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Decision Support Systems to Selection of Diet Type Using Fuzzy Sugeno and Naïve Bayes Method

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ABSTRACT

Sugeno Fuzzy algorithm is one of the algorithms contained on Fuzzy Inference System, that used to describe the condition between the two pieces of the decisions represented in the form of rules IF - THEN, where the output is constant or linear equations. While the Naive Bayes algorithm is an algorithm that uses data classification to a particular class based on the probability of each data class. Both of these algorithms can be implemented on a Decision Support System (DSS) for diet selection, using Fuzzy Sugeno as an additional determinant of energy and Naive Bayes method as decision maker. This is because the need for food intake and diet has become a problem for humans. To prevent excess intake of food it needs dietary adjustments or so-called diet. But in daily life, people sometimes hard to determine the type of diet that is suitable for them. So we need a system that can determine the type of diet that is suitable for a person. The data that used as a reference for decision support are age, daily caloric requirement, Body Mass Index (BMI), blood pressure, cholesterol, uric acid and blood sugar levels. Results of system testing showed from a sample of 30 data there are 26 appropriate data and 4 inappropriate data to determine the type of diet by the system with the success rate of 86.7%.

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1. Introduction

Fuzzy Sugeno algorithm is one of the algorithms contained on Fuzzy Inference System, which is used to explain the situation between the two pieces of decisions that are represented in the form of rules IF - THEN, which results in a constant or linear equations. While the method of Naive Bayes is a machine learning method that uses probability calculations. The basic concept used is the Bayes theorem, that classification by calculating the probability value.

Both of these algorithms can be implemented on a Decision Support System (DSS) selection of the type of diet. This is because the need for food intake and eating habits has become a problem for humans. Excessive food intake will result in weight gain. If left unchecked it will lead to obesity and the onset of various diseases. Therefore, every meal must be consumed in accordance with the normal limits. To prevent excess intake of food it is necessary dietary adjustments or so-called diet. But in daily life, people can sometimes be difficult to determine the type of diet that is suitable for users, this is due to diet types and different patterns. For that we need a system that can determine the type of diet that is suitable for someone. DSS is one way to solve the problem. On the background, then made a system that aims to determine the type of diet that is appropriate for the user by using Fuzzy Sugeno method for determining the additional energy on daily calorie needs and Naive Bayes method is used as a determinant of the decision on the system type of diet. The data used as a reference for decision support is of age, the daily caloric needs, body mass index (BMI), bloods pressure, cholesterols, uric acid and blood sugar levels.

The purpose of this research is to develop a decision support system for the selection of diet by using fuzzy Sugeno and Naive Bayes method.

2. Discussion

Decision Support System (DSS) [1] is a system that is able to provide problem-solving ability and ability settlement to problems with the condition of semi-structured and unstructured. This system is used to help make decisions in situations of semi-structured and unstructured situations, where no one knows for sure how the decision should be made.

Generally DSS built by three major components, namely database management, models base and user interface. Components of DSS can be described as in Figure 1.

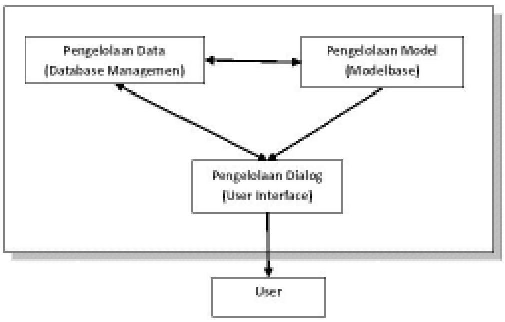

Figure 1 Components of Decision Support System

a. Database Management

Database Management is a subsystem of data organized in a database. Data that is a decision support system may come from outside and within the environment.

b. Model Base
Model Base is a model that represents the problem in a quantitative format (mathematical model as an example) as the basis of simulations or decision making.

c. User Interface
The user interface is a subsystem of dialogue which is a merger between the two previous components, namely Database Management and Model Base are incorporated into the third component (user interface), and presented in the models understood by computers.

