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Nutrition Optimization through the Application of Fuzzy Logic in Determining the Best Packaged Milk Drinks

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Abstract

The application of fuzzy logic in decision making is growing, especially in determining products that meet certain criteria. This study aims to apply the Mamdani fuzzy logic method to recommend the best packaged milk based on protein content and price. Input data in the form of price and protein content are converted into fuzzy sets and processed using the MATLAB application. The process of fuzzification, rule determination, inference, and defuzzification produces ideal milk recommendations according to consumer preferences. The results show that products with high protein content and affordable prices have the highest recommendation rate. This method helps consumers in choosing dairy products that suit their nutritional needs and budget.

Keywords: fuzzy logic, matlab, milk, price, protein

INTRODUCTION

As technology develops, the use of information technology becomes a medium that can help various human jobs. One example is information technology in the field of web, which can now be accessed and used by anyone easily. Ease of access and attractive interfaces provide a different experience compared to traditional methods that rely on paper in data processing. This creates an opportunity to utilize web-based information technology in the implementation of data processing using fuzzy logic, so that the process becomes more efficient. Fuzzy logic is a problem-solving control system methodology suitable for implementation in systems ranging from simple systems, small systems, PC networks, multi-channel or workstation-based data acquisition and control systems. The concept of fuzzy logic was introduced by Prof. Lotfi Astor Zadeh in 1962 (Harahap 2022).

One application that can be used to support fuzzy logic processing is the MATLAB application. MATLAB or Matrix Laboratory is software used for programming, analysis, and matrix-based technical and mathematical computing. The first MATLAB was released in 1970 by Cleve Moler (Febrianti and Harahap 2021). This program can be used to increase speed and accuracy in various calculations in solving linear program problems.

Fuzzy logic is often used in various food and beverage quality studies. One of them is on nutrient-rich drinks, namely milk. Milk is one of the foods that have high nutritional content. Milk has nutrients such as protein, carbohydrates, fat, potassium, and vitamins. Milk is also known as a source

of calcium which helps bone formation and prevents osteoporosis in elderly people (Nisa et al. 2020). However, milk is also known as a perishable food due to the content of bacteria originating from contamination during milking (Dinata et al. 2024). One of the milk processing methods that uses heating to maintain milk quality and safety is pasteurization. Pasteurization is one of the actions that can be taken to kill pathogenic bacteria. Pasteurization is usually done at 72°C for 15 seconds because it does not change the composition of milk, so the composition remains the same as fresh milk (Aprialdi et al. 2017).

The circulation of packaged milk today is wide and varied as consumer demand for convenient and nutritious dairy products increases. With good distribution and packaging technology, packaged milk products can be found in various places, from supermarkets to grocery stores in rural areas. Consumers are faced with a wide selection of milk brands, which is one of the considerations in choosing milk. Apart from considering the nutritional content issues in it, consumers also consider price issues (Nisa et al. 2020). Price is one of the cues used by consumers in the perception process, where price will affect consumer judgment about a product. Consumers have several different assessments of the price of a product. Prices set above the price of competitors will be seen as too expensive, while prices set below the price of competing products will be seen as cheap products or seen as low quality products (Purwoko et al. 2021).

This paper aims to apply the fuzzy logic method in determining the best packaged milk based on nutritional value and consumer preferences. By using this approach, it is expected to provide recommendations for packaged milk that can support a healthier and more nutritious diet according to individual needs.

METHODS

This research uses a literature study approach (literature review) in the process of collecting data and information related to nutritional optimization through the application of Fuzzy Logic in determining bottled milk drinks using a fuzzy logic model by considering protein content and price in producing the best packaging. The author summarizes and makes an in-depth analysis of the previous literature.

The data collection technique used is a literature search related to the nutritional optimization of milk drinks with the parameters of the price of packaged milk and its protein nutrient content as input to be processed. Then the selection of literature was carried out based on relevance, journal quality, and recency of information. Furthermore, the selected literature in this study refers to the scientific papers of Nisa AK, Abdy M & Zaki A (2020) which will be processed and discussed based on the sub-discussion in this study.

