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Application Of Fuzzy Logic In Determining Full Cream Milk Drink Recommendations Based On Milk Price And Nutrition

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Abstract

Milk is a source of nutrition that comes from cows and goats. The large number of dairy products on the market means consumers are faced with various brands by considering the nutritional content and price of dairy products. This research aims to use the fuzzy method to determine the recommended full-cream milk drink based on the price and nutrition of the packaged milk itself using fuzzy logic, observation, and literature study. The fuzzy method used is the Mamdani method with the assistance of the Fuzzy Inference System (FIS) in MATLAB R2015a application. Based on the research results, it is found that sample milks 4, 5, and 6 are suitable for recommendation to consumers because, through fuzzy logic analysis, they obtained membership degree values of 0.92, 0.92, and 0.91 respectively, which fall into the category of highly recommended.

Keywords: Fuzzy logic, Mamdani, Milk, Price, Nutrition

INTRODUCTION

Fuzzy logic is part of the branch of mathematics that analyzes random number processes using computer science-based mathematical statistical theory. The pioneer of fuzzy logic is professor Lotfi A. Zadeh, a professor at the University of California. Fuzzy logic was first developed through his 1965 paper on fuzzy set theory (Rosyidin et al., 2023). Fuzzy inference systems have been applied in various fields, for example control systems, pattern recognition, expert systems, image processing and forecasting or prediction (Ansar et al., 2023). Fuzzy sets are a development of firm sets, where firm sets divide elements into two categories, namely members and non-members (Sari, 2018). Fuzzy logic has the concept of partial membership, which means that there can be values between 0 and 1. The concept of fuzzy analysis is more efficient, such as binary stating that milk is hot or cold. Meanwhile, fuzzy differentiates between all possible temperature fluctuations. Fuzzy logic is a method that can be said to be very flexible and can accept all existing data (Haque & Srian, 2023). Fuzzy logic can help overcome doubts between one criterion and another, so it is often implemented in various food and beverage quality research (Nisa et al., 2020). Milk is a common beverage that is analyzed using fuzzy logic.

Milk is a drink that contains high nutrients, but is susceptible to microorganisms. Therefore, milk is a material that is not durable and susceptible to mold (Singgih et al., 2018). Milk is the result of the mammary gland of an animal through the process of secretion, and essentially serves as a source of

nutrition for the young animal itself (Badaini & Abadi, 2015). States that milk contains several nutrients, including protein (3,5%), fat (3,9%), lactose (4,9%), and vitamins (0,7%) (Putri, 2016). Protein is a very important nutritional component in milk because it contains essential amino acids needed by the body (Sigit et al., 2021). The main protein components of milk are whey and casein which have high quality (Rahmaniar et al., 2021). Milk protein contains 95% crude protein, 5% contain free amino acids, small peptides, and non-protein nitrogen (Guetouache et al., 2014).

One of the food products that is needed to support the nutritional needs of the community is milk (Santoso et al., 2010). Therefore, Indonesian people's milk consumption increases every year. According to data from the Central Statistics Agency (BPS), in 2023 Indonesia produced milk reaching 837,223.2 tonnes and this number increased by 1.6% from the previous year which only produced 824,273.2 tonnes. Based on this data, it shows that Indonesian people's awareness of the importance of nutrition and milk is increasing. Nowadays, milk is easy to get in supermarkets or even the nearest shop around your house. Usually, ready-to-drink milk is found in shops inbox or bottle form. Ready-to-drink milk drinks available under various brands usually offer a variety of flavors and attractive additional benefits, such as protein, low fat, low sugar, high calcium, and others.

The large number of ready-to-drink milk products on the market means that consumers are faced with various brands of milk that they can choose from, thus making them consider purchasing milk products. Considerations in ready-to-drink milk products are related to the nutritional content or price of the product. When determining the price of milk to be purchased, consumers can see the differences in criteria determined using the fuzzy logic method. One of the steps of the fuzzy logic method used in describing milk prices can be using membership functions (Malik & Abadi, 2017).

If we consider the identification of milk prices, we can define them using two fuzzy sets - "expensive" and "cheap". We can then create a function that describes the price of milk by assigning values to both sets. The value of membership in the expensive set will be low at low prices and high at high prices. Conversely, the value of membership in the cheap set will be high at low prices and low at high prices (Sirait & Gultom, 2022). Consumers are mainly concerned with the practicality of consumption and affordable prices when purchasing drinks (Nisa et al., 2020). This study aims to utilize the fuzzy method to identify the most recommended full-cream milk drink based on the price and nutritional value of the packaged milk.

METHODS

The Study research was conducted through meticulous observation and extensive literature review. In the observational phase, data samples of dairy products were meticulously collected from a prominent supermarket in Bogor. The literature review was conducted to enrich the research, sourcing information from reputable internet sources, including various scholarly journals. This study method uses the Fuzzy Mamdani method. The weakness in the fuzzy Mamdani method is that it can only be applied to data quantitative and cannot be used on data qualitative (Matondang et al., 2023).