2.1. Fuzzy Logic

According to Asus Naba, fuzzy logic is: "A calculation methodology that uses words variable (linguistic variable) instead of counting the numbers". In fuzzy logic, there are several types of fuzzy logic system including the Mamdani method, the method of Sugeno and Tsukamoto method. This research will be used Sugeno method. The method is used as an inference engine for the system [2], [3].

2.1.1. Sugeno Method

Sugeno method is a method of inference engine for rules that are represented in the form of IF - THEN, in which the (consequent) system is not in the form of fuzzy sets, but in the form of a constant or linear equations. Sugeno models using Singleton membership functions namely the membership function has a membership degree 1 in a single crisp value and 0 on the value of another crisp. To Order 0 by the equation:

$$\text{IF } (\text{x1 is A1})^\circ\, (\text{x2 is A2})\, ^\circ \ldots ^\circ (\text{xn is An}) \text{ THEN } z = k$$

Equation 1 Sugeno Method for Order to 0

Ai is the fuzzy set to i as an antecedent (reason), ° is the fuzzy operator (AND or OR) and k are constants firmly as consequent (conclusion). As for the Order to-1 equation is:

$$\text{IF } (\text{x1 is A1})^\circ\, (\text{x2 is A2})^\circ \ldots ^\circ (\text{xn is An}) \text{ THEN } z = p1 * x1 + \cdots + pn * xn + q$$

Equation 2 Sugeno Method for Order to 1

Ai is the fuzzy set to i as an antecedent, ° is the fuzzy operator (AND or OR), pi is a constant to i and q is also a constant in the consequent.

2.2. Naive Bayes Method

Naive Bayes method is a method of classification probability and statistics discovered by the British scientist Thomas Bayes, which predict future opportunities based on the experience of earlier and became known as Bayes' Theorem [4], [5].

The theorem combined with Naive which assumed the conditions between the attributes are independent. Naive Bayes classification is assumed that there is or is not a specific characteristic of a class has nothing to do with the characteristics of other classes [6]. Equation of Bayes' theorem is:

$$P(H|X) = \frac{P(X|H).P(H)}{P(X)}$$

Equation 3 Bayes' Theorem

Based on these similarities, there are some statements that can be translated:
X: Data with unknown class
H: Hypothesis X data, which is a specific class
P (H|X): The probability of the hypothesis H based on the conditions (posteriori probability)
P (H): The probability of a hypothesis (prior probability)
P (X|H): Probability based on conditions on the hypothesis H
P (X): Probability X

On Naive Bayes method, the probability for class data is ignored while the conditions of the attributes are independent. Naive Bayes equation of the equation is as follows:

$$P(C|X) = P(X1|Ci) * P(X2|Ci) * \ldots * P(Xn|Cn). P(C)$$

Equation 4 Naive Bayes Equation

Where the variable C represents a decision, whereas X represents the condition of each class of data.

2.3. Definition Diet and Stages of Calculating Daily Calorie Needs

Correct diet is still consuming foods with the composition of the body needs in equal amounts. Of course the number of calories is lower than commonly consumed, so the body will use the energy reserves of the body, the body fat.

To determine the nutritional status of a person is used calculation of Body Mass Index (BMI) [7], [8]. How to determine the person's BMI can be done in the following way :

$$BMI = BB / (TB \times TB)$$

BMI = Body Mass Index
BB = Weight (Kg)
TB = Height (cm)

Equation 5 Body Mass Index

BMI for every country in the world is different. BMI qualifying for the state of Indonesia can be seen in Table 1.

Table 1 Qualification of BMI in Indonesia

BMI Category	BMI (Kg/M^2)
Thin	< 19
Normal	19 – 22
Fat	>22

Based on the Harris-Benedict equation, for an activity factor is divided into four equations are very light, light, normal, and weight. Such as Table 2 below.

Table 2 Equation of Daily Activities

Factor Of Activity	Equation	Information
very light	1,20	Activities are classified as very light covering the bed, lying down, watching television, playing games, reading and relaxing walks.
light	1,37	Activities relatively light includes driving, teaching, fishing, drawing, painting, planting flowers, cooking, sewing, fishing, typing, washing and shopping.
Normal	1,55	Activities were classified as normal covers housework, office work, jogging, swimming, printing work, mechanic, janitor, dancers, cycling (recreation) and the work of paramedics.

