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# Application of Fuzzy Inference System for Quality Assessment of Formula Milk for Pregnant Women in Stunting Program

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## ABSTRACT

Abstract— Stunting remains a significant global public health challenge, affecting more than 149 million children under five years of age worldwide as reported by the United Nations in 2020. Indonesia alone accounts for approximately 6.3 million stunted children, highlighting the urgent need for effective intervention strategies. Stunting is primarily caused by chronic malnutrition during the first 1,000 days of life, which includes inadequate nutritional intake during pregnancy, poor infant feeding practices, and environmental factors such as inadequate sanitation. The 2022 Indonesian Nutrition Status Survey (SSGI) indicated a stunting prevalence of 21.6%, showing improvement from 24.4% in 2021, yet still significantly above the national target of 14% set for 2024. Given the critical role of maternal nutrition in reducing stunting risk, providing pregnant women with appropriate nutritional guidance is essential. This study aims to develop a decision support model using a Fuzzy Inference System (FIS) to assist pregnant women in selecting the most suitable formula milk based on nutritional value and affordability. The Mamdani FIS method was applied to analyze data from eight commercially available formula milk products. The evaluation measured the membership degrees corresponding to recommendation levels, factoring in both price and nutrition. The results identified Anmum Materna as the most favorable option, with a membership degree of 0.937, classified under the "Highly Recommended" category. This formula is priced at IDR 70,000 and contains a total nutritional value of 1024 grams, offering a balance of quality and affordability. This model demonstrates potential as a practical tool to support informed nutritional choices during pregnancy, contributing to stunting prevention efforts.

Keywords: *fuzzy, mamdani, maternal, milk, nutrition, stunting.*

## I. INTRODUCTION

Based on UN 2020 data, more than 149 million children under five in the world are stunted, with 6.3 million of them in Indonesia. According to UNICEF, factors such as malnutrition in children in their first two years of life, lack of nutrition in mothers during pregnancy, and poor sanitation contribute to stunting. This highlights the urgency of addressing stunting with a holistic approach involving nutrition interventions, maternal and child health services, and improved sanitation to ensure optimal child growth and development [5].

Indonesia's high stunting rate, reaching 21.6% according to the 2022 Survey on the Status of Nutrition in Indonesia (SSGI), highlights the serious challenges in improving children's well-being. Despite a decrease from the previous year, which reached 24.4% in 2021, the rate is still far from the national

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target set at 14% by 2024. Stunting, which is a condition of failure to thrive in children, not only impacts physical height, but also has the potential to cause long-term health problems, including stunted cognitive development and weakened immunity [6].

The importance of fulfilling maternal nutrition since early pregnancy is an important highlight in stunting prevention. The prevalence of stunting in newborns, at 18.5% with a body length of less than 48 cm, shows that this condition can occur even before birth. Therefore, greater attention to maternal nutrition before and during pregnancy is crucial. A better understanding of the importance of adequate nutrition, easy access to quality maternal health services, and support in implementing healthy nutrition practices are important steps in reducing the prevalence of stunting and creating a healthier generation with more potential [6].

The pregnancy period affects the quality of future human resources because the condition of the fetus in the womb greatly affects its development [7]. The first trimester requires 2485 Kcal per day, while a normal adult woman only needs 2200 Kcal. The second and third trimesters require an additional 285 Kcal per day. The diet of pregnant women should follow the 4 healthy 5 perfect formula with additional consumption of milk as a source of animal protein that is rich in nutrients and easily digested. Fulfillment of calcium through milk as recommended is the best choice [8].

One important aspect of pregnant women's nutritional intake is milk consumption, which is a source of essential nutrients such as protein, calcium, and vitamins. However, the quality assessment of milk used by pregnant women today is often conventional and inaccurate [9]. This is where the importance of applying the fuzzy inference system method in assessing the quality of milk for pregnant women as part of the strategy to support the stunting prevention program.

The fuzzy inference system method allows the use of a more flexible and adaptive approach in assessing milk quality based on various complex and often ambiguous factors [10]. By utilizing data on the nutritional content of milk, the health condition of pregnant women, and other relevant factors, fuzzy inference systems can produce more accurate and reliable milk quality assessments..

## II. RESEARCH METHODS

This research focuses on the mathematical analysis of dairy products using fuzzy logic method. Within the framework of this research, data was collected from infant formula products available in supermarkets and minimarkets in the research locations. In addition, data was also collected online from various sources such as e-commerce sites and official websites of manufacturers of infant formula. A total of 8 samples of infant formula, namely:

1. Anmun Materna
2. Lactamil
3. Frisomum Gold
4. SGM Bunda
5. Prenagen Emesis
6. Frisian Flag Mama
7. Vidoran Ibunda
8. Enfamama A+

The data analyzed included the content of nutrients such as protein (P), calcium (K), vitamin B9 (folic acid), iron, vitamin A, vitamin B6, vitamin B12, vitamin C, and vitamin D, which were then accumulated into total nutrients (NT).