Fuzzy Method is a method to make a conclusion or a decision in an expert system. The Mamdani method was chosen because the conclusions can be easily understood, so this method can give the best results (Septiawati et al., 2023). Data collection was carried out by determining variables in carrying out calculations and analyzing problems from 6 sample milk products and with help from FIS (Fuzzy Inference System) in the application of MATLAB. According to (Safitri & Abadi, 2015) states to get the output there are 6 steps, the steps are determining the input variables of dairy products, defining the set of inputs and outputs, fuzzification, determining fuzzy rules for dairy product selection, determining fuzzy inference, and defuzzification.

The explanation of the fuzzification stage can be defined as a mapping from a firm set to a fuzzy set. The fuzzy rule stage used in fuzzy sets is the IF-THEN rule. The fuzzy inference stage is an evaluation stage of fuzzy rules which is carried out based on reasoning using fuzzy input and fuzzy rules so that an output is obtained in the form of a fuzzy set. Meanwhile, the defuzzification stage is a process that is the opposite of the fuzzification process, namely as a mapping from a fuzzy set to a firm

set. The fuzzy set referred to in the defuzzification stage is the output result obtained from the inference results. At this stage, there are three criteria that must be met, namely reasonable, simple and continuous calculations (Sari & Rani, 2021).

RESULTS AND DISCUSSION

Fuzzy Mamdani was first introduced in 1975 by Ebrahim Mamdani. The Mamdani fuzzy method uses linguistic principles and fuzzy algorithms in each process (Sinaga et al., 2023). The Mamdani method is the simplest method and is most often used for research compared to other methods. The input and output in this method are fuzzy sets. The Mamdani method uses min implication and max aggregation functions so that the Mamdani method is also called the MIN-MAX (min-max inferencing) method (Ningsih et al., 2017). Fuzzy logic can be interpreted as logic that has a bias value between true and false (Pratama et al., 2023).

The Fuzzy Mamdani method has been widely applied in various fields such as intelligent control systems, decision making, and modeling systems involving uncertainty. Its main advantage lies in its ability to handle problems that cannot be explained by traditional binary logic (Narulita & Ahmad, 2024). Fuzzy logic is used to make purchasing decisions for full-cream milk products available on the market. Purchasing decisions have several main factors that many consumers consider, including price and nutrition. This fuzzy logic can think like a human in determining certainty, for example, to find out the nutritional content and price of six samples of full-cream milk which can be stated as not recommended, less recommended, recommended, or highly recommended.

The fuzzy logic method will be applied based on taking six samples of full-cream milk. This method can accommodate various decision variables and can be adapted to various socio-economic conditions and customer needs by changing input variables and fuzzy rules. A food product selection system that considers price and nutrition, as well as subjective assessments, can be created using the fuzzy basic method. In fuzzy logic for nutritional decision-making, there is a range of values for nutrients, although there is no optimal value (Nakandala, 2013). This study used six data samples of full-cream milk with the largest size as objects of observation with nutritional content and price of each sample. The nutritional content taken was fat (g), proteins (g), and carbohydrates (g) accumulated in total nutrition (g). The data used was taken from direct observations at one of the supermarkets in Bogor. Data on nutrient content and prices from each sample are shown in Table 1.

Table 1. Nutritional Content and Prices of 6 Full Cream Milk Products

No Sample	Price (H)	Fat (g)	Proteins (g)	Carbohydrate (g)	Total Nutrition (g)
1	20.500	7	7	10	24
2	20.000	7	7	12	26
3	40.000	6	7	11	24
4	25.000	9	8	12	29
5	18.200	8	8	12	28
6	21.500	8	8	13	29

In this study, the topic that will be discussed is how to determine the right full-cream milk for consumers by considering the parameters of milk price and the nutritional content of milk using the

application of fuzzy logic. There are six steps that need to be taken in using the fuzzy Mamdani method. The following are the steps that need to be taken:

1. In the first step, the input and output must be determined first. The input specified in this study is the nutritional content and price of full-cream milk, while the output specified is the consumer's recommended full-cream milk.