Factor Of Activity	Equation	Information
Weight	1,72	Activities were classified as weight include construction workers, aerobics, boxing, climbing, cycling (race), wrestling, football, unskilled laborers and athletics.

In calculating the caloric needs use the Harris-Benedict equation which perform the calculation of the multiplication of the energy needs of basal / basal metabolic rate (BMR) with an activity factor (AF). In general, the equation for calculating BMR is:

$$\text{BMR men} = (66) + (13{,}7\ \text{BB}) + (5\ \text{TB}) - (6{,}8\ \text{U})$$
$$\text{BMR women} = (655) + (9{,}6\ \text{BB}) + (1{,}8\ \text{TB}) - (4{,}7\ \text{U})$$
$$\text{BB} = \text{Weight (kg)}$$
$$\text{TB} = \text{Height (cm)}$$
$$\text{U} = \text{Age (years)}$$

Equation 6 Basal Energy Needs

In the first stage of the workflow diagram, users are required to fill in the data for age, sex, height, weight and daily activity to determine daily caloric needs. Then the system performs an additional measure of energy by using Sugeno Fuzzy algorithm. Fuzzy process can be described as follows:

1. Determine the degree of membership
2. Match the input data with fuzzy rules
3. Calculate the predicate of each fuzzy rule
4. Defuzzification process by calculating the average value
5. Then obtained calculation results

For the determination of the degree of membership fuzzy, the variables used in the system is the age and body mass index or BMI. In the fuzzy set [9] for age, there are three parts, namely fuzzy set young age, adulthood and old age with the following caption:

1. 18-30 years for the young age (Y)
2. 25-45 years of adult age (A)
3. 40-60 years for old age (O)

Fuzzy set of the age variable can be described with a curve trapezoid fuzzy Sugeno as found in Figure 2.

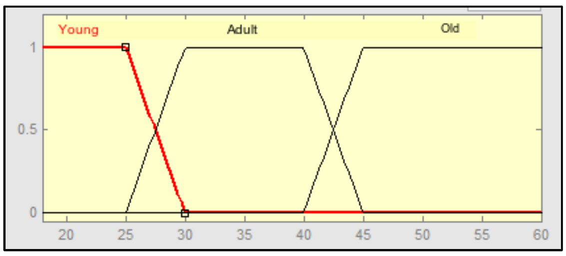

Figure 2 Fuzzy set for Variable Age

Fuzzy set on the variable BMI divided into three fuzzy sets, namely BMI underweight, normal BMI and BMI fat with the following details.

1. < 19 for BMI thin (underweight)
2. 18 - 23 for BMI normal

3. > 22 for BMI fat

Fuzzy set for variable BMI can be described with a curve trapezoid fuzzy Sugeno as found in Figure 3.

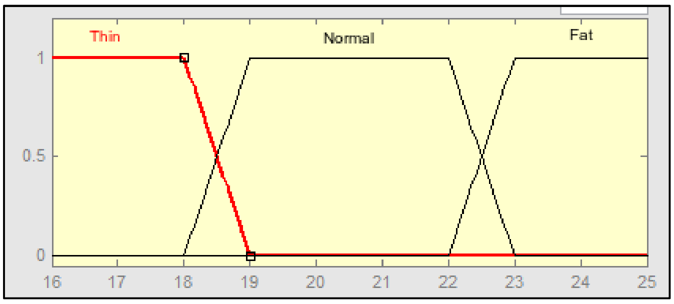

Figure 3 Fuzzy Set for Variable BMI

Based on fuzzy sets that have been formed can be made a fuzzy relation matrix to represent fuzzy rules and results. Such as Table 3 below.

Table 3 Fuzzy Relation Matrix

Age BMI	Young	Adult	Old
Thin	+ 10 %	+ 5 %	+ 5 %
Normal	+ 5 %	0 %	0 %
Fat	0 %	- 5 %	- 10 %

Based on the fuzzy relation matrix, can be formed a fuzzy rules that can be used to determine the additional energy. Fuzzy Classification consists of 9 fuzzy rules based on variables of age and BMI. Table 4 shows 9 fuzzy rules. The fuzzy rules are based on Source: Himpunan Studi Obesitas Indonesia (HISOBI).