This research method is an applied research that aims to build a model for determining the best formula milk drink for pregnant women based on price and nutrition variables. The steps used in this research include the fuzzification process, determination of fuzzy rules, fuzzy inference with the Mamdani method, and the defuzzification process.

1. Determine Input and Output Variables
   The first step is to determine the variables that will be used as input and output in the fuzzy model. Input variables may include price and nutritional content such as calories, fat, protein, and others, while the output variable is a recommendation for the quality of infant formula for pregnant women.
2. Define the Universal Set of Inputs and Outputs

After defining the input and output variables, the next step is to define the universal set for each variable. This includes determining the range of values that each input and output variable can take.

3. Fuzzification
   The fuzzification process involves converting the numerical values of the input variables into fuzzy values. This is done by using membership functions to convert numerical data into membership levels in fuzzy sets.
4. Determining Fuzzy Rules for Milk Selection
   The next step is to formulate fuzzy rules that will be used to determine recommendations for pregnant women's formula. These rules connect input variables with outputs based on certain knowledge and logic.
5. Determining Fuzzy Inference
   In the fuzzy inference stage, predefined rules are applied to obtain fuzzy results from the fuzzified inputs. This process uses fuzzy logic mechanisms to generate fuzzy outputs.
6. Defuzzification
   The final step is defuzzification, which converts the fuzzy results back into numerical values that can be interpreted as concrete recommendations. This process produces an output value that provides a recommendation for the best maternity formula based on fuzzy logic analysis.

This study analyzes price data and nutritional content of 8 samples of formula milk products for pregnant women. The goal is to produce optimal formula recommendations for pregnant women using fuzzy logic. Data analysis is carried out with the Mamdani model using the Fuzzy Inference System (FIS) in the MATLAB application.

## III. RESULTS AND DISCUSSIONS

The nutrient content and price data of each sample are shown in Table 1 below:

*Tabel 3. 1 Price Data and Nutricient Content of Samples*

| No | Price IDR | P (g) | K (g) | Vit B9 (g) | Iron (g) | Vit A (g) | Vit B6 (g) | Vit B12 (g) | Vit C (g) | Vit D (g) | NT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 70.000 | 44 | 120 | 180 | 100 | 100 | 140 | 160 | 140 | 40 | 1024 |
| 2 | 87.000 | 48 | 100 | 120 | 100 | 80 | 120 | 120 | 120 | 40 | 848 |
| 3 | 95.000 | 52 | 80 | 80 | 100 | 80 | 100 | 100 | 140 | 40 | 772 |
| 4 | 35.000 | 33 | 60 | 60 | 75 | 60 | 60 | 90 | 75 | 24 | 537 |
| 5 | 86.625 | 44 | 140 | 180 | 80 | 100 | 160 | 120 | 120 | 40 | 984 |
| 6 | 45.000 | 22 | 60 | 40 | 50 | 40 | 60 | 60 | 70 | 70 | 472 |
| 7 | 35.000 | 31,5 | 70 | 122,5 | 105 | 70 | 105 | 70 | 105 | 35 | 714 |
| 8 | 135.890 | 52 | 100 | 100 | 80 | 80 | 120 | 80 | 120 | 24 | 756 |

This research uses the Mamdani fuzzy approach to analyze the data. This process involves five main steps: fuzzy set identification, fuzzification, fuzzy rule formation, inference, and defuzzification. The initial data was presented in percentage format. To convert percentages to grams, the percentage number is divided by one hundred and the result is multiplied by the weight of the dairy product in question. With this conversion, the data can be converted into grams, enabling further analysis regarding the optimization of the nutritional content of the dairy products.be identified, as well as understanding how the model adapts to changes in the input data.

3.1 Defining Fuzzy Variables and Value Ranges

*Tabel 3. 2 Defining Fuzzy Variables and Value Ranges*

| Function | Variable Name | Conversation Set |
|---|---|---|
| Input | Harga | [0 140000] |
| | NT | [0 1025] |
| Output | TK | [0 1] |

3.2 Perform Fuzzification

This process involves determining and calculating the membership function for each variable based on the collected data. For example, the price variable is divided into five membership levels: very cheap (SU), cheap (MU), medium (S), expensive (MA), and very expensive (SM). The same is true for the variables of total nutrition and recommendation level, each of which is classified into several membership levels according to the relevant categories.