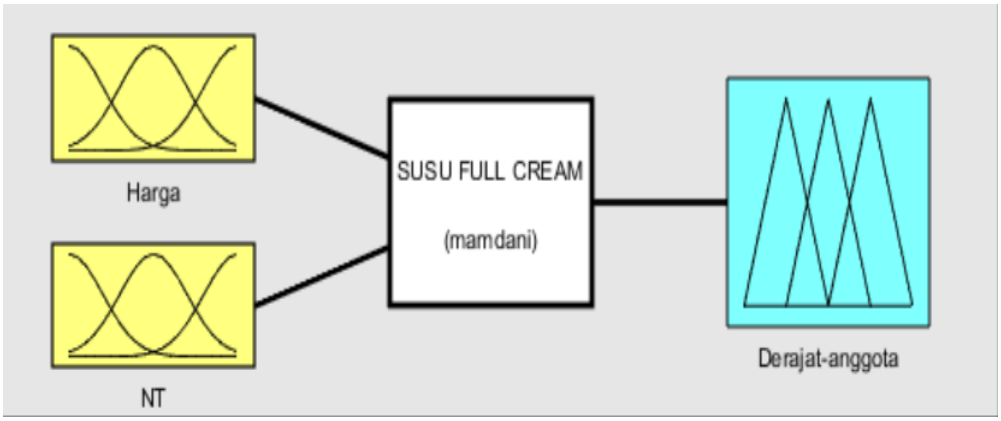

Figure 1. Determination of Input and Output Variables

In manual calculation methods, input values can be determined by calculating the geometric building sides formed on the graph. The calculation formula used is:

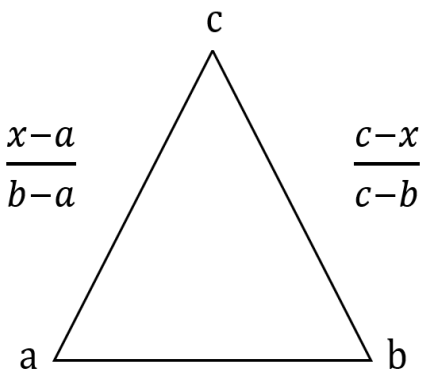

Figure 2. Fuzzy Input Formula

Through this formula, the value of the set on each side will be obtained, according to the formula used. The value of the set will later be juxtaposed with the set value of other variables which will then be obtained from the pair's value as the input of the fuzzy operator. When the pair has been determined, a value will be selected that determines the use of the area on the next graph. That area of the graph will play a role in determining the degree of membership for milk recommendation output. In this study, the manual calculation process was only carried out on sample one as an example.

2. The second step is to determine the range interval of the price and nutrition parameters of full-cream milk as well as the recommended values specified in the range of membership degrees that can be seen in the following data:

Table 2. Range Of Membership Degrees

Variable	Parameters	Range			
		Set	a	b	c
Price	Very Cheap	15-20	0	15	20
	Cheap		20	24	28
	Expensive		28	32	36
	Very Expensive		36	40	40
Nutritional	Low	20-32	0	20	24.5
	Standard		24.5	26	27.5
	High		27.5	32	32
Recommended	Not Recommended	0-1	0	0	0.2
	Less Recommended		0.2	0.35	0.5
	Recommended		0.5	0.65	0.8
	Highly Recommended		0.8	1	1

3. The third step is fuzzification. Fuzzification is the stage that defines the membership level of each input and output. Through fuzzification, data that has quantitative properties will be converted into fuzzy sets that have membership value (Siregar et al., 2023). Additionally, fuzzification refers to the transformation of crisp input into membership functions expressed with linguistic numbers (Septiani & Djatna, 2015). Price parameters are defined as four membership levels that are very *cheap (SMr), cheap (Mr), expensive (Ma)*, and *very expensive (SMa)*. Meanwhile, the nutritional parameters are defined as three levels of membership, that is *low (R), standard (S), and high (T)*. Then, the outcome of the recommendation was defined as four levels of membership, that is *not recommended (TR), less recommended (KR), recommended (R), and highly recommended (SR).*

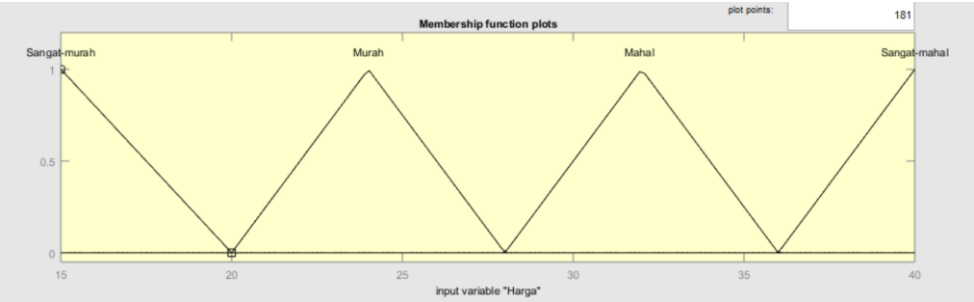

Figure 3. Price Membership Level Graphic

$$\mu \text{ Very Cheap} = \begin{cases} 0 & x < 0 \\ 1 & x = 15 \\ \frac{c-x}{c-b} & 15 < x \leq 20 \end{cases}$$

$$\mu \text{ Cheap} = \begin{cases} 0 & x < 20 \\ \frac{x-a}{b-a} & 20 \leq x < 24 \\ 1 & x = 24 \\ \frac{c-x}{c-b} & 24 < x \leq \\ 0 & x \end{cases}$$

$$\begin{cases} 0 & x < 28 \\ \frac{x-a}{b-a} & 28 \leq x < 32 \\ 1 & x = 32 \\ \frac{c-x}{c-b} & 32 < x \leq 36 \\ 0 & x > 36 \end{cases}$$

$$\begin{cases} 0 & x < 36 \\ 1 & x = 40 \\ \frac{x-a}{b-a} & 36 < x \leq 40 \\ 0 & x > 40 \end{cases}$$