Data processing using the MATLAB application. The steps taken in data processing are as follows:

a. Formation of fuzzy set
b. Formation of membership function
c. Formation of rules
d. Defuzzification

RESULTS AND DISCUSSION

Data Processing Using Fuzzy Mamdani Method

Data on the protein content and price of each sample are shown in Table 1.

Table 1. Data on protein content and price

No sampel	Harga (Rp)	Protein (g)
1	9600	3
2	9600	3
3	9600	3
4	4600	6
5	5300	6
6	5500	7
7	5500	6
8	5500	5
9	5500	5
10	5500	6
11	5500	5
12	4900	7
13	4900	5
14	4900	6
15	4200	4
16	4200	5
17	6900	6
18	6900	5
19	5500	3
20	5500	3
21	4200	4
22	4200	4
23	5400	7
24	6700	5
25	12900	7
26	4400	3
27	4400	3
28	8000	2
29	8000	2
30	8000	1
31	3000	2
32	3000	2

In this research, the fuzzy mamdani method is applied to analyze data on the price and protein of packaged milk. There are five stages in the mamdani fuzzy method in obtaining outputs, namely determining fuzzy sets, fuzzification, forming fuzzy rules, inference and defuzzification.

a. Determining Fuzzy Variables and Talking Universe

   The universe of speech of each variable is determined based on the data obtained from the research results. In this study, the value limits for the price and protein content variables of packaged milk have been set. The number notation for milk price ranges from 0 to 20, while the protein value is in the range of 0 to 11. This range of values will be the basis for building fuzzy sets for each variable, which will later be used in the fuzzy inference process.

b. Fuzzification

   After defining the domain for the variables of price and nutritional content of packaged milk, the next step is to define the membership function for each variable. This membership function will map each value in the domain to a membership value between 0 and 1. A

membership value of 1 indicates that a value fits perfectly into a particular fuzzy set, while a value of 0 indicates that the value does not fit at all. The result of this process is a fuzzy set that describes the distribution of values in the variable domain.

In this study, the variables of price and milk protein are divided into several membership levels. For price, there are 5 membership levels namely very cheap (VC), cheap (C), medium (Med), expensive (E), and very expensive (VE). Meanwhile, for protein, there are 5 membership levels ranging from very low (VL), low (L), medium (Med), high (H) to very high (VH). The milk recommendation variable is also divided into four membership levels, namely packaged milk recommendations are defined into 3 membership levels namely not recommended (NR), less recommended (LR), recommended (R), and highly recommended (HR).