Price fuzzy variable

$$\mu_{(SU)} = \begin{cases} \left(\frac{30.000-x}{30.000-0}\right); & 0 \le x \le 30.000 \\ 0; & x \ge 30.000 \end{cases}$$

$$\mu_{(MU)} = \begin{cases} 0; & x < 20.000 \; atau \; x > 60.000 \\ \left(\frac{x-20.000}{30.000-20.000}\right); & 20.000 \le x \le 30.000 \\ 1; & 30.000 \le x \le 50.000 \\ \left(\frac{60.000-x}{60.000-50.000}\right); & 50.000 \le x \le 60.000 \end{cases}$$

$$\mu_{(S)} = \begin{cases} 0; & x < 50.000 \; atau \; x > 90.000 \\ \left(\frac{x-50.000}{60.000-50.000}\right); & 50.000 \le x \le 60.000 \\ 1; & 60.000 \le x \le 80.000 \\ \left(\frac{90.000-x}{90.000-80.000}\right); & 80.000 \le x \le 90.000 \end{cases}$$

$$\mu_{(MA)} = \begin{cases} 0; & x < 80.000 \; atau \; x > 120.000 \\ \left(\frac{x-80.000}{90.000-80.000}\right); & 80.000 \le x \le 90.000 \\ 1; & 90.000 \le x \le 110.000 \\ \left(\frac{120-x}{120-110}\right); & 110.000 \le x \le 120.000 \end{cases}$$

$$\mu_{(SM)} = \begin{cases} 0; & x < 110.000 \\ \left(\frac{x-110.000}{120.000-110.000}\right); & 110.000 \le x \le 120.000 \\ 1; & 120.000 \le x \le 140.000 \end{cases}$$

3.3 Implementation of Fuzzy Logic FIS with MATLAB

In this research, a method to determine the appropriate formula for pregnant women by considering the balance between price and nutrition will be examined. The approach used is fuzzy logic with Fuzzy Inference System (FIS) implemented using MATLAB software.

The steps to be executed are as follows:

### 3.3.1. Input and Output Identification

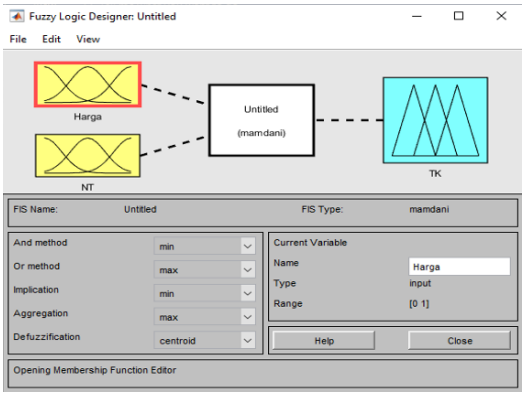


*Figure 3 1 Determination of Input and Output Parameters in FIS Editor*

### 3.3.2. Fuzzification

The next step in this process is fuzzification to define fuzzy sets for the parameters of price, nutrition, and recommendation of infant formula for pregnant women. The value range for price is [0 - 140,000], while nutrition has a range of [0 - 1025] and the recommendation level has a range of [0-1]. This fuzzification is done to establish the membership level of each input and output, which is then implemented in MATLAB to produce graphs that demonstrate the fuzzification process visually.