μ Expensive =

μ Very Expensive =

Sample price 1 = Rp 20.500 (Cheap)

$\frac{x-a}{b-a} = \frac{20.5-20}{24-20} = 0.125$

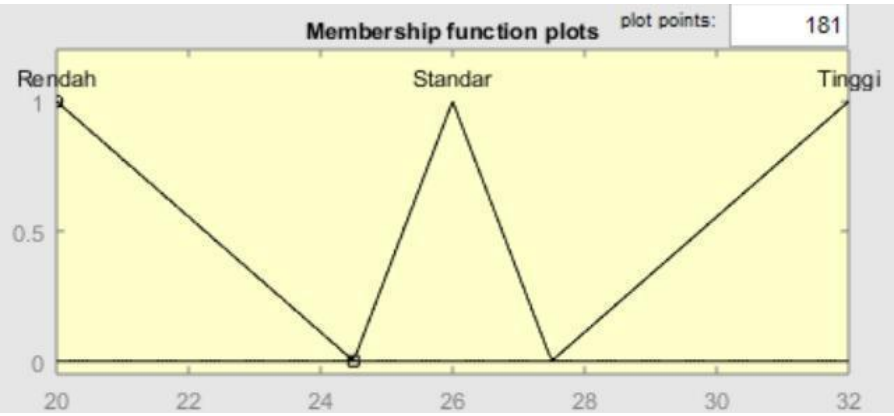

Figure 4. Nutrition Membership Level Graphic

$$\mu \text{ Low} = \begin{cases} 0 & x < 0 \\ 1 & x = 20 \\ \frac{c-x}{c-b} & 20 < x \leq 24.5 \\ 0 & x > 24.5 \end{cases}$$

$$\mu \text{ High} = \begin{cases} 0 & x < 27.5 \\ 1 & x = 32 \\ \frac{x-a}{b-a} & 27.5 < x \leq 32 \\ 0 & x > 32 \end{cases}$$

$$\mu \text{ Standard} = \begin{cases} 0 & x < 24.5 \\ \frac{x-a}{b-a} & 24.5 \leq x < 26 \\ 1 & x = 26 \\ \frac{c-x}{c-b} & 26 < x \leq 27.5 \\ 0 & x > 27.5 \end{cases}$$

Total nutrition sample 1 = 24 (Low)

$\frac{c-x}{c-b} = \frac{24.5-24}{24.5-20} = 0.11$

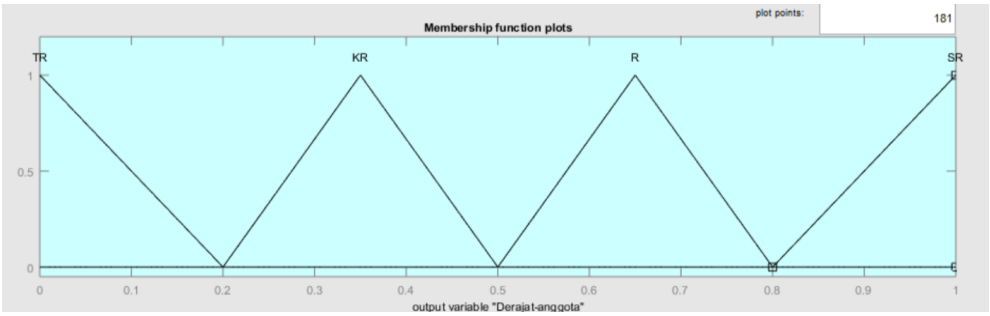

Figure 5. Membership Level of Milk Recommendations Graphic

$$\begin{cases} 0 & x < 0 \\ 1 & x = 0 \\ \frac{c-x}{c-b} & 0 < x \leq 0.2 \\ 0 & x > 0.2 \end{cases}$$

$$\begin{cases} 0 & x < 0.2 \\ \frac{x-a}{b-a} & 0.2 \leq x < 0.35 \\ 1 & x = 0.35 \\ \frac{c-x}{c-b} & 0.35 < x \leq 0.5 \\ 0 & x > 0.5 \end{cases}$$

μ Not Recommended =

$$\mu \text{ Recommended} = \begin{cases} 0 & x < 0.5 \\ \frac{x-a}{b-a} & 0.5 \le x < 0.65 \\ 1 & x = 0.65 \\ \frac{c-x}{c-b} & 0.65 < x \le 0.8 \\ 0 & x > 0.8 \end{cases}$$

μ Less Recommended =

$$\mu \text{ Highly Recommended} = \begin{cases} 0 & x < 0.8 \\ 1 & x = 1 \\ \frac{x-a}{b-a} & 0.8 < x \le 1 \\ 0 & x > 1 \end{cases}$$

Recommendation sample 1

α_4 = KR

$\frac{x-a}{b-a} = \frac{x-0.2}{0.35-0.2} = 0.11$

X1 = 0.2165

$\frac{c-x}{c-b} = \frac{0.5-x}{0.5-0.35} = 0.11$

X2= 0.4835

4. The fourth step, determine the fuzzy rules that will be used to determine recommendations for full cream milk to consumers.

