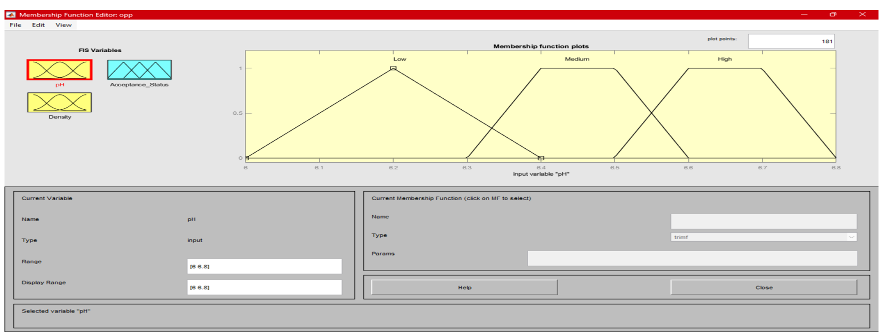

Figure 3. Milk pH input

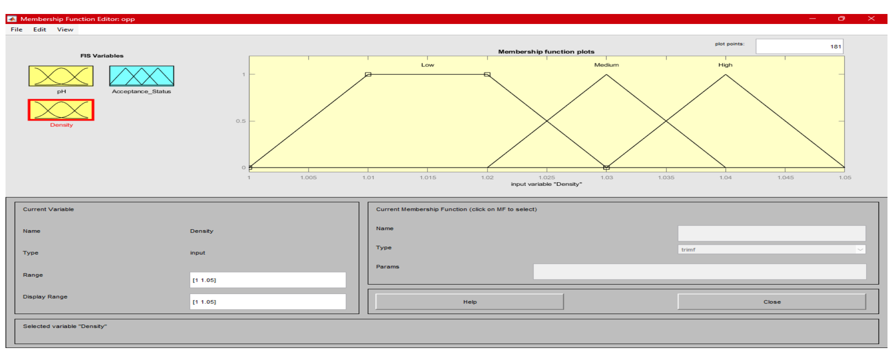

Figure 4. Density input

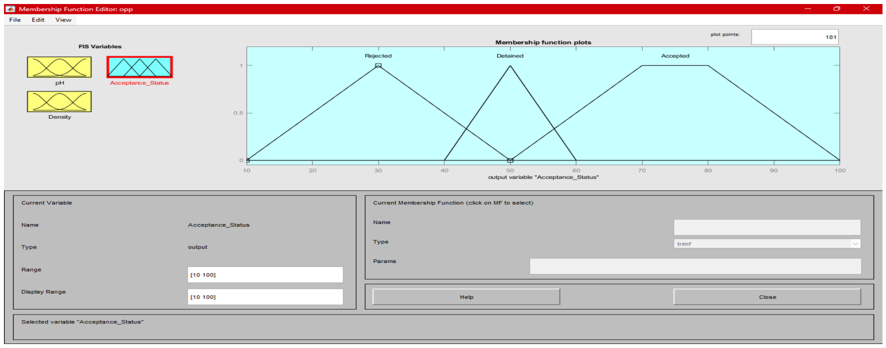

Figure 5. Accepted Output

Building Fuzzy Membership Sets

Based on the input and output variables above, the next step is to determine the membership set of acidity (pH) and density. The two membership sets are then used to determine the membership levels of the inputs and outputs obtained from the previous data.

pH Input Membership Set

The membership function for the input variable pH is divided into three fuzzy sets, namely "Low" with a center value of 6.2, "Medium" with center values of 6.4 and 6.5, and "High" with center values of 6.6 and 6.7.

$$\mu Low = \begin{cases} x < 6.0 & 0 \\ 6.0 \le x < 6.2 & \dfrac{x-a}{b-a} \\ x = 6.2 & 1 \\ 6.2 < x \le 6.4 & \dfrac{c-x}{c-b} \\ x > 6.4 & 0 \end{cases}$$

In the "Low" parameter, formulas that produce a value of 0 can be ignored so that there are three parts that can be used as formulas, where the first formula is the left side formula (6.0 x < 6.2), the second formula is the peak point (x = 6.2) and the third is the right-side formula (6.2 < x6.4).

$$\mu Medium = \begin{cases} x < 6.3 & 0 \\ 6.3 \le x < 6.4 & \dfrac{x-a}{b-a} \\ 6.4 = x = 6.5 & 1 \\ 6.5 < x \le 6.6 & \dfrac{d-x}{d-c} \\ x > 6.6 & 0 \end{cases}$$