Table 4 Fuzzy Rules

Code	Rules	Energy Supplement
R1	If a young age and thin BMI then	+10%
R2	If a young age and normal BMI then	+5%
R3	if a young age and fat BMI then	0%
R4	If any adult age and thin BMI then	+5%
R5	If any adult age and normal BMI then	0%
R6	If any adult age and fat BMI then	-5%
R7	If old age and thin BMI then	+5%
R8	If old age and normal BMI then	0%
R9	If old age and fat BMI then	-10%

For example, the calculation method of Fuzzy Sugeno, a user known to have the following criteria:

- Age = 35 years
- Gender = Female
- Weight = 82 Kg
- Height = 182 cm
- Activity = Lightweight

$$\Theta_A(x) = \begin{cases} \dfrac{x-y}{a-y} \, if \; 25 < x < 30 \\ \dfrac{o-x}{o-l} \, if \; 40 < x < 45 \\ 1 \, ifx \; ,30 < x < 40 \end{cases}$$

Equation 7 Membership Function for Example

Based on these criteria, matching of user data with Fuzzy sets [9]:

- Figure 4 shows a graph of Age = 35 years of entry to the adult age categories, with representation Fuzzy = 1.0

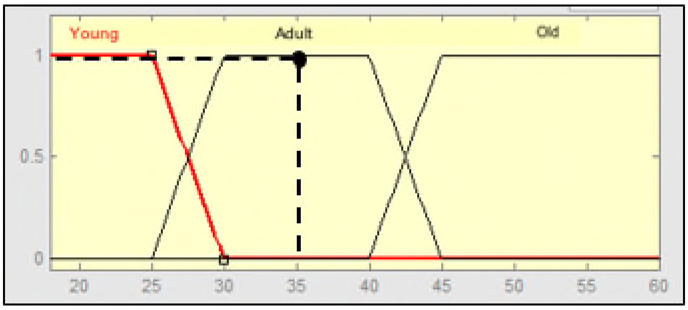

Figure 4 Fuzzy Set to Age 35 Years

- Figure 5 shows a graph of BMI = 82 / (1.82 x1.82) = 24.76 (According to equation 5 p. 22) entered the fat BMI categories, with representation Fuzzy = 1.0

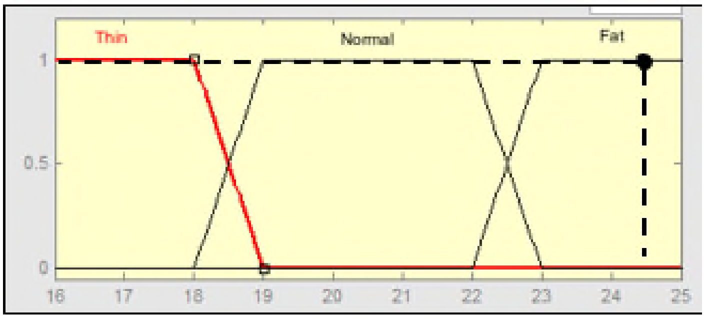

Figure 5 Fuzzy Set for BMI 24.76

For defuzzification process, because Fuzzy representation of each set is worth 1 it can be concluded there is only one output by Fuzzy rules are rules R6 (if any adult age and BMI fat then additional energy = -5%).

Having obtained additional energy will be calculated daily calorie needs of users (based on the equation 6).

BMR = (655) + (9.6 x weight) + (1.8 x height) - (4.7 x age)
BMR = (655) + (9.6 x 82) + (1.8 x 182) - (4.7 x 38)
BMR = 1591.2

Additional results of energy that has been obtained is then multiplied by BMR.