Table 3. The Fuzzy Rules

Price (H)	**Nutritional Content (NT)**		
	Low (R)	**Standard (S)**	**High (T)**
Very cheap (SMr)	TR	KR	SR
Cheap (Mr)	KR	R	SR
Expensive (Ma)	TR	KR	R
Very Expensive (SMa)	TR	KR	R

Fuzzy rules formed from the table above :

1. If the price is *very cheap* and the nutritional content is *low* then the membership level is *not recommended* (TR)
2. If the price is *very cheap* and the nutritional content is *standard* then the level of membership is *less than recommended* (KR)
3. If the price is *very cheap* and the nutritional content is *high* then the membership level is *highly recommended* (SR)
4. If the price is *cheap* and the nutritional content is *low* then the level of membership is *less than recommended* (KR)
5. If the price is *cheap* and the nutritional content is *standard* then the membership level is *recommended* (R)
6. If the price is *cheap* and the nutritional content is *high* then the membership level is *highly recommended* (SR)

7. If the price is *expensive* and the nutritional content is *low* then the membership level is *not recommended* (TR)
8. If the price is *expensive* and the nutritional content is *standard* then the level of membership is *less than recommended* (KR)
9. If the price is *expensive* and the nutritional content is *high* then the membership level is *recommended* (R)
10. If the price is *very expensive*, and the nutritional content is *low*, then the membership level is *not recommended* (TR)
11. If the price is *very expensive* for the *standard* nutritional content, then the level of membership is *less than recommended* (KR)
12. If the price is *very expensive*, and the nutritional content is *high*, then the membership level is *recommended* (R)

The rules used in the table above are IF-THEN logic with the aim of comparing the price and nutritional criteria of a milk product so that it can be seen which products can be highly recommended to not recommended for consumers (Andrari et al., 2021).

5. The fifth step is inference using the Mamdani method

In the Mamdani method, there is a formation of fuzzy sets on input and output variables, which are divided into one or more fuzzy sets (Al-jabbar, 2024). The formation of such sets can be done in the following steps:

1. Based on the 12 rules that have been created, the rule used in sample number 1 is rule number 4, which contains:
   - Rule number 4, If the price is cheap and the nutritional content is low, then the degree of membership is less recommended
   - Next, calculating the predicate of each rule with the min implication function, with μ low (20.5) = 0.11 and μ cheap (24) = 0.125 is as follows :
     μ_4 = min [μ cheap (20.5), μ low (24)]= min [0.125 ; 0.11] = 0.11 **(KR)**
2. The rule composition
   The rule composition from the result of applying the implication function of each rule using the Max method to perform composition among all rules

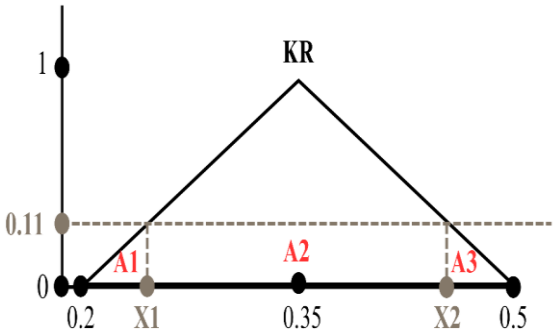

Figure 6.Fuzzy Rule Composition

The intersection area of Figure 6 is at point KR, after which it is determined using the previously obtained recommendation level rules.

Recommendation sample 1

α_4 = KR

$\frac{x-a}{b-a} = \frac{x-0.2}{0.35-0.2} = 0.11$ **X1 = 0.2165**

$\frac{c-x}{c-b} = \frac{0.5-x}{0.5-0.35} = 0.11$ **X2= 0.4835**

6. The final step is defuzzification. Defuzzification is the conversion of fuzzy output into a firm value based on the degree of membership (Nuraida et al., 2013). Apart from that, this stage is carried out to obtain crips from the many fuzzy conclusions to state the critical level so that corrective actions can be determined according to priority (Septiani et al., 2021). In this study, the membership degrees of each sample are calculated based on their respective nutritional content and price values. The nutritional content and price values of the sample are substituted into the input boxes, resulting in membership degrees in the recommendation column, as shown in the following image result.

