Implementation of Fuzzy Logic in Determining Recommendations for Purchasing Folic Acid Supplements based on Fruit and Vegetable Consumption Patterns in Pregnant Mothers

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Abstract

This research aims to implement fuzzy logic in determining the level of recommendation for folic acid supplements based on the input of the amount of vegetable and fruit consumption and folic acid content. The output of the developed system is in the form of recommendation level with categories of "not recommended", "less recommended", and "recommended". This research data was obtained based on literature studies and through observation of samples of supplements containing folic acid in several related pharmacies. This research method includes direct calculations and the use of MATLAB. The results show that in the example case with the amount of vegetable and fruit consumption of 550 with a folic acid content of 175 can produce an output value of 400 which puts the recommendation level based on dosage in the "not recommended" position. This result has been verified both through direct calculation and the use of MATLAB software. Studies have concluded that the application of using of fuzzy logic can help in providing supplement levels. This contributes to considerate of decision-making in the community, especially in pregnant women, which can help determine the supplements consumed so that the fulfillment of daily consumption of folic acid content can be met.

Keywords: folic acid, fuzzy logic, Mamdani, MATLAB, supplement recommendations

INTRODUCTION

Pregnancy is a natural phase that involves the meeting of two different cells, namely sperm and ovum in the ovary until a zygote is formed. The conception process continues until the birth of the fetus into the world. During pregnancy, energy metabolism in the body will increase. The process of fetal growth and development, the changes of uterine organs size, the composition and metabolism of mother's body are all impacted by increased energy that pregnant women experience. To equilibrate such increased energy, a pregnant mother should take care of food consumption to meet the needed nutrients during pregnancy. Consumption of these nutrients consists of various substances and compounds such as carbohydrates, proteins, vitamins, minerals, fats, and vitamins, especially folic acid which is more than the state when not pregnant (Ernawati, 2017).

Folic acid is vitamin B9 which acts as a coenzyme in the body. Folic acid will be active in tetrahydrofolate which carries one carbon unit in metabolism. Folic acid intake during pregnancy is necessary to avoid birth defects in newborns such as low birth weight, neural tube defects, anencephaly, spina bifida, placental detachment, and megaloblastic anemia (S. Nisa & Handayani, 2019). Based on research conducted by Atunnisa 2020, The Ministry of Health in Indonesia (2018) stated that the outcomes of a survey conducted from September 2014 to March 2018 on infants born with congenital abnormalities in Indonesia showed that NTDs or abnormality in structural structure of the central nervous system and vertebral bones were the third most common cause of total cases of birth defects with a percentage of 18.4%. NTD or neural tube defects are often associated with the phenomenon of insufficient consumption of folic acid intake in pregnant women.

According to Septiyeni et al., 2016, the average rate of folic acid consumption is 341.95 µg/hr in pregnant women in Padang. This consumption figure is still quite far from the recommended consumption of folic acid intake which should be done before pregnancy for at least three months as much as 0.4 mg or 0.8 mg per day through the gestation period to lower the potential of birth defects in infants (Atsani et al., 2021). This deficiency can be caused by the lack of consumption of folic acid sources from food sources such as vegetables, fruits, and nuts. In addition to eating vegetables and fruits, to support folic acid intake in pregnant women can also be helped by consuming folic acid supplements (Eka & Sikumbang, 2016). The purchase of folic acid supplements can be influenced by several factors and their determination can be helped by recommendations. The identification can be helped by applying of fuzzy logic.

Fuzzy logic is a method of solving problems of uncertainty and complexity in optimization and an integral component of artifical intelligence systems that can mimic human thinking by using algorithms to process data (Sitompul et al., 2024). This metod will map inputs into outputs by involving factors so that it is possible to process uncertain information and make decisions based on a scale between 0 and 1. Thus, the resulting decisions are more accurate and realistic by considering the factors involved and compromising on various choices (Haque & Sriani, 2023). This fuzzy logic itself has several methods in the fuzzy inference system include Tsukamoto, Mamdani, and Sugeno Method (Kartika et al., 2018). Of the methods mentioned, the Mamdani Method is the oldest. The fuzzy inference system of mamdani method is commonly used in fuzzy models because of its ability to produce results that are easy to interpret with a straightforward structure (Nisa et al., 2024). This research performs fuzzy logic calculations based on using MATLAB software calculations. MATLAB software is one of the high-level programming language tools developed by MathWorks, especially in the fields of numerical computing, visualization, and programming (Shuhaila et al., 2024). The calculation results derived from the MATLAB software will be compared with the outcomes of manual calculations.

The application of using fuzzy logic has been widely used in various types of research, such as in helping determine elections or recommendations. In research conducted by Al-jabbar, 2024 mamdani's fuzzy logic can analyze instant noodle recommendations based on a combination of nutrients and products. The results showed that sample 2 instant noodles were obtained with the highest degree of membership out of 25 other instant noodle samples and were recommended best because of their high nutritional content and fairly economical prices. However, the study has not developed other alternative models so that the results obtained are less exploratory.

In addition, fuzzy logic can also be used in the analysis method of determining the number of calories of pregnant women. The research conducted by Kartika & Safira, 2020 explains that the fuzzy mamdani logic can be applied in determining the criteria for the number of calories of pregnant women based on determining height, weight, and age. The results of the study explained that fuzzy mamdani logic helps in calculation efficiency, analysis data processing, and decision making appropriately and accurately in determining the nutritional needs of pregnant women to be balanced. Even so, the

calculation and data analysis in the study were not presented related to the comparison of calculations so that the resulting data was less accurate because there was no comparison in the data processing carried out.