In the "Medium" parameter, formulas that produce a value of 0 can be ignored so that there are three parts that can be used as formulas where the first formula is the left side formula (6.3 x < 6.4), the second formula is the peak point (6.4 = x = 6.5), and the third is the right-side formula (6.5 < x 6.6).

$$\mu High = \begin{cases} x < 6.5 & 0 \\ 6.5 \le x < 6.6 & \dfrac{x-a}{b-a} \\ 6.6 = x = 6.7 & 1 \\ 6.7 < x \le 6.8 & \dfrac{d-x}{d-c} \\ x > 6.8 & 0 \end{cases}$$

In the "High" parameter, formulas that produce a value of 0 can be ignored so that there are three parts that can be used as formulas where the first formula is the left side formula (6.5 x < 6.6), the second formula is the peak point (6.6 = x = 6.7), and the third is the right-side formula (6.7 < x 6.8).

Density Input Membership Set

The membership function for the input variable Density is divided into three fuzzy sets, namely "Low" with a center value of 1.0100 and 1.0200, "Medium" with a center value of 1.0300, and "High" with a center value of 1.0400.

$$\mu Low = \begin{cases} x < 1.0000 & 0 \\ 1.0000 \leq x < 1.0100 & \dfrac{x-a}{b-a} \\ 1.0100 = x = 1.0200 & 1 \\ 1.0200 < x \leq 1.0300 & \dfrac{d-x}{d-c} \\ x > 1.0300 & 0 \end{cases}$$

In the "Low" parameter, formulas that produce a value of 0 can be ignored so that there are three parts that can be used as formulas where the first formula is the left side formula (1.0000 x < 1.0100), the second formula is the peak point (1.0100 = x = 1.0200), and the third is the right-side formula (1.0200 < x 1.0300).

$$\mu Medium = \begin{cases} x < 1.0200 & 0 \\ 1.0200 \leq x < 1.0300 & \dfrac{x-a}{b-a} \\ x = 1.0300 & 1 \\ 1.0300 < x \leq 1.0400 & \dfrac{c-x}{c-b} \\ x > 1.0400 & 0 \end{cases}$$

In the "Medium" parameter, formulas that produce a value of 0 can be ignored so that there are three parts that can be used as formulas where the first formula is the left side formula (1.0200 x < 1.0300), the second formula is the peak point (x = 1.0300), and the third is the right-side formula (1.0300 < x 1.0400).

$$\mu High = \begin{cases} x < 1.0300 & 0 \\ 1.0300 \leq x < 1.0400 & \dfrac{x-a}{b-a} \\ x = 1.0400 & 1 \\ 1.0400 < x \leq 1.0500 & \dfrac{c-x}{c-b} \\ x > 1.0500 & 0 \end{cases}$$

In the "High" parameter, formulas that produce a value of 0 can be ignored so that there are three parts that can be used as formulas where the first formula is the left side formula (1.0300 x < 1.0400), the second formula is the peak point (x = 1.0400), and the third is the right-side formula (1.0400 < x 1.0500).

Acceptance Output Membership Set

The membership function for the input variable Acceptance is divided into three fuzzy sets, namely "Rejected" with a center value of 30, "Detained" with a center value of 50, and "Accepted" with center values of 70 and 80.

$$\mu Rejected = \begin{cases} x < 10 & 0 \\ 10 \leq x < 30 & \dfrac{x-a}{b-a} \\ x = 30 & 1 \\ 30 < x \leq 50 & \dfrac{c-x}{c-b} \\ x > 50 & 0 \end{cases}$$

In the "Rejected" parameter, formulas that produce a value of 0 can be ignored so that there are three parts that can be used as formulas where the first formula is the left side formula (10 x < 30), the second formula is the top point (x = 30), and the third is the right-side formula (30 < x 50).

$$\mu Detained = \begin{cases} 0 & x < 40 \\ \dfrac{x-a}{b-a} & 40 \le x < 50 \\ 1 & x = 50 \\ \dfrac{c-x}{c-b} & 50 < x \le 60 \\ 0 & x > 60 \end{cases}$$

In the "Detained" parameter, formulas that produce a value of 0 can be ignored so that there are three parts that can be used as formulas where the first formula is the left side formula (40 x < 50), the second formula is the top point (x = 50), and the third is the right-side formula (50 < x 60).

$$\mu Accepted = \begin{cases} 0 & x < 50 \\ \dfrac{x-a}{b-a} & 50 \le x < 70 \\ 1 & 70 = x = 80 \\ \dfrac{d-x}{d-c} & 80 < x \le 100 \\ 0 & x > 100 \end{cases}$$

In the "Accepted" parameter, formulas that produce a value of 0 can be ignored so that there are three parts that can be used as formulas where the first formula is the left side formula (50 x < 70), the second formula is the top point (70 = x = 80), and the third is the right-side formula (80 < x 100).