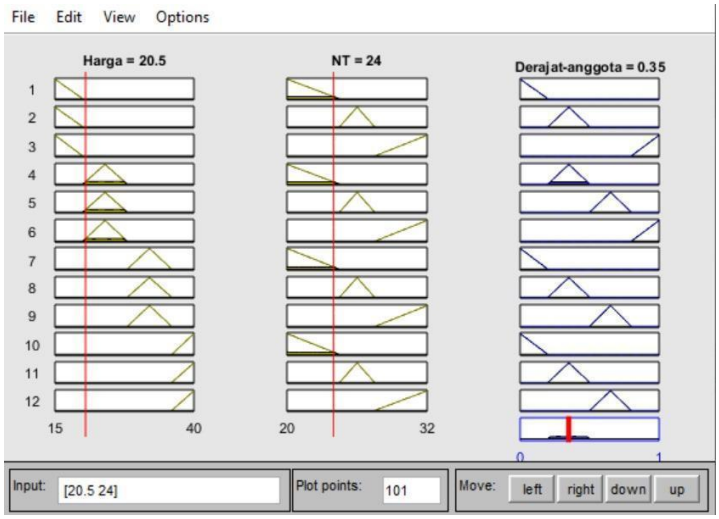

Figure 7. Sample 1

Create a composition function for the 3 affected areas and then simplify the composition:

$$\mu(x): \begin{cases} 0 & x \leq 0.2 \text{ or } x \geq 0.5 \\ \frac{x-0.2}{0.35-0.2} & 0.20.2 \leq x < 0.2165 \\ 0.11 & 0.2165 \leq x \leq 0.4835 \\ \frac{0.5-x}{0.5-0.35} & 0.4835 < x \leq 0.5 \end{cases} \xrightarrow{\text{Simplified}} \mu(x) = \begin{cases} 0 & x \leq 0.2 \text{ or } x \geq 0.5 \\ 6{,}67x - 1.33 & 0.20.2 \leq x < 0.2165 \\ 0.11 & 0.2165 \leq x \leq 0.4835 \\ 3.33 - 6.67\,x & 0.4835 < x \leq 0.5 \end{cases}$$

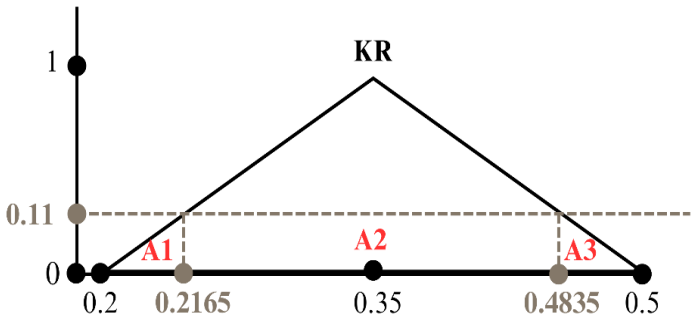

Figure 8. Fuzzy Rule Composition with Division into Three Regions of Planar Shapes

The results of calculating the area and moment of the three planar shapes:

- **A1** = $\frac{(0.2165-0.2)\ x\ 0.11}{2}$ = **0.0009**
- **A2** = $(0.4835 - 0.2165)\ x\ 0.11$ = **0.0294**
- **A3** = $\frac{(0.5-0.4835)\ x\ 0.11}{2}$ = **0.0009**

- **M1** = $\int_{0.2}^{0.2165}(6.67x - 1.33)x\ dx = 0.0001$
- **M2** = $\int_{0.2165}^{0.4835}(0.11)x\ dx = 0.0103$
- **M3** = $\int_{0.4835}^{0.5}(3.33x - 6.67)x\ dx = 0.0004$

As a result, the center point is:

Z*= $\frac{(M1+M2+M3)}{(A1+A2+A3)} = \frac{(0.0001+0.0103+0.0004)}{(0.0009+0.0294+0.0009)}$ **= 0.346 ~ 0.35** (Less Recommended (KR))

Here are some other results processed using the MATLAB application. Manual calculations for the following results can follow the example calculations in sample one above.