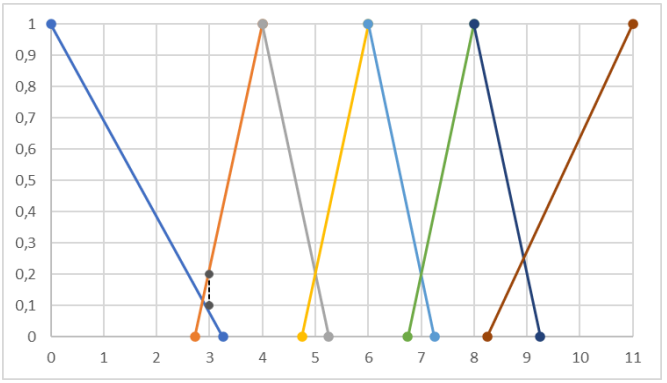

Figure 1 Protein Membership Level Chart

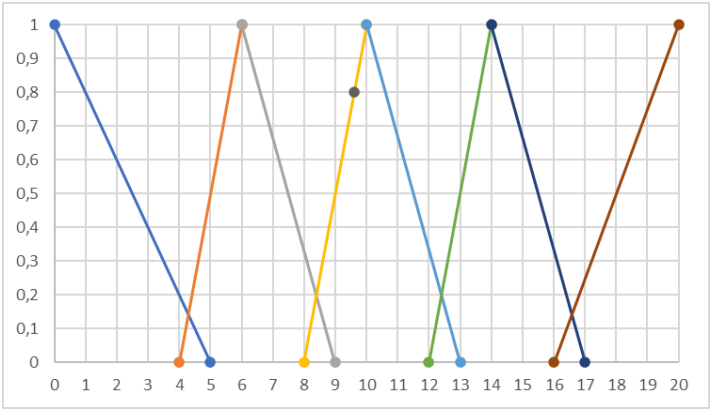

Figure 2 Price Membership Level Chart

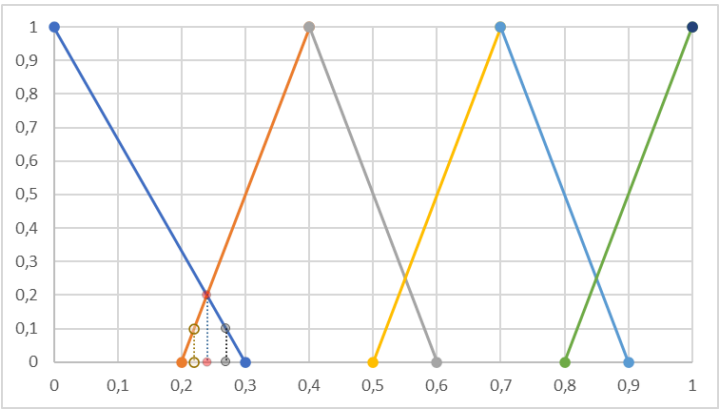

Figure 3 Membership Level Graph of Milk Packaging Recommendation

Based on sample number 1 in table 1, the membership levels of milk recommendations are μ(x) and μ(y) with x = 3 and y = 9.6. From the calculation results, obtained:

$\mu_{VL}(x)= \frac{3,25-x}{3,25-1} \rightarrow \mu_{VL}(3) = \frac{3,25-3}{3,25-1} = 0,1$ $\mu_{Med}(y)= \frac{y-8}{10-8} \rightarrow \mu_{Med}(9,6) = \frac{9,6-8}{10-8} = 0,8$

$\mu_{L}(x)= \frac{x-2,75}{4-2,75} \rightarrow \mu_{L}(3) = \frac{3-2,75}{4-2,75} = 0,2$

Fuzzy Rule Formation

The next step after determining the membership function for each variable is to compile fuzzy rules. Fuzzy rules consist of statements that connect inputs (conditions) with outputs (actions) in a fuzzy logic system. The fuzzy rule function plays a role in determining how input variables will be converted into output variables. In addition, fuzzy rules are also an important component in fuzzy inference systems (Yulmaini 2015).

Based on the data obtained, the following rules are obtained:

1. IF the protein content of the milk is very low AND the price is very cheap THEN it is not recommended.
2. IF the protein content of the milk is low AND the price is very cheap THEN it is not recommended.
3. IF the protein content of the milk is medium AND the price is very cheap THEN recommended.
4. IF the protein content of the milk is high AND the price is very cheap THEN it is recommended.
5. IF the protein content of the milk is very high AND the price is very cheap THEN it is recommended.
6. IF the protein content of milk is very low AND the price is cheap THEN not recommended.
7. IF the protein content of the milk is low AND the price is cheap THEN it is not recommended.
8. IF the protein content of the milk is medium AND the price is low THEN it is recommended.
9. IF the protein content of the milk is high AND the price is low THEN it is recommended.
10. IF the protein content of the milk is very high AND the price is low THEN it is recommended.
11. IF the protein content of milk is very low AND the price is moderate THEN not recommended.
12. IF the protein content of milk is low AND the price is medium THEN it is not recommended.
13. IF the protein content of the milk is medium AND the price is medium THEN it is not recommended.
14. IF the protein content of the milk is high AND the price is medium THEN recommended.

15. IF the protein content of the milk is very high AND the price is medium THEN recommended.
16. IF the protein content of milk is very low AND the price is high THEN not recommended.
17. IF the protein content of milk is low AND the price is high THEN not recommended.
18. IF the protein content of the milk is medium AND the price is high THEN not recommended.
19. IF the protein content of milk is high AND it is expensive THEN it is not recommended.
20. IF the protein content of milk is very high AND the price is high THEN recommended.
21. IF the protein content of milk is very low AND it is very expensive THEN it is not recommended.
22. IF the protein content of the milk is low AND the price is very expensive THEN not recommended.
23. IF the milk is medium in protein content AND very expensive THEN not recommended.
24. IF the protein content of milk is high AND it is very expensive THEN it is not recommended.
25. IF the milk is very high in protein AND very expensive THEN not recommended.