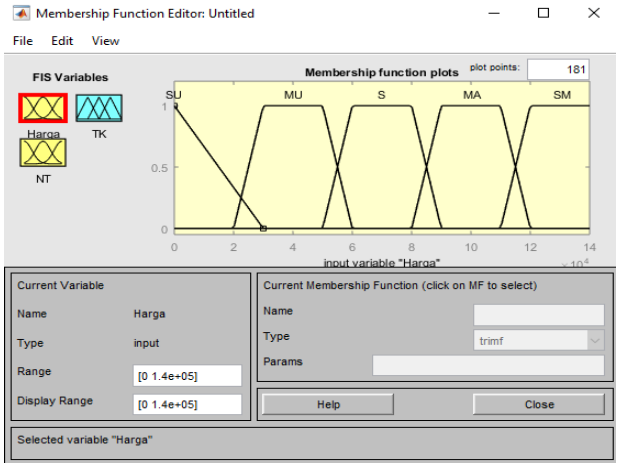


*Figure 3 2 Price Membership Level Chart*

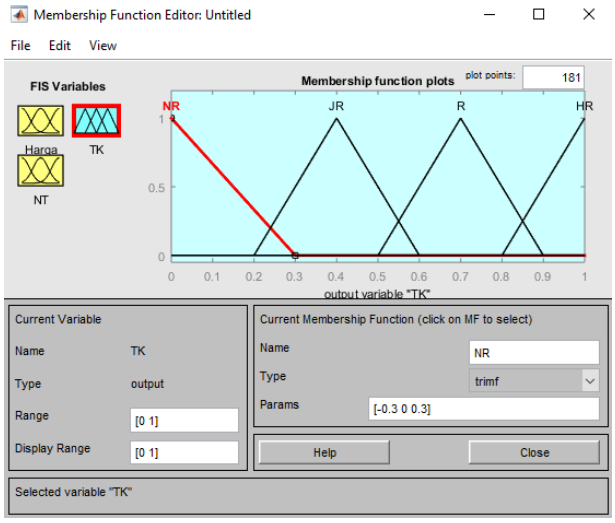


*Figure 3 3 NT Membership Grade Chart*

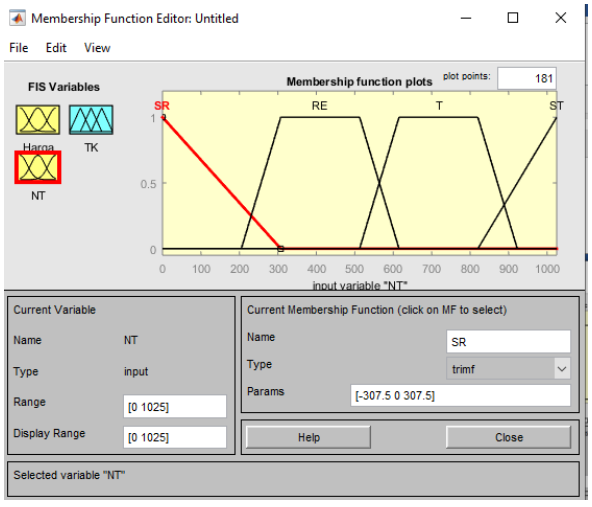


*Figure 3 4 TK Membership Grade Chart*

The next step is to set up fuzzy rules to determine milk formula recommendations for pregnant women. For sample 1 in table 1, with a price of Rp 70,000 and NT 1024, we find the membership level of milk recommendation, namely μ(x) and μ(y), with x=1024 and y=70,000. The calculation result shows

$\mu_{SR}(1024) = 0$
$\mu_{R}(1024) = 0$
$\mu_{T}(1024) = 0$

$\mu_{SU}(70.000) = 0$
$\mu_{MU}(70.000) = 0$
$\mu_{S}(70.000) = 1$

$\mu_{ST}(1024) = \frac{1024-820}{1025-820} = 1$ $\mu_{MA}(70.000) = 0$

$\mu_{SM}(70.000) = 0$

Furthermore, calculating the predicate of each rule with the Min implication function in sample 1 of table 1, with μ_ST (1024)=1; μ_S (70,000)=1 is as follows:

$\alpha_1 = min[\mu_S(70.000), \mu_{ST}(1024)] = min[1\ ; 1] = 1$

3.3.3. Fuzzy Rule Formation

Based on the rules that have been created :

- [R1] IF the price is very cheap (SU) AND the nutritional content is very high (ST) THEN highly recommended (HR).
- [R2] IF the price is very cheap (SU) AND the nutritional content is high (T) THEN recommended (R).
- [R3] IF the price is very cheap (SU) AND the nutritional content is low (RE) THEN less recommended (LR).
- [R4] IF the price is very cheap (SU) AND the nutritional content is very low (SR) THEN not recommended (NR).
- R5] IF the price is low (MU) AND the nutritional content is very high (ST) THEN highly recommended (HR).
- R6] IF low price (MU) AND high nutritional content (T) THEN recommended (R).
- R7] IF low price (MU) AND low nutritional content (RE) THEN less recommended (LR).
- R8] IF low price (MU) AND very low nutritional content (ST) THEN not recommended (NR).
- R9] IF medium price (S) AND very high nutritional content (ST) THEN highly recommended (HR).
- [R10] IF the price is medium (S) AND the nutritional content is high (T) THEN recommended (R).
- R11] IF price is medium (S) AND nutritional content is low (RE) THEN less recommended (LR).
- [R12] IF price is medium (S) AND nutritional content is very low (SR) THEN not recommended (NR).
- R13] IF the price is expensive (MA) AND the nutritional content is very high (SR) THEN recommended (R).
- [R14] IF the price is expensive (MA) AND the nutritional content is high (T) THEN recommended (R).
- [R15] IF the price is expensive (MA) AND the nutrient content is low (RE) THEN not recommended (LR).
- [R16] IF the price is expensive (MA) AND the nutritional content is very low (SR) THEN not recommended (NR).
- R17] IF the price is very expensive (SM) AND the nutritional content is very high (ST) THEN recommended (R).
- R18] IF the price is very expensive (SM) AND the nutritional content is high (T) THEN recommended (R).
- R19] IF the price is very expensive (SM) AND the nutritional content is low (RE) THEN not recommended (LR).