The value of the additional energy = (-5% x 1591.2)
The value of the additional energy = 79.56 calories
BMR = 1591.2 to 79.56
BMR = 1511.64 calories
The need for calories = BMR x AF
The need for calories = 1511.64 x 1.37
The need for calories = 2070.95 calories

In the second stage of the workflow diagram, the user fill out health data such as blood pressure, cholesterol, uric acid and blood sugar levels to determine the type of diet that is suitable for him. Determining the type of diet were calculated using a Naive Bayes methods. Naive Bayes process can be described as follows:

1. classification based on the results of the decision
2. classification based on each class of data and the outcome of the decision
3. looking for a probability value
4. then obtained calculation results

Determining the type of diet is obtained from the processing variables of age, the daily caloric needs, body mass index (BMI), blood pressure, cholesterol, uric acid and blood sugar levels that have been entered by the user. Each of these variables are grouped based on the boundaries that have been adapted by health sciences. Limitations on each variable can be seen in Table 5.

Table 5 Limits in Variable to Determine Diet Type

No.	Type	Limitation
1	Age	< 30 Years
		31-40 Years
		41-50 Years
		>50 Years
2	Daily Calorie Needs	< 2200 calorie
		2201-2700 calorie
		> 2700 calorie
3	Body Mass Index (BMI)	< 19
		19,1 - 22
		> 22
4	Blood Pressure	Low (< 100/80 mmHg)
		Normal (100/80 mmHg – 140/100 mmHg)
		High (> 140/100 mmHg)
5	Total Cholesterol Levels	Normal (< 200 mg/dl)
		High enough (201-239 mg/dl)
		High (> 240 mg/dl)
6	Uric acid	Normal (2-7,0 mg/dl men, 2-6,0 mg/dl women)
		High (> 7,0 mg/dl men, > 6,0 mg/dl women)
7	Blood Sugar Levels	Normal (70-125 mg/dl fasting, < 180 mg/dl after meals)
		Prediabetes (126-140 mg/dl fasting, 180-200 mg/dl after meals)
		High (> 140 mg/dl fasting, > 200 mg/dl after meals)

As an example of calculating the Naive Bayes method, will be explained the calculation to determine the type of diet is based on the definition of Naive Bayes methods that have been established. Test data or training data were used 223 data and derived from interviews with health experts. Classification of each test data or training data can be seen in Table 6.

Table 6 Criteria Test Data Naive Bayes

Type Of Diet	Amount of data (P)	Probability Record (P/Q)
DASH Diet 1	20	0,092
DASH Diet 2	19	0,087
Weight Watchers Diet	31	0,142
Flexitarian Diet	25	0,115
Diet Mayo	15	0,069
Uric Acid Diet	32	0,147
Diabetes Diet 1	19	0,087

Type Of Diet	Amount of data (P)	Probability Record (P/Q)
Diabetes Diet 2	12	0,055
Diabetes Diet 3	31	0,142
Healthy diet	19	0,087
Record number (Q)	**223**	

For example, the user enters criteria of data into the system as follows:

- Age = 31 - 40 Years
- Calorie Needs Daily = 2201-2700 Calories
- Body Mass Index => 22
- Blood Pressure = Normal
- Total Cholesterol Levels = High Enough
- Uric Acid = Normal
- Blood Sugar Levels = Normal

3. Result

Testing of the system was conducted from consultations type of diet, charging personal data to get a decision the type of diet that is appropriate for the user. For consulting, the user can select a button of consultation and will be heading to form an additional measure of energy. Additional calculation appearance of the form of energy can be seen in Figure 6.