Determining the Membership Degrees

After determining the membership set, focus on the case study above where the inputs are LOW pH with a value of 6.2 and HIGH Gravity Input with a value of 1.0320. Determine the degree of membership of each input variable using the formula above.

Input pH (Low: 6.2)

To calculate the input variable pH, we need to consider the value of x. In this case, the x value is 6.2 which belongs to the low parameter.

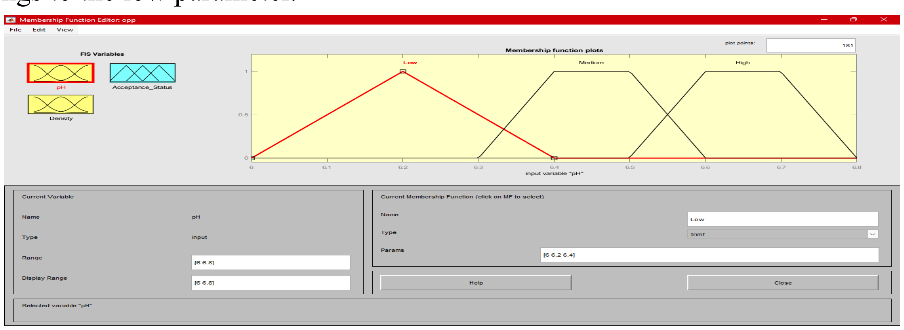

Figure 6. Input pH (6,2)

Since the x value belongs to the low parameter, the formula for the low parameter is used for the calculation. If a straight line is drawn upwards from figure 6.2, it will be found that the line hits the cusp of the low parameter.

$$\mu Low = \begin{cases} 0 & x < 6.0 \\ \dfrac{x-a}{b-a} & 6.0 \le x < 6.2 \\ 1 & x = 6.2 \\ \dfrac{c-x}{c-b} & 6.2 < x \le 6.4 \\ 0 & x > 6.4 \end{cases}$$

Referring to the formula above, if x = 6.2, it is found that the degree of membership for the pH variable is 1.

Density Input (High: 1.0320)

Just like the previous calculation, to calculate the density input variable, it is necessary to focus on the x value. In this case, the x value is 1.0320 which falls under the high parameter.

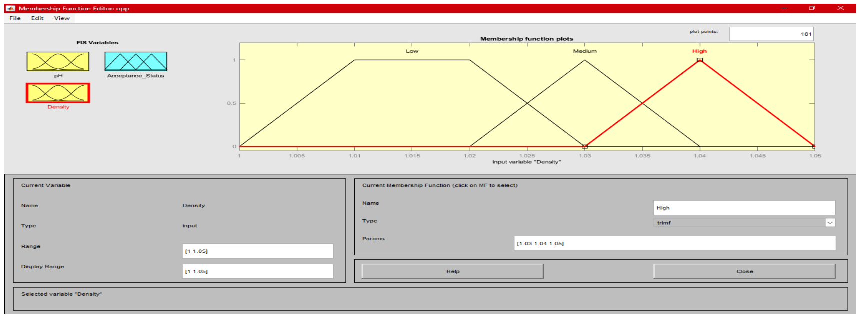

Figure 7. Input density (1,0320)

Since the value of x is included in the height parameter, we use the formula for the height parameter. If a straight line is drawn upwards from 1.0320, it will be found that the line touches the left side.

$$\mu High = \begin{cases} x < 1.0300 & 0 \\ 1.0300 \leq x < 1.0400 & \frac{x-a}{b-a} \\ x = 1.0400 & 1 \\ 1.0400 < x \leq 1.0500 & \frac{c-x}{c-b} \\ x > 1.0500 & 0 \end{cases}$$

Referring to the formula above, the calculation is done using the left-side formula, and the result obtained is 0.2 for the degree of membership of the density variable.

$$x = 1.0320, \textit{use the left side formula}$$
$$\frac{x-a}{b-a} = \frac{1.0320-1.0300}{1.0400-1.0300} = \frac{0.0020}{0.0100} = \mathbf{0.2}$$

$$\propto 3 = \min\ (\mu(x)Low[6{,}2] \cap (\mu(y)High[1.0320]$$
$$\propto 3 = \min(1\ ;\ 0.2)$$
$$\propto 3 = \mathbf{0.2}$$

From the above calculation, two degrees of membership are obtained from each variable, namely 1 from the first input variable (pH) and 0.2 from the second input variable (density).