Figure 4 Fuzzy Rules

Inference with Mamdani Method

Inference using the Mamdani method is a decision-making process with fuzzy rules such as If-Then to convert fuzzy inputs into outputs rules such as If-Then to convert fuzzy inputs into outputs. The use of the mamdani method has several functions, including the fuzzification phase, rule evaluation, aggregation, and defuzzification (Yulmaini, 2015). From the experiments conducted, the amount of protein content is very low and the price is very cheap. This indicates that the rules used are rules 11 i.e. “If the protein content is very low and the price is medium, then the sample is not recommended” and 12 i.e. “If the protein content is low and the price is medium, then the sample is not recommended”. Based on these rules, the fuzzy formation operation is obtained as follows:

[R11] IF protein is Very Low AND price is Medium THEN Recommendation is NR
[R12] IF protein is Low AND price is Medium THEN Recommendation is NR

The predicate of each rule calculated using the minimal implication function with μVL(3) = 0.1; μL(3) = 0.2; μMed(9.6) = 0.8 is as follows:

α_{11}= min [$\mu_{VL}(3)$; $\mu_{Med}(9,6)$] = min [0,1 ; 0,8] = 0,1

α_{12}= min [$\mu_{L}(3)$; $\mu_{Med}(9,6)$] = min [0,2 ; 0,8] = 0,2

Furthermore, the intersection area for NR through the previous recommendation level rule so that the implication area is obtained as follows:

$$\mu(z) = \begin{cases} 0\,;\, z \leq 0{,}2 \; or \; z \geq 0{,}3 \\ 0{,}1\,;\, 0 < z < 0{,}22 \\ 0{,}1\,;\, 0{,}22 < z < 0{,}27 \\ 0{,}2\,;\, 0 < z < 0{,}24 \\ \dfrac{z - 0{,}2}{0{,}4 - 0{,}2}\,;\, 0{,}22 \leq z \leq 0{,}24 \\ \dfrac{0{,}3 - z}{0{,}3}\,;\, 0{,}27 \leq z \leq 0{,}3 \end{cases}$$

Defuzzification

Defuzzification is the process of converting the output produced by a fuzzy logic system into numerical values in the original domain. This process is carried out after the fuzzy inference stage, starting with the output of the fuzzy logic system in the form of a fuzzy set that needs to be converted into a concrete value that can be used. The defuzzification function plays a role in converting the fuzzy set into a single value, with various methods that can be used (Yulmaini 2015). The composition function obtained from determining the implication area is simplified first to get the following function:

$$\mu(z) = \begin{cases} 0\,;\, z \leq 0{,}2 \; or \; z \geq 0{,}3 \\ 0{,}1\,;\, 0 < z < 0{,}22 \\ 0{,}1\,;\, 0{,}22 < z < 0{,}27 \\ 0{,}2\,;\, 0 < z < 0{,}24 \\ 5z - 1\,;\, 0{,}22 \leq z \leq 0{,}24 \\ 1 - 3{,}3z\,;\, 0{,}27 \leq z \leq 0{,}3 \end{cases}$$

$$\int_{0}^{0,22} (0,1)z\,dz = \int_{0}^{0,22} 0,1z\,dz = 0,05z^2\Big|_0^{0,22} = 0,00242$$

$$\int_{0,22}^{0,27} (0,1)z\,dz = \int_{0,22}^{0,27} 0,1z\,dz = 0,05z^2\Big|_{0,22}^{0,27} = 0,001225$$

$$\int_{0}^{0,24} (0,2)z\,dz = \int_{0}^{0,24} 0,2z\,dz = 0,1z^2\Big|_0^{0,24} = 0,00576$$

$$\int_{0,22}^{0,24} (5z - 1)z\,dz = \int_{0,22}^{0,24} 5z^2 - z\,dz = \frac{5z^3}{3} - \frac{z^2}{2}\Big|_{0,22}^{0,24} = 0,0007$$

$$\int_{0,27}^{0,3} (1 - 3,3z)z\,dz = \int_{0,27}^{0,3} z - 3,3z^2 dz = \frac{z^2}{2} - \frac{3,3z^3}{3}\Big|_{0,27}^{0,3} = 0,0005$$