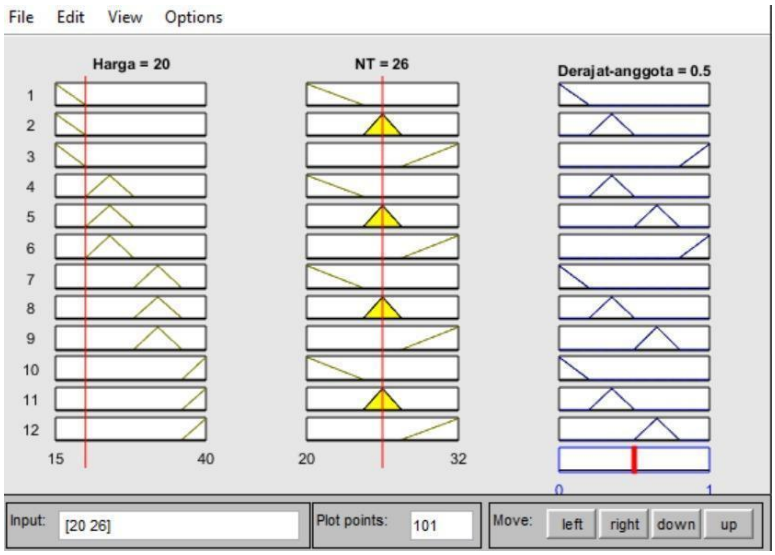

Figure 9. Sample 2

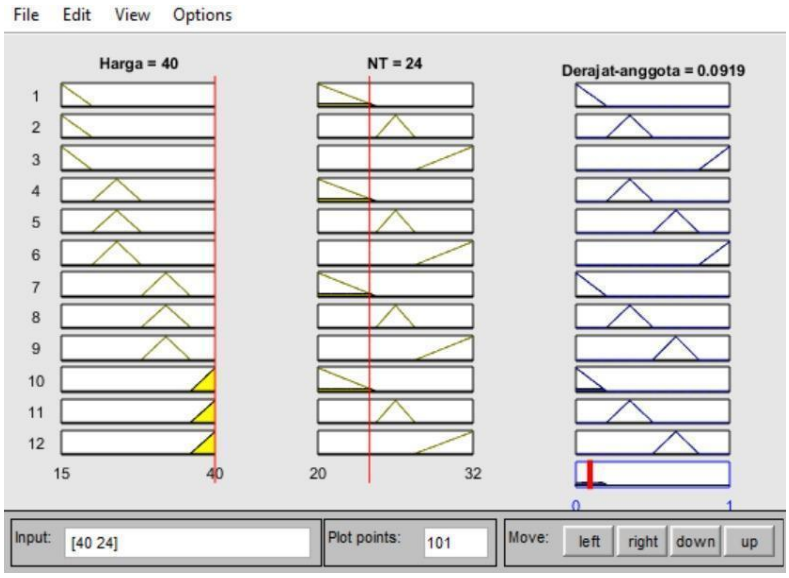

Figure 10. Sample 3

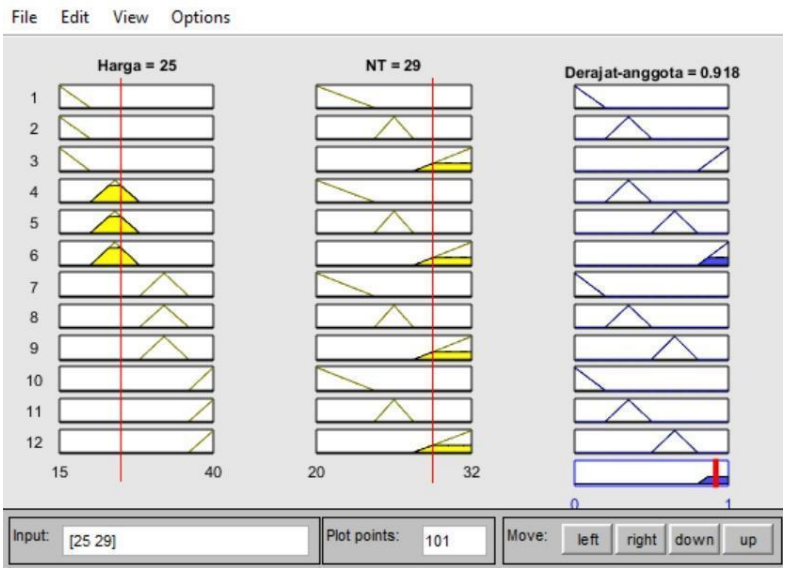

Figure 11. Sample 4

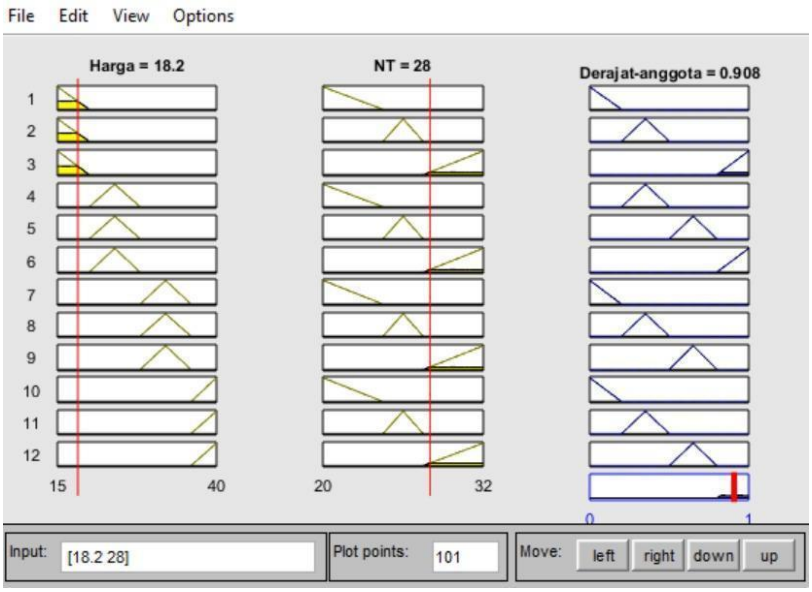

Figure 12. Sample 5

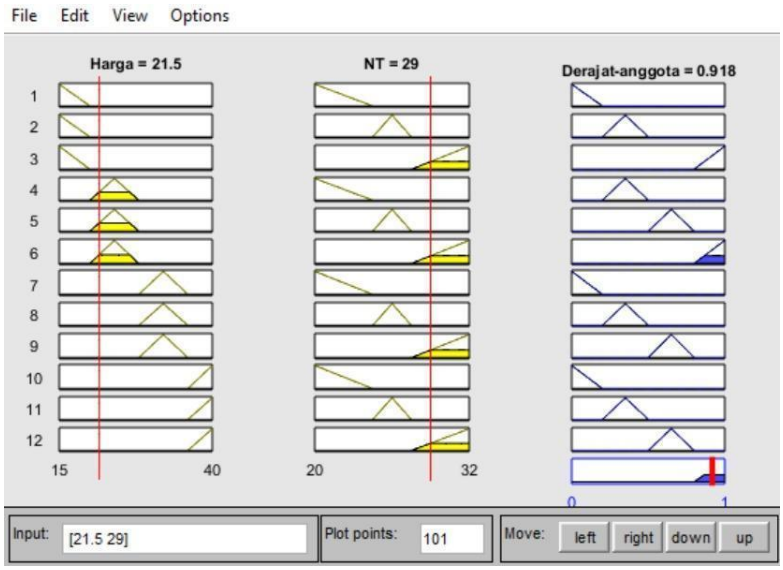

Figure 13. Sample 6

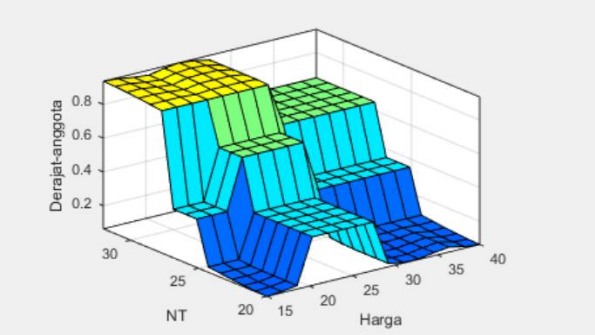

Figure 14. Surface Samples

The recommendation results of the six samples of full-cream milk can be seen in table 4 which has been arranged based on the order of recommendations.

Table 4. Result Summary

Sample	Price	Total Nutrition (g)	Membership Degree	Category
6	21.500	29	0.92	Very Recommended (SR)
4	25.000	29	0.92	Very Recommended (SR)
5	18.200	28	0.91	Very Recommended (SR)
2	20.000	26	0.50	Recommended (R)
1	20.500	24	0.35	Less Recommended (KR)
3	40.000	24	0.09	Not Recommended (TR)

Based on the results of the membership degree analysis in Table 4 above, it can be seen that milk samples 6, 4, and 5 are included in the category of *highly recommended* (SR) with membership degree values respectively, namely 0.92, 0.92, and 0.91, meanwhile, sample 2 with a membership degree value of 0.50 is included in the category of *recommended* (R), sample 1 with a membership degree value of 0.53 is included in the category of *less than recommended* (KR). Sample 3 with a membership degree value of 0.09 falls into the category of *not recommended* (TR).

From table 4 above, all samples that fall into the category of *highly recommended* (SR) have high total nutritional values of carbohydrates, proteins, and fats. These three ingredients are important considerations for consumers in choosing milk. This is because carbohydrates, proteins, and fats are macronutrients needed by the body. Macronutrients are the main nutrients