Step 2: Determining Fuzzy Operators

After obtaining the membership degree, the next stage of the Fuzzy Inference System (FIS) is to determine the fuzzy operators. Fuzzy operators require a Fuzzy Rule Base, which must also be obtained by the expert handling it (Santosa, Hidayat, & Siskandar, 2021). The author found the Fuzzy Rule Base data as follows:

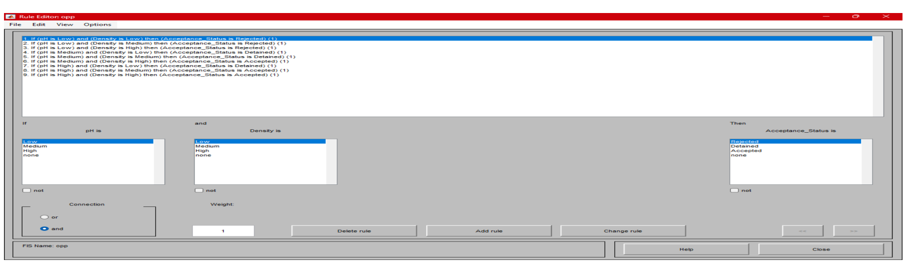

Figure 8. Fuzzy Rule Base

In this case study, the rule used is intersection using the "AND" operator. The AND operator will connect each condition of the input and output variables used. The AND operator is related to the intersection operation used in the set (Rizky & Mulyoto, 2023). After forming 9 rules that will be used, proceed with the reasoning process using the MIN method. The minimum value is used to modify the fuzzy region, apply it to the output through the AND operator, and produce a ∝-predicate (Rizky & Mulyoto, 2023). Based on the Fuzzy Rule Base above, it is found that this case study is influenced by rule number three (3), with the output parameter rejected. Since the operator used is the "AND" operator, the next step is to determine the minimum value of the two input membership degrees (1 and 0.2).

$$x = 1.0320, \textit{use the left side formula}$$
$$\frac{x-a}{b-a} = \frac{1.0320-1.0300}{1.0400-1.0300} = \frac{0.0020}{0.0100} = \mathbf{0.2}$$

$$\propto 3 = \min\ (\mu(x)Low[6,2] \cap (\mu(y)High[1.0320]$$
$$\propto 3 = \min(1\ ;\ 0.2)$$
$$\propto 3 = \mathbf{0.2}$$

Step 3: Determining the Implication Function

After obtaining the minimum value of both membership degrees, based on the Fuzzy Inference System (FIS) stage, the next step is to determine the value of the implication function of the output variable "rejected". Through various compiled rules, the fuzzy implication function will state the correlation or relationship between the input variable and the output variable (Priyo, 2017).

Figure 9. Implication value

The determination of the implication value uses the same formula for the two-output data above, namely using the left side formula for X1 and the right-side formula for X2 and it is found that the value of X1 is **14** and the value of X2 is **46.**

Left side output: $\propto = \frac{x1-a}{b-a}$
$= 0.2 = \frac{x1-10}{30-10}$
$= 0.2\,.\,20 = x1 - 10$
$= 4 = x1 - 10$
$= 4 + 10 = x1 \rightarrow x1 = \mathbf{14}$

Right side output: $\propto = \frac{c-x2}{c-b}$
$= 0.2 = \frac{50-x2}{50-30}$
$= 0.2\,.\,20 = 50 - x2$
$= 4 = 50 - x2$
$= 4 - 50 = -x2 \rightarrow x2 = \mathbf{46}$

Left side output: $\propto = \frac{x1-a}{b-a}$
$= 0.2 = \frac{x1-10}{30-10}$
$= 0.2\,.\,20 = x1 - 10$
$= 4 = x1 - 10$
$= 4 + 10 = x1 \rightarrow x1 = \mathbf{14}$