Further research was also conducted by Surbakti et al., 2020 on the use of mamdani method in optimizing tempe yeast on soybean fermentation. In light of the study's outcome, mamdani fuzzy logic is able to help the process of determining the optimization of the use of tempeh yeast with a comparatively high degree of precision which 93.75%. However, the determination of variable domain ranges and fuzzy sets needs to be considered again in optimization so that the concept of the fuzzy method can be implemented properly and thoroughly. The development of predictive optimization of yeast in soybean fermentation can also be done by adding variables and sets to fuzzy.

From several previous studies about the implementation of fuzzy logic using mamdani method, this research will implementing fuzzy logic using mamdani method to determine the recommendations for purchasing folic acid supplements for pregnant women to support folic acid consumption needs. The purpose of using this method is to enrich the research that has been done so the development of insight and preparation of this journal are expected to be better than previous research. This is proven by verification through direct calculation and based on the results of MATLAB software. The combination of verification is to compare the two results and produce a more accurate output.

METHODS

According to Adiguna & Widagdo 2023, fuzzy logic is a logic with real data types, multiple values, and truth values between 0 and 1. Fuzzy logic can help resolve uncertainty between on criterion and another (Nisa et al., 2020). Therefore, fuzzy logic is often used in various studies such as in helping to determine the selection or recommendation and determination in decision making. The advantage of fuzzy logic is can relate between inputs and ouputs without ignoring existing factors. The fuzzy logic is recognized as having high tolerance and flexibility to the data used in its use (Sufarnap & Sudarto, 2019).

Research Design

The research design used is about research case studies in providing decisions. The purpose of this design is to determine recommendations for purchasing folic acid supplements in pregnant women to support the needs of folic acid consumption.
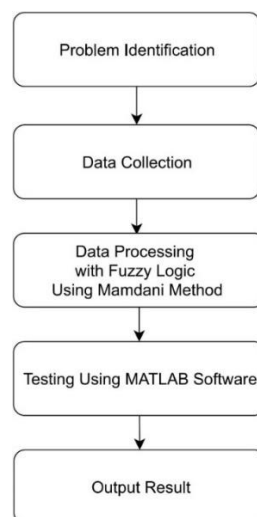

Figure 1. Reaserch Design

The research design conducted on the application of fuzzy logic in determining recommendations for folic acid content in purchasing supplements to support folic acid needs in pregnant women as follows:

a. Problem Identification

Problem identification was carried out to determine the problem in this study, namely the presence of abnormalities in infants because of lack of folic acid amount of consumption in pregnant mothers.

b. Data Collection Techniques

Data collection was carried out by looking for literature studies on the average amount of vegetable and fruit consumption in pregnant women and the dose of folic acid consumption that will be used to determine supplement recommendations. In addition, observations will also be made in determining samples, namely supplements containing folic acid in several related pharmacies.

c. Data Processing Techniques

The collected data is then analyzed with fuzzy logic mamdani method.

d. Data Testing Using MATLAB

The calculations in this study were tested manually first, and then to find out the right results, the researchers used MATLAB software.

e. Result

The last stage is to issue the outcomes of computations done by manual and processed using the mamdani technique and the calculation results using MATLAB software. Both results will be compared for accuracy so that the results listed are accurate using MAPE. MAPE calculation is a calculation that compares prediction results with actual actual data so that an error value is obtained from the prediction using the following formula:

$$MAPE = \left| \frac{Xt - Ft}{Xt} \right| x \ 100\%$$

Information:
Xt : Actual data
Ft : Predicted value

The results of forecasting value is able to state to be good if it has a small deviation value from the actual value. If MAPE has a value $< 10\%$, the value can be state as excellent (Fakriyana & Brilliant, 2023). MAPE (Mean Absoluet Percent Error) is used when the size of the forecasting variable is an important factor in evaluating the accuracy of the forecast. MAPE shows an indication of how much the forecasting error is compared to the actual value of the series (Barus & Ramli, 2013). The usage of Mean Absolute Percentage Error (MAPE) in fuzzy logic aims to evaluate forecasting results by the level of accuracy of forecasting figures and realization figures (Nabillah & Ranggadara, 2020).

Location and Time of Research

The research was conducted by searching for literature studies and determining samples of supplements containing folic acid from several pharmacies in one of the Bogor areas on April 9, 2024.

System Design

The research's analytical method is fuzzy logic with the type of mamdani approach assisted by the FIS (Fuzzy Inference System) program on the computer applications. The mamdani technique is commonly known as the min-max system. According to Rahakbauw et al., 2019 states that there are four stages to using this method, namely: (1) Define fuzzy set; (2) Application for implication functions; (3) Composition between rules; and (4) Affirmation or defuzzification.

1. Define fuzzy set

In define fuzzy set, both inputs and outputs are split into two or more fuzzy sets. Furthermore, the degree of membership of each variable is determined, so that the linguistic value will be obtained (Widaningsih, 2017).

2. Application for implications function

Applying the implication function to get the conclusion of an IF-THEN rule is done based on degrees of truth. The implication function used is the MIN function by taking minimum membership from input variables as the output (Rahakbauw et al., 2019).