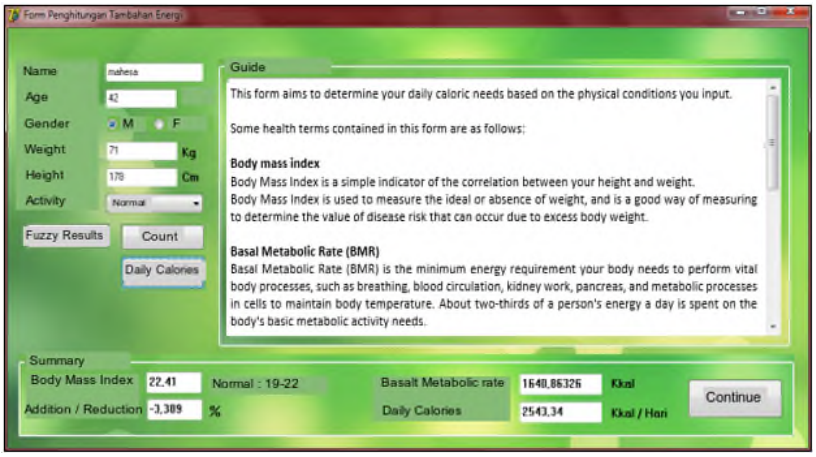

Figure 6 Tests on Form Calculations Energy Supplement

In this form will be calculated on the additional energy to the user based on the personal data that is loaded by the user. Columns for charging the user data itself can be seen in Figure 7.

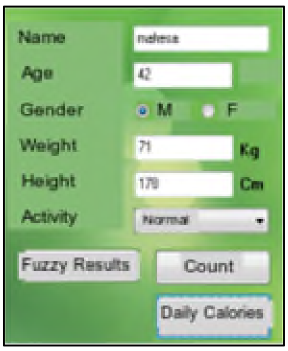

Figure 7 Completion of Personal Data on Form of Energy Supplement

After the column is filled, the system will calculate the extra energy and daily caloric needs users to get the calories during one day. Display for additional energy results can be seen in Figure 8. While views on the results of the daily caloric needs can be seen in Figure 9.

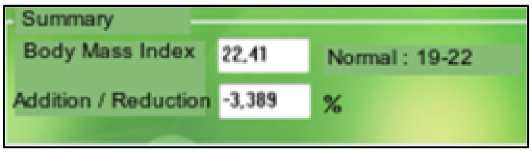

Figure 8 Calculation Results for Energy Supplement

Figure 9 Results Calculation for Daily Calorie Needs

Then the user can continue to form the choice of diet. Appearance of the form choosing the type of diet can be seen in Figure 10.

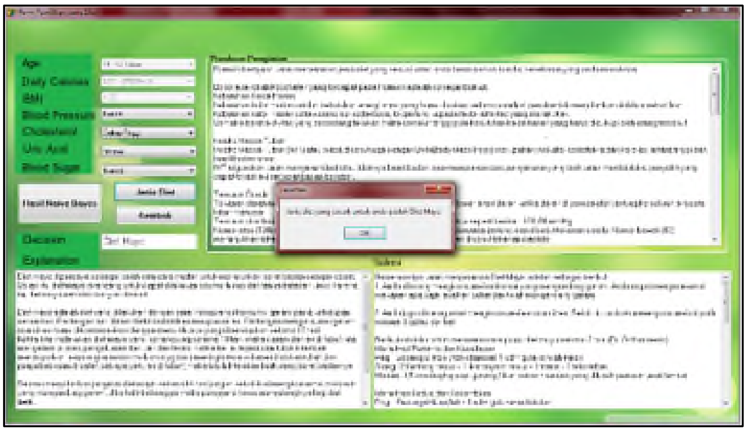

Figure 10 Testing on Form for the Selection Type Diet

After that, the user must first fill out health data such as blood pressure, cholesterol, blood sugar and uric acid that is on the left side of the form. Columns for charging user health data can be seen in Figure 11.

Figure 11 Charging Data of Health on Form for the Selection Type Diet

After the column is filled, the user can select the type of diet to determine the type of diet that is appropriate for the user. The system will display information about diet along with tips and sample menus of food for one day and information about diet can be seen in Figure 12.

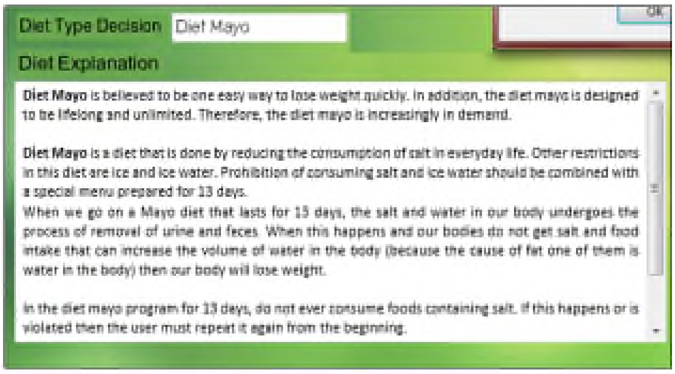

Figure 12 Result of Decision for Type Diet

For the test to the user, the application system has been tested to 30 users. Users who tested in this study were patients from health professionals. To improve the accuracy of the result of the decision, any user who tested required to determine the condition of the value of blood pressure, cholesterol, uric acid and blood sugar levels first. Each user has the characteristics and different backgrounds.