Right side output: $\propto = \frac{c-x2}{c-b}$
$= 0.2 = \frac{50-x2}{50-30}$
$= 0.2\,.\,20 = 50 - x2$
$= 4 = 50 - x2$
$= 4 - 50 = -x2 \rightarrow x2 = \mathbf{46}$

The composition of these output data values forms a new formula that will be used in the next calculation stage, namely the moment calculation stage. If formulas that produce a value of 0 is ignored, it's divided into three parts as follows:

$$f(x,a,b,c) = \begin{cases} x < 10 & 0 \\ 10 \le x < 14 & \dfrac{x-10}{30-10} \\ 14 \le x \le 46 & 0.2 \\ 46 < x \le 50 & \dfrac{50-x}{50-30} \\ x > 50 & 0 \end{cases}$$

Calculating the Area

At this stage, the area calculation will be related to the next calculation step. The area calculation focuses on the output variable that has been determined based on the implication value.

Figure 10. Area

The area calculation uses the area formula of each flat shape formed. Areas I and III form a triangular flat shape where the formula used is $\frac{axt}{2}\frac{axt}{2}$, and area II forms a rectangular flat shape where the formula used is $pxl\ pxl$. So that, the following calculation is obtained:

Area I (Triangle) : $\frac{(14-10)0.2}{2} = \mathbf{0.4}$
Area II (Rectangle) : $(46 - 14)\ .\ 0.2 = \mathbf{6.4}$
Area III (Triangle) : $\frac{(50-46)0.2}{2} = \mathbf{0.4}$

Step 4: Moment Calculation

The moment calculation formula is an extension of the implication value formula that has been obtained previously, which is as follows:

$$x < 10; = 0$$
$$10 \leq x < 14; \frac{x-10}{20} = \mathbf{0.05x - 0.5}$$
$$14 < x \leq 46; = \mathbf{0.2}$$
$$46 < x \leq 50; \frac{50-x}{20} = \mathbf{2.5 - 0.05x}$$
$$x > 50; = 0$$

After obtaining the moment calculation formula, the formula that produces a value of 0 can be ignored, leaving three moments. The x value of each area is entered into the moment formula to continue the calculation.

Moment Calculation 1

In the first moment of calculation, the calculation uses the integral formula with the x value used is 10 as the lower limit and 14 as the upper limit.

$$\int_{10}^{14}(0{,}05x - 0{,}5)x.dx = (0{,}05x^2 - 0{,}5x).dx = \left(\frac{0{,}05x^3}{3} - \frac{0{,}5x^2}{2}\right) = (0{,}0167x^3) - (0{,}25x^2)$$

$$\int\{(0{,}0167(14)^3) - (0{,}25(14)^2)\} - \{(0{,}0167(10)^3) - (0{,}25(10)^2)\}$$

$$\int\{0{,}0167.2744) - (0{,}25.196)\} - \{(0{,}0167.1000) - (0{,}25.100)\}$$

$$\int\{45{,}8248 - 49\} - \{16{,}7 - 25\}$$

$$(-3{,}1752) - (-8{,}3) = \mathbf{5{,}1248}$$

Moment Calculation 2

The second moment calculation also uses the integral formula, with the x values used being 14 as the lower limit and 46 as the upper limit.

$$\int_{14}^{46}(0{,}2)x.dx = (0{,}2x).dx = \frac{0{,}2x^2}{2} = 0{,}1x^2$$

$$\int\{(0{,}1(46)^2\} - \{(0{,}1(14)^2\}$$

$$\int\{0{,}1.2116\} - \{0{,}1.238\}$$

$$(211{,}6) - (23{,}8) = \mathbf{187{,}8}$$

Moment Calculation 3

The calculation of the third moment also uses the same formula, with the x value used is 46 as the lower limit and 50 as the upper limit.