3. Composition between rules

The composition of the rule uses the MAX function, so in this process the rules's maximum value is selected and also used to modify the fuzzy region.

4. Affirmation or defuzzification

The input of affirmation or defuzzification is the fuzzy set resulting from the composition of fuzzy rules, while the output comes from a fuzzy set domain number.

Design Framework

The framework explains the sequence that is systematically made so it can be used as a reference is solving existing problems. Each step carried out is interrelated with other steps. This study aims to provide the best recommendations for folic acid supplements products that can be purchased for pregnant mom. Through the target of the research, there are things to consider such as the average amount of fruit and vegetable along with the folic acid consumption in pregnant mom. Both variables are inputs based on the data step in the research design section of data collection with a description through the design framework. As for the expected output is a folic acid supplement product with recommended dose beside 3 categories, there are not recommended, less recommended, and recommended.

The determination of the output is based on the member function. Member functions have the purpose determining firm value (crips) where the X is the variable and the Y is the membership degree (Rachman & Nuryuliani, 2022). The method used to achieve these goals is the fuzzy logic using mamdani method and MATLAB software. The following is a diagram of the framework in solving problems in this study:
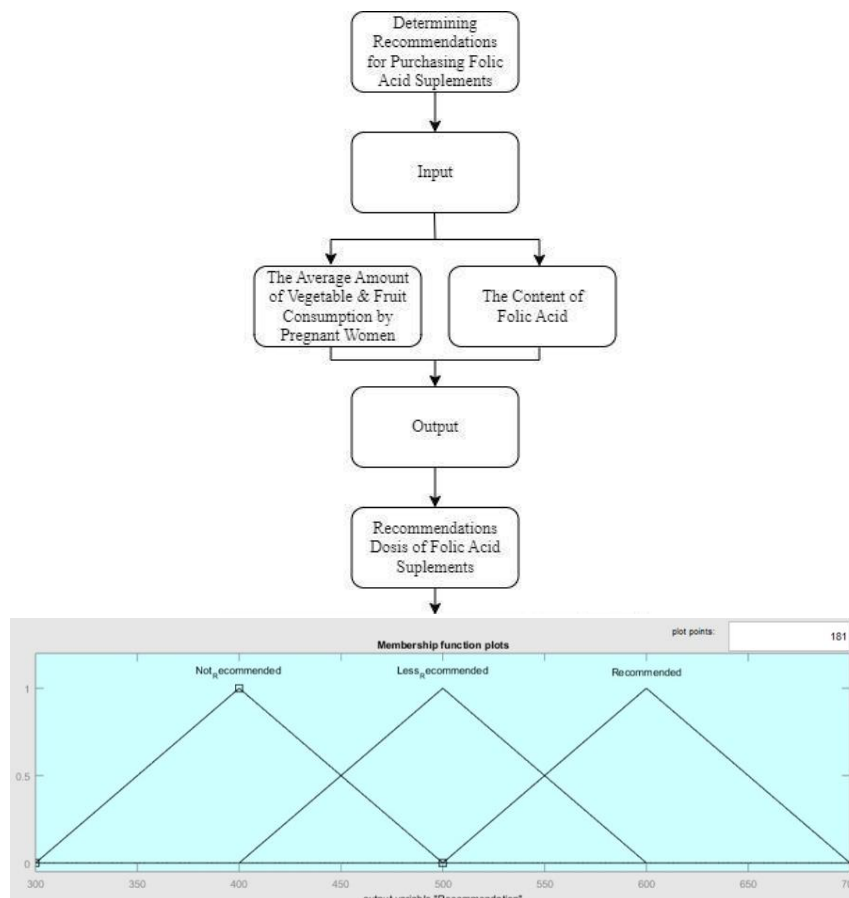

Figure 2. Design Thinking Framework

RESULTS AND DISCUSSION

Mamdani fuzzy logic is an existing method with excellent flexibility and tolerance for existing data. This method can be easily understood and accepted by humans because of the easy representation of inputs on machines. The Mamdani approach is commonly known as the min-max system (Wulan et al., 2019) which was introduced in 1975 by Ebrahim Mamdani. Mamdani fuzzy method is widely used for intelligent system research. The mamdani fuzzy approach was chosen because of its ability to deal with uncertainty and data complexity (Prihamayu, 2022). In conclusion, mamdani fuzzy logic is a logic system that allows processing uncertain information and making decisions based on a scale between 0 and 1. This logic offers the possibility to make more accurate and realistic decisions because it takes into account many factors and makes compromises between the different options available.

The fuzzy logic method used has several membership functions that are defined as a graphical representation based on the participation value of each input. These membership functions associate a weight with each processed input, determines the overlap between inputs, and finally determine the output response. The rule uses the input membership value as a weighting factor to determine its effect on the output set fuzzy final result (Saputra, 2020). Research was conducted using a form of membership function in the form of Triangular Fuzzy Number (Ma'ruf & Marianti, 2022).