To get the center point, the area of the implication area is needed so that the following value is obtained:

$A\alpha_{11} = \frac{(0,3 + 0,27)\ x\ 0,1}{2} = 0,0285$

$A\alpha_{12} = \frac{(0,3 + 0,24)\ x\ 0,2}{2} = 0,054$

Furthermore, the center point is obtained:

$$z^* = \frac{M1 + M2 + M3 + M4 + M5}{A\alpha_{11} + A\alpha_{12}}$$

$$z^* = \frac{0{,}00242 + 0{,}001225 + 0{,}00576 + 0{,}0007 + 0{,}0005}{0{,}0285 + 0{,}054}$$

$$z^* = \frac{0{,}010605}{0{,}0825}$$

$$z^* = 0{,}13$$

From the results of the defuzzification step, a final value of 0.13 is obtained. This value is the recommendation level indicating that the sample is “not recommended” in this case which proves that the calculations carried out are in accordance with the rules that have been used, namely “If the protein content is very low and the price is medium, then the sample is not recommended” and “If the protein content is low and the price is medium, then the sample is not recommended”.

Fuzzy Assertion Analysis Using Computer Application

Raw data from the input variables, namely price and nutrition, are converted into fuzzy sets, then processed using predefined fuzzy rules to generate recommendations based on the Mamdani method. In the defuzzification process, the fuzzy value of the output is converted back to a firm value to provide recommendations for ideal packaged milk. This research aims to determine the appropriate milk packaging for consumers in terms of price and protein nutrition content, using fuzzy logic through the FIS (Fuzzy Inference System) application on a computer. The steps are as follows:

1. First determine the desired inputs and outputs. In this case, the price of milk packaging and its protein nutrient content are determined as inputs. Meanwhile, the output is the recommended milk package for consumers.
2. Next, the universal set of milk price, milk protein content, and milk recommendation is defined. The price and protein content are respectively expressed in the interval price = [0, 20] and nutrition = [0, 11].
3. The next step is fuzzification, which involves defining the membership level of each input and output. Price is broken down into five levels: very cheap (VC), cheap (C), medium (Med), expensive (E), and very expensive (VE). Protein content is broken down into five levels: very low (VL), low (L), medium (Med), high (H), and very high (VH). The output recommendation has three levels: not recommended (NR), less recommended (LR), recommended (R), and highly recommended (HR).
4. The next step is to determine the fuzzy rules that will be used to determine the recommendation of packaged milk for consumers.
5. The last stage is defuzzification carried out to calculate the membership degree of each sample. The degree of membership of the recommendation of each sample is calculated by entering the price value and protein content into the system. For example, the substitution of the protein content and price values of sample 1 results in the degree of membership in the recommendation column as shown in Figure 5.

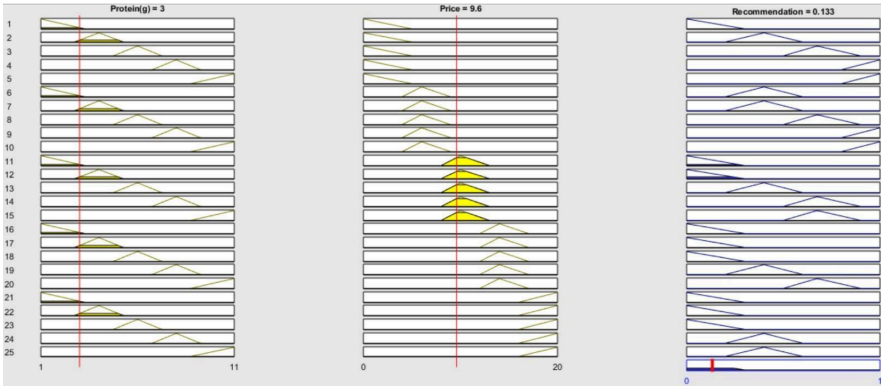

Figure 5 Rule Viewer

Figure 5 shows the results of fuzzy analysis on three main variables: protein content, price, and recommendation value for 32 packaged milk samples. The first column shows the distribution of protein content, with the reference line at 3 grams. The second column depicts the variation in price with the reference line at 9.6, which is considered the medium price. The last column shows the fuzzy recommendation value, with 0.133 as the reference. Only a few samples have recommendation values above this reference, indicating conformity to the ideal criteria based on price and protein content. This figure clarifies the products that meet the ideal criteria in terms of nutrition and price.