$$\int_{46}^{50}(2{,}5x - 0{,}05x)x.dx = (2{,}5x - 0{,}05x^2).dx = \left(\frac{2{,}5x^2}{2} - \frac{0{,}05x^3}{3}\right) = (1{,}25x^2) - (0{,}0167x^3)$$

$$\int\{(1{,}25(50)^2) - (0{,}0167(50)^3)\} - \{(1{,}25(46)^2) - (0{,}0167(46)^3)\}$$

$$\int\{1{,}25.2500) - (0{,}0167.125000)\} - \{(1{,}25.2116) - (0{,}0167.97336)\}$$

$$\int\{3125 - 2087{,}5\} - \{2645 - 1625{,}5112\}$$

$$(1037{,}5) - (1019{,}4888) = \mathbf{18{,}0112}$$

Step 5: Defuzzification

Defuzzification is the last stage in a system of fuzzy logic. Defuzzification is the affirmation stage of the calculation results of the fuzzy set that has been processed either based on manual calculations or with the Matlab application. Defuzzification has the aim of converting each inference engine result into a fuzzy set of real numbers, or it can be said that defuzzification is used to prove the results that have been calculated using the Matlab application (Haerani, 2015). According to (Vinsensia, 2021), the input process of defuzzification is a fuzzy set that has been obtained from calculations that have been carried out previously, with the resulting output being the number in the fuzzy set itself.

$$Z^* = \frac{\Sigma\,\text{moment}}{\Sigma\,\text{area}} = \frac{5.1248 + 187.8 + 18.0112}{0.4 + 6.4 + 0.4} = \frac{210.936}{7.2} = \mathbf{29.30}\ rounded\ up\ \mathbf{30}$$

The manual calculation above gets a lift of 29.30; do the math rounding up, and the result obtained is a value of 30.

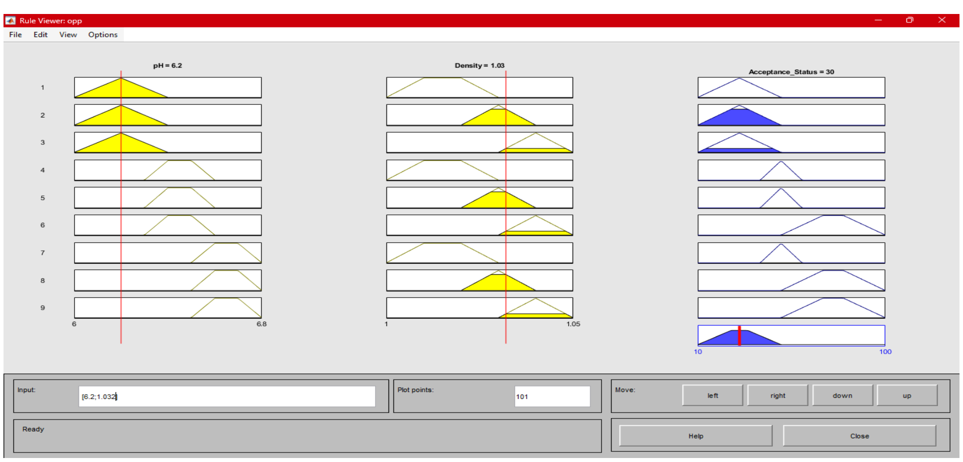

Figure 11. Matlab Calculation

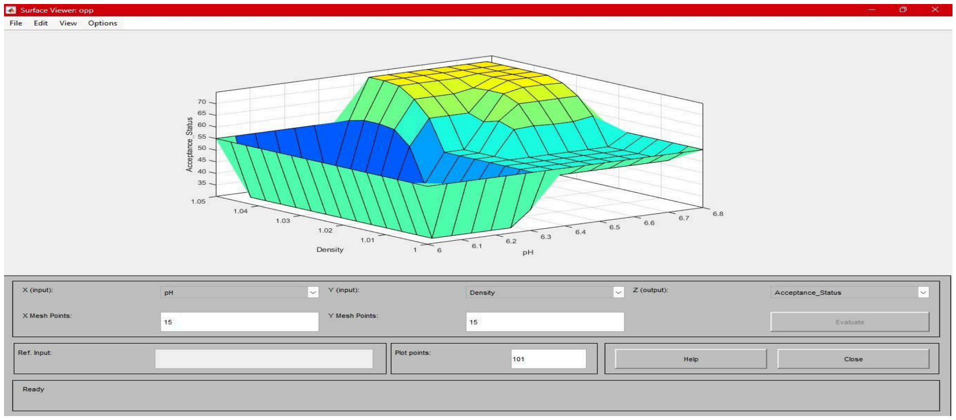

Figure 12. Surface

After calculating using the Matlab application, it is found that the acceptance status of fresh milk if pH = 6.2 and density = 1.0320 is 30. It can be interpreted that the above calculation is in accordance with manual calculations. The use of fuzzy logic is used to determine the output value, or the value of the data reading results easily and accurately. In this case study, the use of Fuzzy Logic aims to estimate the acceptance status of dairy products (rejected, withheld, or accepted) in certain situations and conditions based on predetermined parameter criteria. The Matlab application can be used to compare manual calculations and validate output variables or program code that has been created and uploaded into a tool correctly; the results of the Matlab application with the resulting output value are almost close to manual calculations (Qothrunnada, Yanti, & Pauzan, 2024).