This is because the triangular Fuzzy Number membership function is the easiest, most widely implemented function curve shape and provides high accuracy results. The triangular membership function has 3 parameters, namely {a, b, c} which aims to determine the x coordinate of three angles and is a combination of two lines (linear). To divide the membership set based on the position of the variable value, the formula can be used as follows:

$$\mu[x] = \begin{cases} 0; & x \leq a \; atau \; x \geq c \\ \dfrac{x-a}{b-a}; & a \leq x \leq b \\ \dfrac{c-x}{c-b}; & b \leq x \leq c \end{cases}$$

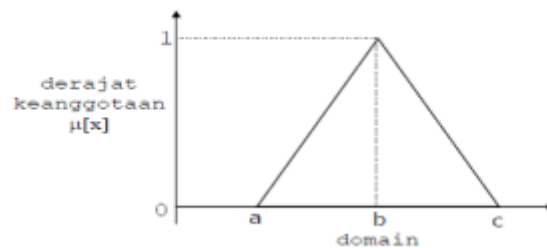The equation for the triangular shape is:

Figure 3. Graph of the Triangular Curve Representation Function

Source : (Sri kusumadewi, 2010 : 11)

Data Processing Using Fuzzy Mamdani Method

Basically, the content of folic acid in some samples used is different, this is what underlies the conduct of the study, which is to provide decisions on the adequacy of folic acid intake for pregnant mothers. Data on folic acid content of each sample are shown in **Table 1.**

Table 1. Sample Folic Acid Content Data

Sample No	Folic Acid Content (mcg/tablet)
1	500
2	1000
3	800
4	400
5	1000

The content of folic acid is one of the nutrients needed by pregnant women in supporting nutrition during pregnancy. Folic acid is used to diagnose folic acid deficiency and to treat topical oral thrush, megaloblastic and macrocytic anemia, hematological complications of folic acid deficiency. Folic acid is indicated for the prevention of some birth defects and appears to provide significant protection against cardiovascular disease and some cancers. Lack of folic acid consumption generally occurs in people with low knowledge and attitudes, and less aware of folic acid-rich food sources. Folic acid deficiency causes disruptions in DNA metabolism and anemia in pregnant mothers, and in the fetus causing abnormalities in the baby it contains. Anemia can also cause miscarriage (Khadijah, 2022). Other effects of folic acid deficiency result in neurological, psychological and carbon metabolism abnormalities. One way to detect folic acid deficiency can be seen from the growth and development of

the fetal brain during pregnancy, is able to seen from the size of the newborn's head circumference (Khairani, 2021). Consumption of folic acid in pregnant women does not only come from supplements consumed, but mainly comes from the amount of daily consumption of foods that have the main source of folic acid content. Foods that contain folic acid usually come from vegetable foods such as vegetables and fruits. Recommendations for vegetable and fruit consumption are said to be sufficient if 3-5 servings a day or equivalent to 250-400 grams of the amount of vegetable and fruit consumption that must be met by pregnant women (WHO, 2023). Basically, during the processing period, foods that contain high folic acid content will lose as much as 80% of their content, so supporting supplements are needed to meet the daily intake of folic acid in pregnant mothers. Pregnant women should increase folic acid consumption by partake of folic acid supplements to prevent defects such as spina bifida. Fetuses that lack folic acid can cause brain and spinal defects, early birth, and low birthweight (<2.5 kg) (Fathonah, 2016).

Table 2. Variable Operating Results

Function	Variable	Fuzzy *Set*	Fuzzy *Domains*	Speaker Universe
Input	The average amount of vegetable and fruit consumption in pregnant women	Little	[0 125 250]	0 - 500
		Medium	[200 300 400]	
		Many	[350 450 500]	
Input	Folic acid content	Low	[400 500 600]	400 - 1000
		Medium	[550 700 850]	
		High	[800 900 1000]	
Output	Recommendations	Not recommended	[300, 400, 500]	300 - 700
		Less recommended	[400, 500, 600]	
		Recommended	[500, 600, 700]	

Based on Ummah et al., 2021, there are five steps to calculate the fuzzy mamdani method to obtain output, including the following:
a. Determining the Fuzzy Logic Set

A fuzzy set is a range between values in a variable and has a membership degree between 0 and 1. For example, a fuzzy set A in the universe of speech X is denoted by a membership function μ in the interval [0.1] then, briefly expressed by $\mu A = X \rightarrow [0,1]$ (Mardiana et al., 2020). As for some information that needs to be recognized on the fuzzy order, such as:

1) Universe of Talks

The speech universe is all fuzzy variables ranging from the smallest value to the largest value (upper limit and lower limit) which are monotonous up (Yulmaini, 2015). The universe of talk used in this study is the recommended range of folic acid for pregnant women. The nutritional adequacy rate of pregnant women for folic acid needs is 600 μg / day (Rahayu et al., 2019).

2) Fuzzy Variables

Yulmaini 2015 explain that fuzzy variables are a series of variables whose values are not definite or unequivocal, but can be expressed in the form of fuzzy sets that have degrees of membership. In this study the variables used, namely the average amount of vegetable and fruit consumption in pregnant women, data on folic acid content, and folic acid dose.

3) Crisp Set

A *crisp* set is a set that is able to distinguish between members and non-members with clear and definite boundaries which are generally symbolized by uppercase letters and members of the set are symbolized by lowercase letters (Yulmaini, 2015). The crisp set has 2 membership values (μ): one (1) if a (item) belongs to A (set); zero (0) if a (item) does not belong to A (set). The crisp set for this study is one (1) is indicates that the item is a part of the set.