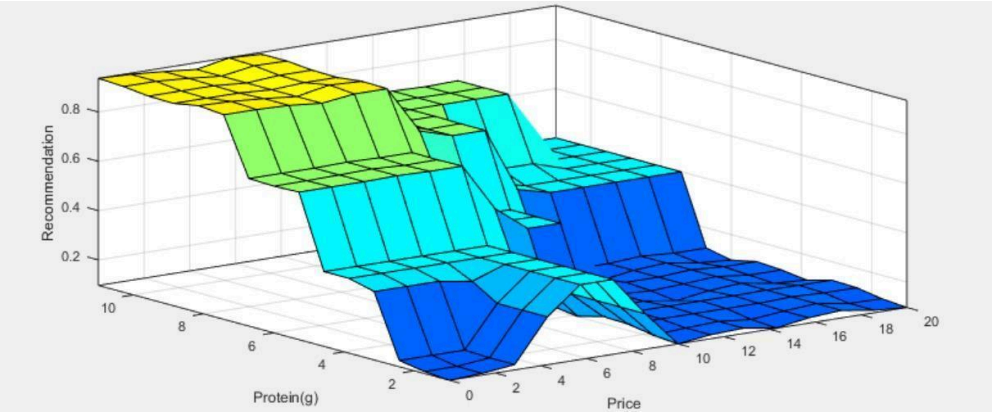

Figure 6. Rule Viewer

After analyzing the fuzzy logic model, the recommendation results for purchasing packaged milk are determined based on protein content and price. In the second figure, the surface plot displays the results of the rules made in fuzzy logic for the two input variables. Surface viewer is useful to see the mapping relationship between output and input variables. The result of this surface viewer is a three-dimensional graph with X, Y, and Z axes that displays the relationship of protein content and price to the level of recommendation output (Ramdani 2015).

The second figure is a surface plot that displays the results of the mapping between two input variables (protein and price) to the recommendation output, based on the fuzzy rules applied. The color gradient, from yellow to blue, indicates the recommendation level; yellow represents a high recommendation level and blue indicates a low recommendation. High recommendation scores appear in the combination of products with high protein content and affordable prices, indicating consumer preference for products with optimal nutrition at reasonable prices. Conversely, products with high prices but low protein content received low recommendation scores (Ramadhan *et al.,* 2020).

From these results, it appears that protein content has a positive correlation to recommendation; the higher the protein content, the higher the recommendation level. Price, on the other hand, has a negative correlation with recommendation; the higher the price, the lower the recommendation level, especially if it is not supported by a high enough protein content. This fuzzy logic model effectively considers the balance between nutrition and price to provide packaged milk recommendations that suit consumer needs, with fuzzy logic principles handling uncertainty in determining preferences.

CONCLUSION

The conclusion of this study shows that the fuzzy logic approach used in the research successfully provides optimal packaged milk product recommendations by considering the balance between nutritional content and price. The fuzzy assertion process is carried out by inputting price and protein content variables as inputs, which are then converted through the fuzzification, rule formation, and defuzzification processes to produce clear recommendations. By using a Fuzzy Inference System (FIS) system based on MATLAB application.

Analysis of the displayed graph shows that products with high protein content and affordable prices tend to have higher recommendation scores. This result illustrates the positive correlation between protein content and recommendation level, while product price shows a negative correlation. This means that the higher the protein content of the packaged milk and the more affordable the price, the more recommended the product is to consumers. Conversely, products with a high price but low protein content received a low recommendation score, indicating that these products do not meet the needs of consumers who want nutritious products at a reasonable price.

Overall, this fuzzy logic model demonstrates efficiency in handling uncertainty and variations in consumer preferences in the food industry, particularly in packaged dairy products. With surface plots that map the relationship between inputs and outputs, the results of this analysis provide a clear visualization of products that meet the ideal criteria of nutrition and price. The model provides alternatives for consumers in choosing suitable products, and has the potential to be implemented more broadly on a variety of other food products to support data-driven decision-making and nutritional needs.

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