Product acceptance status depends on quality control in a product. In this case, the parameters that can be set for quality control of dairy products are acidity (pH) and density. Based on manual calculations and the use of the Matlab application, the value of the acceptance status for milk that has low pH (6.2) and high density (1.0320) criteria is 30, where this value (30) is in the "rejected" parameter for the acceptance status output variable. This can occur due to several factors. For the pH parameter, the high-low pH of fresh milk can be influenced by milking hygiene factors, the condition of the dairy cow before milking, the length of milking, the way milk is handled after milking, and improper measurement (Yusuf, Kentjonowaty, & Humaidah, 2021). Milk properties are also closely related to milk acidity (Susilorini, 2006; Wahyuningsih & Pazra, 2022). Based on SNI 3141.1:2011, the ideal pH for fresh milk is between 6.3 - 6.8. The pH of milk that is too low indicates an excessive acidification process by bacterial activity so that the pH will decrease significantly (Soeparno, 1996; Kencanawati, Suprayogi, & Sayuti, 2015). Ramadhani, Ramadhanu, & Hidayat (2024), stated that fresh milk that has a very low pH could prove that the milk has been contaminated with strong lactic acid bacteria. The bacteria contained in milk are directly proportional to the amount of milk lactose, which is converted into lactic acid so that the milk turns sour. It can be concluded that the greater number of bacteria in the milk significantly affects the pH, which results in the quality of the milk being contaminated and the pH value tending towards acidic due to the presence of bacteria in the milk (Sasongko et al., 2012; Pramesthi, Suprayogi, & Sudjatmogo, 2015).

In addition to pH, another rejection factor of fresh milk is density, which is not in accordance with the applicable SNI standards. Based on SNI 3141.1:2011, the density of fresh milk should not be less than

1.0280 g/cm2. The density of milk is determined based on the overall nutrient components contained in the milk, so the determination of density in milk also plays a role as a variable that determines the quality of milk. The higher the density contained in fresh cow's milk, the higher the dry matter contained therein. Dry matter in milk consists of protein, vitamins, fat, carbohydrates, and minerals. In the fuzzy logic value that has been carried out, the results obtained for the density of milk are at a value of 1.0320, the density is quite high when compared to the SNI value range set. The increase in density value can occur after going through the milking process caused by the presence of carbon dioxide and nitrogen gas in milk, which can increase the specific gravity of fresh milk (Rosiartio et al. 2015; Christi, Salman, Widjaja, & Sudrajat, 2022). Milk contains gases such as carbon, oxygen, and nitrogen gasses that are harmful when they meet. The meeting of nitrogen compounds contained in milk with hydrogen compounds in the air chemically produces ammonia gas caused by chemical decay where the protein component will gradually be broken down by proteolytic bacteria, which will be able to produce ammonia gas (Salam N. Aritonang, 2017; Nugroho, Syauqy, & Fitriyah, 2023). The chemical content contained in milk, such as fat, protein, minerals, lactose, and others, can affect the density of milk (Wulandari, Taufik, & Syarif, 2017). Milk is a biological material that is susceptible to physical and chemical changes, so if these changes occur, the quality of milk will decrease and can endanger consumers (M. N. Hidayat, 2017).

CONCLUSION

Fuzzy logic maps the input space to the output space, and this concept is closely related to the management of uncertainty in data. In the context of applying fuzzy logic in this study, the variables pH and density of milk are considered as inputs whose value domains are divided into low, medium, and high categories. The result of the fuzzy system is the acceptance status of fresh milk. By applying this method, simulation results using manual calculation and Matlab application show that milk with pH 6.2 and density 1.0320, has a value of 29.30 ~ 30 for the output variable of the acceptance status, so it is found that the status of milk acceptance is declared "rejected" because the value of the output variable of the acceptance status is in the range of 10-50. From these results, it can be concluded that the use of fuzzy logic provides a fairly high level of accuracy to support progressive decision-making. This allows the system to take into account the complexity of milk quality criteria that cannot always be measured in a binary way (e.g., good or bad), thus enabling precise and accurate decision-making.

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