4) Fuzzy Set

Fuzzy sets are sets discussed on a variable in a fuzzy system whose elements have degrees of membership (Yulmaini, 2015). For input variables, namely the average amount of consumption and folic acid content are defined into 3 fuzzy sets consisting of low (KR), medium (KS), high (KT). As for the output variable, namely folic acid dose, there are 3 fuzzy sets consisting of not recommended (NR), less recommended (MR), and recommended (HR).

5) Fuzzy Set Domain

Fuzzy set domains are values that exist in the speech universe and belong to the set of real numbers that increase from the left to the right both positive and negative numbers. In this study, the domain used is a variable from the number range of fuzzy sets that have different parameters and will affect the final result.

6) Membership Functions

A curve that describes and counts the mapping of data input points in the membership in a set of fuzzy called membership function. The membership function is usually used to describe the strong relationship of an input value to a member of a fuzzy set (Sitohang & Napitupulu, 2017). The most typical examples of membership functions are the triangular function and the trapezoidal function. In this study using the membership function of the triangular.

7) Process Requirements

Process needs aim to manage uncertainty and provide solutions to the variables used in research. The technique used in this research is the FIS-Mamdani method.

8) Output Requirements

These output needs aim for accuracy in decision making, ease of interpretation by other users, control efficiency, and understanding of system conditions.

b. Fuzzification

Fuzzification is the first step to using fuzzy logic that allows input variables to be expressed in the form of linguistics which are then processed in fuzzy logic systems. The main function of fuzzification is the process of converting from a continuous domain into a form capable of being operated in fuzzy logic (Yulmaini, 2015)

For folic acid content is defined into 3 membership levels, namely low (KR), medium (KS), and high (KT). Likewise, the average amount of vegetable and fruit consumption is defined into small (LK), medium (MK), and many (HK). Then the dosage recommendation is defined into not recommended (NR), less recommended (MR), and highly recommended (HR).
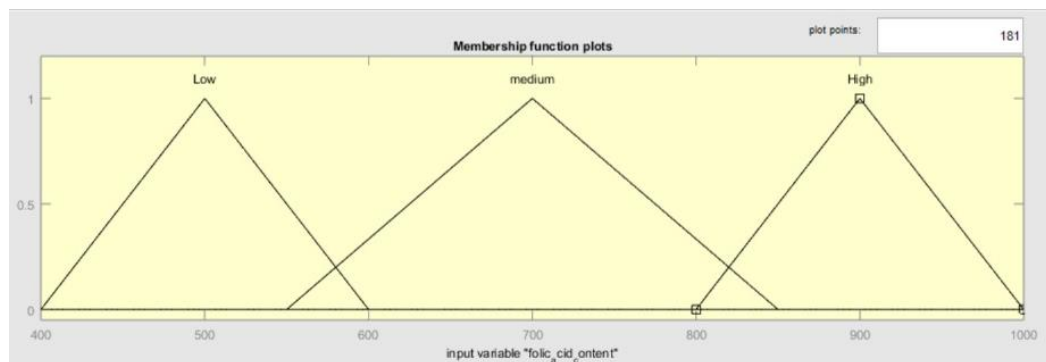

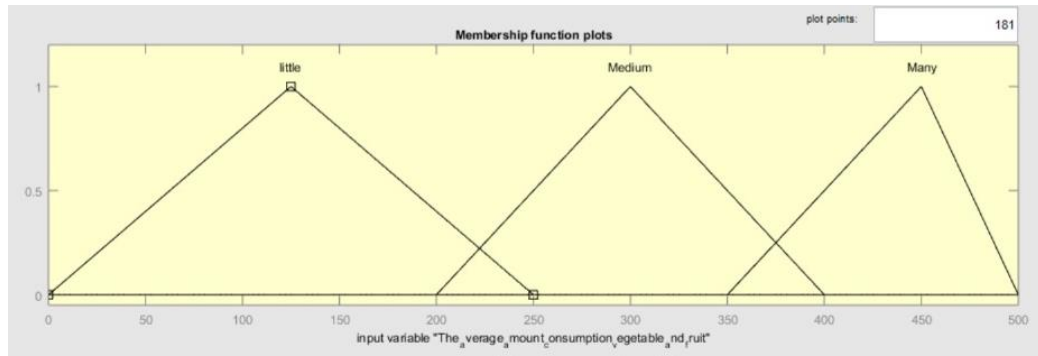Figure 4. Folic Acid Content Membership Rate Graph

Figure 5. Membership Level Graph Average Amount of Vegetable and Fruit Consumption
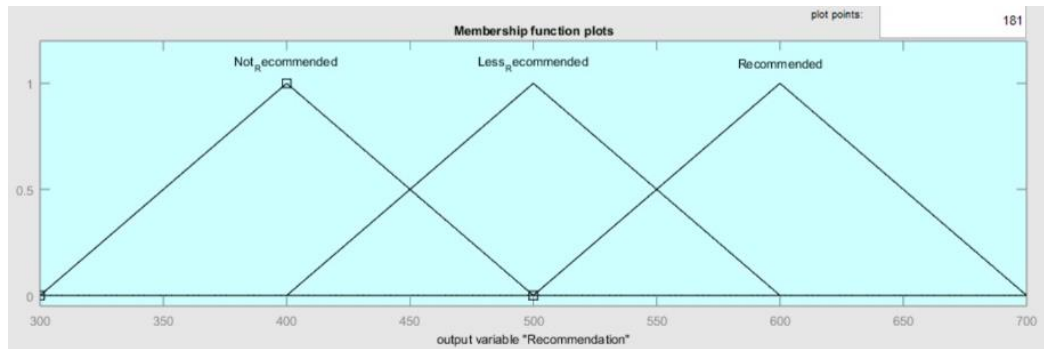