- [R20] IF the price is very expensive (SM) AND the nutrient content is very low (SR) THEN not recommended (NR).

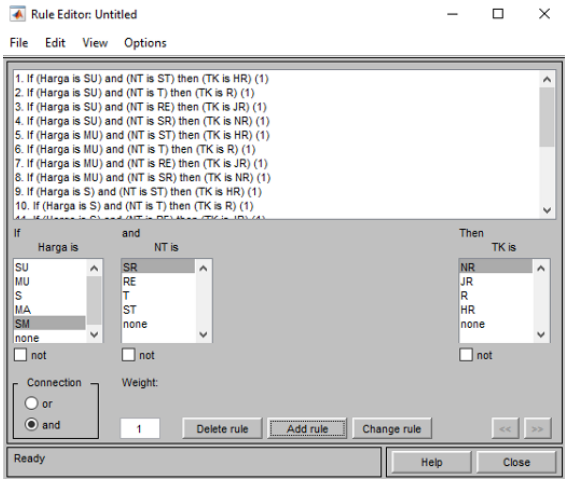


*Figure 3 5 Fuzzy Rules*

### 3.3.4. Defuzzification

The last step is the defuzzification process, where the membership degree of each sample is calculated based on the nutritional content and price. By entering the nutritional content and price values of the first sample, the membership degree in the recommendation column is obtained as shown in Figure 6. This result shows the membership degree for the recommendation in the first sample.


*Figure 3 6 Memberhip Degree Canculation of Sample 1 Recommendation*

Using the price and total nutritional value of sample 1 [70,000; 1024], a substitution is made in the input section. As a result, the membership degree for the recommendation of pregnant women's milk in sample 1 is 0.937. The same step is repeated for the other 7 samples of infant formula. The membership degree results of the 8 formula milk samples are organized in Table 4.3 based on the order of recommendation.

*Tabel 3. 3 Membership Degree Sequence of Each Formula Milk Sample*

| No | Price (Rp) | NT(g) | Orde | Category |
|---|---|---|---|---|
| 1 | 70.000 | 1024 | 0.937 | HR |
| 5 | 86.625 | 984 | 0.748 | R |
| 2 | 87.000 | 848 | 0.72 | R |
| 7 | 35.000 | 714 | 0.7 | R |
| 3 | 95.000 | 772 | 0.7 | R |
| 8 | 135.890 | 756 | 0.7 | R |
| 4 | 35.000 | 537 | 0.49 | LR |
| 6 | 45.000 | 472 | 0.4 | LR |

Description:

NR : Not recommended

LR : Less recommended

R : Recommended

HR : highly recommended.

The table above presents the results of the fuzzy logic analysis of 8 samples of infant formula for pregnant women, evaluated based on price and total nutritional value (NT). Focus was given to samples with high membership degrees and affordable prices. Anmum Materna formula milk has the highest membership degree (0.937) with a price of IDR 70,000 and NT of 1024 grams, belonging to the "Highly Recommended" category. There are also other recommended samples, such as samples 5 and 2, although at a slightly higher price.

Sample No. 7 has a lower price (IDR 35,000) because the package is 350 grams, which is smaller than the general size (400 grams). Nonetheless, this sample is still recommended with a degree of membership of 0.7, indicating this product is still in the recommended category. The low price does not lower the quality of the recommendation based on the calculated membership degree.

## CONCLUSION

Based on the results obtained with the fuzzy logic method on 8 samples of formula milk for pregnant women, sample 1, Anmum Materna, stands out as the top choice with the highest membership degree of: 0.937 at a price of Rp 70,000 with a total nutrition of 1024 grams, falling into the “Highly Recommended” category. It was also found that other samples, namely 5 (Prenagen emesis) and 2 (Lactamil) were also recommended with fairly high membership degrees of 0.748 and 0.72, albeit at slightly higher prices of Rp. 86,625 and Rp. 87,000, respectively. Sample No. 7 (Vidoran Ibunda), with a lower price of IDR 35,000 and 350 gram packaging, is still recommended with a membership degree of 0.7, indicating good quality relative to its low price. Thus, Anmum Materna is the top choice for finding the best pregnancy milk with affordable price and high nutrition.

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