in food that play a role in energy formation (Lastri &Putra, 2020). The group of nutrients included in macronutrients are carbohydrates, proteins, and fats, each of which has its role. Carbohydrates act as the main energy source, protein plays a role in the formation of hormones and repair damaged tissues, and fat acts as a food reserve and solvent of vitamins A, D, E, and K (Zahra &Muhlisin, 2020).

In addition to the total value of carbohydrate nutrition, protein, and fat, high prices are another factor in deciding to buy full milk, especially for mothers and families with a lower middle-income economy. So consumers from these circles can choose sample 5 which is recommended for purchasing full cream milk by looking at the price which is quite cheap compared to the recommended samples 4 and 6 whose price category is already expensive even though sample 5 is included in full cream milk which is highly recommended last. compared to samples 4 and 6.

CONCLUSION

From the analysis above, it can be concluded that the Mamdani fuzzy method can be used to select the right full-cream dairy product by considering both the selling price and nutritional value contained in the product. The analysis of membership degrees shows that samples 6, 4, and 5 are classified into the highly recommended (SR) category with the highest membership degree values. Besides having high nutritional values such as carbohydrates, proteins, and fats, the selling price factor is also an important consideration, especially for consumers with lower to middle economies. Therefore, consumers can choose sample 5 because although it is more affordable, it still has good nutritional value similar to samples 4 and 6, which have higher prices.

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