Figure 6. Membership Rate Chart Dosage Recommendations

For example cases with the amount of vegetable and fruit consumption = 175 and folic acid content = 550. Membership levels of supplement recommendations will be sought at μ(amount of vegetable and fruit consumption) and μ(folic acid content). From the results of calculations, it is obtained:

μ(amount of vegetable and fruit consumption) μ(folic acid content)
$= \frac{250 - 175}{250 - 125} = 0,6$ $= \frac{650 - 550}{600 - 500} = 0,5$

c. Fuzzy Rule Formation

The next step that is carried out after determining the membership function of every single variable is to compile fuzzy orders. A fuzzy rule is a statement device that connects inputs (conditions) with outputs (actions) in a fuzzy logic system. Fuzzy rules function to regulate how input variables will be converted into output variables, besides fuzzy rules are also an important part of fuzzy inference systems (Yulmaini, 2015).

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

1. IF the average amount consumption vegetable and fruit is little AND folic acid content is low THEN recommendation is not recommended.
2. IF the average amount consumption vegetable and fruit is medium AND folic acid content is low THEN recommendation is less recommended.
3. IF the average amount consumption vegetable and fruit is many AND folic acid content is low THEN recommendation is less recommended.
4. IF the average amount consumption vegetable and fruit is little AND folic acid content is medium THEN recommendation is not recommended.
5. IF the average amount consumption vegetable and fruit is medium AND folic acid content is medium THEN recommendation is less recommended.
6. IF the average amount consumption vegetable and fruit is many AND folic acid content is medium THEN recommendation is recommended.
7. IF the average amount consumption vegetable and fruit is little AND folic acid content is high THEN recommendation is less recommended.

8. IF the average amount consumption vegetable and fruit is medium AND folic acid content is high THEN recommendation is less recommended.
9. IF the average amount consumption vegetable and fruit is many AND folic acid content is high THEN recommendation is recommended.

1. If (The_Average_Aamount_Consumption_Vegetable_and_Fruit is Little) and (Folic_Acid_Content is Low) then (Recommended is Not_Recommended) (1)
2. If (The_Average_Aamount_Consumption_Vegetable_and_Fruit is Medium) and (Folic_Acid_Content is Low) then (Recommended is Less_recommended) (1)
3. If (The_Average_Aamount_Consumption_Vegetable_and_Fruit is Many) and (Folic_Acid_Content is Low) then (Recommended is Recommended) (1)
4. If (The_Average_Aamount_Consumption_Vegetable_and_Fruit is Little) and (Folic_Acid_Content is Medium) then (Recommended is Not_Recommended) (1)
5. If (The_Average_Aamount_Consumption_Vegetable_and_Fruit is Medium) and (Folic_Acid_Content is Medium) then (Recommended is Less_recommended) (1)
6. If (The_Average_Aamount_Consumption_Vegetable_and_Fruit is Many) and (Folic_Acid_Content is Medium) then (Recommended is Recommended) (1)
7. If (The_Average_Aamount_Consumption_Vegetable_and_Fruit is Little) and (Folic_Acid_Content is High) then (Recommended is Less_recommended) (1)
8. If (The_Average_Aamount_Consumption_Vegetable_and_Fruit is Medium) and (Folic_Acid_Content is High) then (Recommended is Less_recommended) (1)
9. If (The_Average_Aamount_Consumption_Vegetable_and_Fruit is Many) and (Folic_Acid_Content is High) then (Recommended is Recommended) (1)

Figure 7. Fuzzy Rules

d. Inference with the Mamdani Method

Inference using the mamdani method is a decision-making process with fuzzy rules such as If-Then to convert fuzzy input into output. 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 vegetable and fruit consumption was used 175 (small) and folic acid content 550 (low). This shows that the rule used is rule 1 which is "If the average amount of consumption is low and the folic acid content is low, then the sample is not recommended". Based on these rules, a fuzzy formation operation is obtained as follows:

$\alpha = \mu$ Average Amount of Vegetable and Fruit Consumption Slightly $\cap$ μ Low Folic Acid Content

$\alpha 1 = Min(\mu$ Average Amount of Vegetable and Fruit Consumption (175) ; μ Folic Acid Content(550))

$\alpha 1 = Min(0,6 ; 0,5)$

$\alpha 1 = 0,5$

e. Defuzzification

Defuzzification is the process of converting output generated by a fuzzy logic system back to numeric values in the original domain. Defuzzification is carried out after the fuzzy inference process, which begins with the fuzzy logic system's output in the form of fuzzy sets that need to be converted into concrete values and can be implemented. The defuzzification function itself plays a role in converting fuzzy sets into single values that are divided into several methods (Yulmaini, 2015).