After testing the system, and then be evaluated to verify the health sciences as a determinant of the type of diet in the system. Evaluation is done by the determination of an appropriate diet by a health expert based on the characteristics and health data owned by the user, and then made to match the diet results released by the system.

The following is a table of system test results to users and then compared based on the decision of health experts. The results of testing the system to the user can be seen in Table 7.

Table 7 Result of System Testing Based on Health Expert Decision

No.	Name	Diet Results (by The System)	Diet Results (According to Health Expert)
1	Nova Setiawan	Diet Mayo	Diet Mayo
2	Yayuk R.	Diabetes Diet 1	Diabetes Diet 1
3	Sri Yanti	Healthy diet	Healthy diet
4	Rusdiono	DASH Diet 2	DASH Diet 2
5	Ainizar	DASH Diet 1	DASH Diet 1
6	Hamdan	Weight Watchers Diet	Weight Watchers Diet
7	Mutia K.	Flexitarian Diet	Flexitarian Diet
8	Rini Kurnia	Diet Mayo	Diet Mayo
9	Endang	DASH Diet 1	DASH Diet 1
10	Andika P.	Healthy diet	Healthy diet
11	Adi Prasetya	Diet Mayo	Healthy diet
12	Budi	Uric Acid Diet	Uric Acid Diet
13	Tarman M.	Weight Watchers Diet	Weight Watchers Diet
14	Abi Lesmana	Diabetes Diet 1	Diabetes Diet 1
15	Siti Nuryanti	Flexitarian Diet	Flexitarian Diet
16	Ahmad Z.	Diabetes Diet 3	DASH Diet 2
17	Tio Aji P.	Healthy diet	Healthy diet

No.	Name	Diet Results (by The System)	Diet Results (According to Health Expert)
18	Tirta S.	Weight Watchers Diet	Weight Watchers Diet
19	Rinjani K.	Diet Mayo	Diet Mayo
20	Dirga	Healthy diet	Healthy diet
21	Anas	Diet Mayo	Diet Mayo
22	Andini	Flexitarian Diet	Flexitarian Diet
23	Ruslan	Uric Acid Diet	Uric Acid Diet
24	Ida	Flexitarian Diet	Healthy diet
25	Parman	Diabetes Diet 3	Diabetes Diet 3
26	Mukhlis	Weight Watchers Diet	Weight Watchers Diet
27	Siddiq	DASH Diet 2	DASH Diet 2
28	Rianti	Healthy diet	Healthy diet
29	Ronny	Diet Mayo	Weight Watchers Diet
30	Anto	Healthy diet	Healthy diet

Based on the results of the evaluation conducted by health experts, of the 30 people who use the system there are 4 types of diets error determination by the system. Based on the analysis, the data does not fit in the system test are caused by errors in the determination of training or lack of completeness of the data in the training data. So it can be concluded that the Decision Support System made already can determine the type of diet that is appropriate for its very well. The level of accuracy (in percent) for testing consisting of 30 people was 86.7%. Based on 30 sample test data there are 4 incorrect data, so decision support system for selection type diet using Fuzzy Sugeno method and Naive Bayes method has error 13.3%.

4. Conclusion

Based on the evaluation and testing carried out by health experts, from the 30 pieces of user data sample contained 26 appropriate data and fourth data that is not appropriate for the determination of the type of diet by the system. So it can be concluded that the Decision Support System made already can determine the type of diet that is appropriate for its very well. The success rate (in percent) for testing consisted of 30 users is 86.7%. So the views of system testing has been done, the general system created have achieved the key objectives to determine the type of diet that is appropriate for the user.

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