Look for value and $X_1 X_2$

$$0,5 = \frac{X_1 - a}{b - a}$$

$$0,5 = \frac{X_1 - 300}{400 - 300}$$

$$0,5 = \frac{X_1 - 300}{100}$$

$$X_1 - 300 = 100 \times 0,5$$

$$X_1 = 350$$

$$0,5 = \frac{c - X_2}{c - b}$$

$$0,5 = \frac{500 - X_2}{500 - 400}$$

$$0,5 = \frac{500 - X_2}{100}$$

$$0{,}5 \times 100 = 500 - X_2$$

$$X_2 = 450$$

After knowing the value of X_1 and X_2, then calculate the area and membership set as follows:

$$LD_1 = \frac{a \times t}{2} = \frac{(350 - 300) \times 0{,}5}{2} = \frac{50 \times 0{,}5}{2} = \frac{25}{2} = 12{,}5$$

$$LD_2 = p \times l = (450 - 350) \times 0{,}5 = 100 \times 0{,}5 = 50$$

$$LD_3 = \frac{a \times t}{2} = \frac{(500 - 450) \times 0{,}5}{2} = \frac{50 \times 0{,}5}{2} = \frac{25}{2} = 12{,}5$$

Membership function output

$$Fx(a,b,c) \begin{cases} 0; & x \le 300 \\ \dfrac{x - 300}{400 - 300}; & 300 < x < 350 \\ 0{,}5; & 300 \le x \le 450 \\ \dfrac{500 - x}{500 - 400}; & 450 < x < 500 \\ 0; & x \ge 500 \end{cases}$$

Counting moments

$$M_1 = \frac{x - a}{b - a} = \frac{x - 300}{400 - 300} = \frac{x - 300}{100} = 0{,}01x - 3$$

$$M_2 = 0{,}5$$

$$M_3 = \frac{c - x}{c - b} = \frac{500 - x}{500 - 400} = \frac{500 - x}{100} = 5 - 0{,}01x$$

Moment $= \int_a^b f(x)x \, dx$

Moment Set 1

$$M1 = \int_a^b f(x)x \, dx \rightarrow \int_{300}^{350}(0{,}01x - 3)x \, dx \rightarrow \int_{300}^{350} 0{,}01x^2 - 3x \rightarrow$$
$$\int_{300}^{350} \frac{0{,}01x^{2+1}}{2+1} - \frac{3x^{1+1}}{1+1} \rightarrow \int_{300}^{350} 0{,}0033x^3 - 1{,}5x^2$$

$$= [0{,}0033(350)^3 - 1{,}5(350)^2] - [0{,}0033(300)^3 - 1{,}5(300)^2]$$

$$= [141487{,}5 - 183750] - [89100 - 135000]$$

$$= -42262{,}5 - (-45900)$$

$$= -42262{,}5 + 45900$$

$$= 3637{,}5$$

Moment Set 2

$$M2 = \int_a^b f(x)x \, dx \rightarrow \int_{350}^{450} 0{,}5x \, dx \rightarrow \int_{350}^{450} \frac{0{,}5x^{1+1}}{1+1} \rightarrow \int_{350}^{450} \frac{0{,}5x^2}{2} \rightarrow \int_{350}^{450} 0{,}25x^2$$

$$= 0{,}25(450)^2 - 0{,}25(350)^2$$

$$= [50625] - [30625]$$

$$= 20000$$

Moment Set 3

$$M3 = \int_a^b f(x)x.\,dx \rightarrow \int_{450}^{500}(5 - 0{,}01x)x.\,dx \rightarrow \int_{450}^{500} 5x - 0{,}01x^2 \rightarrow \int_{450}^{500} \frac{5x^{1+1}}{1+1} - \frac{0{,}01x^{2+1}}{2+1} \rightarrow \int_{450}^{500} 2{,}5x^2 - 0{,}0033x^3$$

$$= [2{,}5(500)^2 - 0{,}0033(500)^3] - [2{,}5(450)^2 - 0{,}0033(450)^3]$$

$$= [62500 - 412500] - [506250 - 300712{,}5]$$

$$= 212500 - 205537{,}5$$

$$= 6962{,}5$$

So that a central point is obtained, namely:

$$Z^* = \frac{\Sigma M}{\Sigma LD}$$

$$= \frac{3637{,}5 + 20000 + 6962{,}5}{12{,}5 + 50 + 12{,}5}$$

$$= \frac{30600}{75}$$

$$= 408$$

From the outcomes of the defuzzification steps, a final value of 408 was obtained. This value is a recommendation level that indicates that the sample is "not recommended" in this case proving that the calculation carried out is in accordance with the rules that have been used, namely "If the average amount of consumption is low and the folic acid content is low, then the sample is not recommended".

Affirmation Analysis Using Applications (Fuzzy Inference System) on Computer Applications

Raw data from input variables, folic acid content and the average amount of fruit and vegetable consumption are grouped into firm values which are then converted into fuzzy sets. The prevailing fuzzy rules are selected and eliminated to produce output depending on the values of the input variables. The output variable's fuzzy value is generated using mamdani method. In the defuzzification process, the fuzzy value of the output is converted back into a firm value (Nisa et al., 2020)

This study discusses how to determine recommendations for purchasing folic acid supplements based on fruit and vegetable consumption patterns in pregnant women using fuzzy logic and the help of computer applications, namely MATLAB. With the following steps:

1. Determine the technique applied, which is the fuzzy technique in computer applications in the form of MATLAB software.
2. In the MATLAB application, the FIS Editor section will appear, then select the file, select add variable and enter input. In this case, it is determined as input the average amount of fruit and vegetable consumption and folic acid content
3. Image input 1, input 2, and output are selected and renamed as needed.
4. After that, from the FIS editor selected edit, then selected membership functions. Then, enter the range of inputs and outputs on each parameter. The folic acid content and the average amount of fruit and vegetable consumption were expressed in the intervals of the amount of vegetable and fruit consumption = [0 500], folic acid content = [400 1000], and recommendation level = [300 700].
5. Then determine the fuzzy rules that will be used to determine folic acid supplement recommendations for pregnant women. In the MATLAB application of the FIS editor, edit is selected, then rules are selected. If-Then rule in input and selected add rule.
6. Next is the last stage, which is to enter the case study to be analyzed in the form of a range of case studies used. To prove the accuracy of the calculation, we tested the MATLAB application

with the input of the average amount of vegetable and fruit consumption of 175 and folic acid content of 550 so that the results of the recommendation level based on the dose of 400 were obtained according to the calculations that had been done with the output results in the MATLAB application. After the results come out, then press "view" and click "surface" to identify the 3D surface of the mamdani method used.
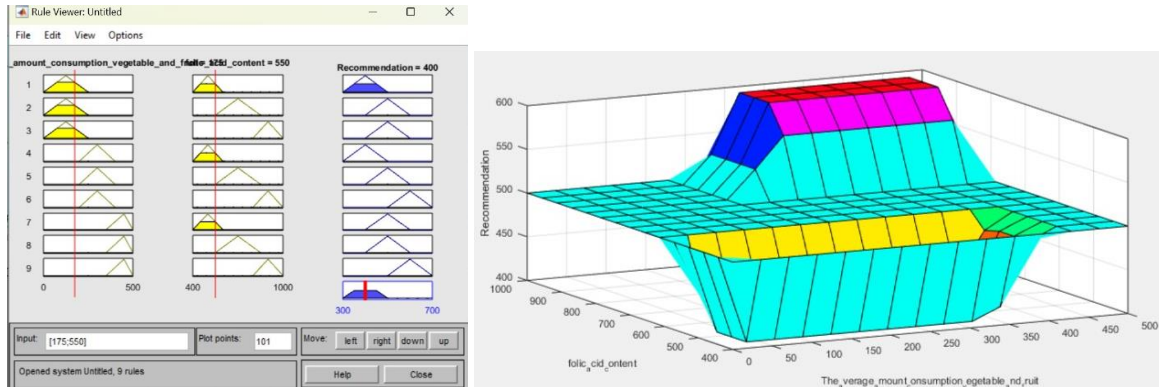

Figure 8. Rule Viewer

After testing fuzzy logic with the mamdani method type which is assisted by MATLAB software to find out the recommendations for folic acid supplements for pregnant women. Furthermore, in figure 8 there is the surface result of the rule created in the fuzzy logic of mamdani. Surface viewer is useful for viewing mapping images between output variables. The results of such images can help to handle uncertainty and complexity in system modeling (Dari, 2018). The output of the surface viewer is a three-dimensional graph with X, Y, Z axes that have fluctuating results from cases with two or more inputs and one output (Ramdani, 2015). Furthermore, testing the results of the system with MAPE (mean absolute percentage error) calculations was carried out which aimed to determine or assess the accuracy of the mamdani method's fuzzy logic prediction results (Aenun & Mashuri, 2014). The smaller error value obtained, the better level of accuracy of the prediction results (Ramadhan et al., 2020). A model with excellent performance has a MAPE value range below 10% and for good performance has a MAPE value in the range between 10% and 20% (Arvie & Pakereng, 2022). So systematically based on the results of the manual comparison calculations and the results using MATLAB software, the MAPE value is obtained as follow:

$$MAPE = \left| \frac{Xt - Ft}{Xt} \right| \, x \, 100\%$$

$$MAPE = \left| \frac{408 - 400}{408} \right| \, x \, 100\%$$

$$MAPE = 1,96\%$$

Information:
Xt : Actual data
Ft : Predicted value

According to the outcome of MAPE calculation, it might be said that the implementation of fuzzy logic in determining recommendations for purchasing folic acid supplements based on fruit and vegetable consumption patterns in pregnant women has excellent performance and produces MAPE values of 1.96% and less than 10%.

CONCLUSION

In this study, fuzzy logic was used with input of folic acid content and the average amount of vegetable and fruit consumption in pregnant women and the output variable used is the recommended dose of folic acid supplements for pregnant women. The input membership levels for folic acid content

are low (400-600 mcg with a peak point of 500 mcg), medium (550-850 mcg with a peak point of 700 mcg), and high (800-1000 mcg with a peak point of 900 mcg) while the input membership level for the average amount of vegetable and fruit consumption is small (0-250 g with a peak point of 125 g), medium (200-400 g with a peak point of 300 g), and many (350-500 g with a peak point of 450 g). Meanwhile, the membership levels for the output variable are not recommended (300-500 mcg with a peak point of 400 mcg), less recommended (400-600 mcg with a peak point of 500 mcg), and highly recommended (500-700 mcg with a peak point of 600 mcg). Based on manual calculations with the analysis outcomes found in the case study, the sample recommendation center point has a value of 408. Then, the calculation processing was carried out with MATLAB software to compare with the manual results obtained. The results of processing calculations with MATLAB show a sample recommendation center point value of 400 which indicates that the case study made is not recommended. From both data, the accuracy rate is 1.95% and can be categorized as very good performance in decision making. In future research, it's necessary to develop a mobile prediction application base that will more help and make it easier for pregnant mom to determine the recommendations for purchasing folic acid supplements.

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