JURTEKSI (Jurnal Teknologi dan Sistem Informasi) ISSN 2407-1811 (Print)
Vol. IX No 1, Desember 2022, hlm. 65 - 74 ISSN 2550-0201 (Online)
DOI: https://doi.org/10.33330/jurteksi.v9i1.1848
Available online at http://jurnal.stmikroyal.ac.id/index.php/jurteksi

IMPLEMENTATION OF THE TSUKAMOTO FUZZY METHOD FOR INFANT FOOD RECOMMENDATIONS ACCORDING TO THE NEEDS AND AKG

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Abstract: Choosing the right foods for babies to eat is easy. Age 0 to 5 years is a golden period for babies in their growth and development, both physically and intellectually. Incorrectly choosing foods that do not meet the needs can lead to the risk of obesity, while foods that do not meet the nutritional adequacy of infants can also cause stunting. An intelligent system taken from the knowledge of baby nutrition experts can be used as a solution to accompany parents in choosing the right food menu for babies during their growth and development. Fuzzy Tsukamoto can be used to group babies by age and weight, to decide which foods are suitable for consumption by the baby, based on the evaluation Images table compiled by the ministry of health as a guide for appropriate nutrition. This research resulted in a system that is able to assist parents in choosing the appropriate food menu for babies so as to prevent stunting.

Keywords: fuzzy tsukamoto; stunting; nutrition

Abstrak: Memilih makanan yang tepat untuk dikonsumsi oleh bayi bukanlah hal yang mudah. Usia 0 sampai 5 tahun merupakan masa-masa emas bagi bayi dalam tumbuh kembangnya, baik fisik maupun kecerdasan. Salah memilih makanan yang tidak sesuai kebutuhan dapat menyebabkan resiko obesitas, sedangkan makanan yang tidak memenuhi angka kecukupan gizi bayi juga dapat menyebabkan stunting. Sistem cerdas yang diambil dari pengetahuan para pakar gizi bayi dapat dijadikan solusi pendamping orang tua dalam memilih menu makanan yang tepat bagi bayi di masa tumbuh kembangnya. Fuzzy Tsukamoto dapat digunakan untuk mengelompokkan bayi berdasarkan usia dan berat badan, untuk memutuskan makanan mana yang cocok dikonsumsi oleh bayi tersebut, berdasarkan tabel angka kecukupan gizi yang telah disusun oleh kementrian kesehatan sebagai panduan pemberian nutrisi yang sesuai. Dari penelitian ini dihasilkan sistem yang mampu membantu orang tua dalam memilih menu makanan yang sesuai bagi bayi sehingga dapat mencegah terjadinya stunting.

Kata kunci: Fuzzy Tsukamoto; stunting; nutrisi

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INTRODUCTION

Indonesia is the third largest country with the highest number of stunting cases in the Southeast Asia region as of 2017. Records from UNICEF in 2017 stated that 22.2% or the same as 150.8 million toddlers in the world are stunted. 55% of stunted toddlers come from Asia, 39% from Africa. Meanwhile, it was reported from RISKESDAS in 2018 that the stunting rate in Indonesia was 30.8%.[1]. In line with this report, the results of a report by the Center for Data and Information of the Ministry of Health of the Republic of Indonesia obtained from the Balitbangkes research stated that 23.6% of toddlers only get <80% of the protein adequacy rate and only 10.6% of toddlers get >80% of the protein adequacy[2]. This means that more than 50% of toddlers only get 80% of the protein adequacy rate[3].

Stunting is a condition where the toddler's height is shorter than the height standards that the toddler should experience at his age. Stunting is classified as a chronic infant nutritional problem[4]. Therefore stunting is one of the things that must be prevented in toddlers because it can hinder the growth and development of the baby, make the baby in an unhealthy condition, and lead to death. Malnutrition is the cause of 45% of deaths in children under 5 years of age worldwide[5]. Not only in Indonesia, stunting or malnutrition is a problem that has been widely studied around the world, such as in research in Nepal[6], Serbia[7], Pakistan[8], and other countries..

The quality of the population in the future is influenced by the quality of the current growth of the baby. Therefore, the baby's growth and development is very important for both parents to pay attention to. Nutrition has an important role in the process of growth and development, intelligence, and physical strength of the baby. The nutrition needed by the baby's body to develop physically and intelligently comes from the given food. Proper nutrition is very important to support the development of a child's brain so that it develops normally from the first 1000 days of life[9].

Nutrition supports cognitive development with long lasting effects. Nutritional deficiencies cause neurocognitive disorders that occur as a result of failure to optimize neurodevelopment in early life. Nutrition plays an important role in the development of children aged 0-59 months[8]. Malnutrition or mistakes in choosing food menus for babies cause malnutrition or stunting problems[6]. In the short term, this can cause brain, intelligence, physical growth, and metabolism disorders in children. On the other hand, in the long term, lack of nutrition causes decreased learning ability and cognitive performance, weakened immunity, susceptibility to disease, high risk of developing diabetes, obesity, heart and blood vessel disease, cancer, stroke, disability in old age, increasing the risk of disease and death, as well as reducing the competitiveness of the quality of work, reducing the quality of human resources (HR), and reducing economic productivity.

Unfortunately, very few parents understand the dangers of malnutrition in infants or stunting, as well as the importance of providing the best intake

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for babies according to the baby's nutritional adequacy rate.

Several studies in Indonesia that have been conducted regarding parental knowledge about providing nutrition to infants, among others, concluded that the number of mothers who had knowledge about under-five nutrition was 16 people or the equivalent of 53.33% of the total respondents[10]. Then another study concluded that 58% of respondents in the study had insufficient knowledge about nutrition, resulting in 56% of children having poor eating patterns, 74% getting infectious diseases, and 48% experiencing malnutrition status[11]. In addition, similar research concludes that mother's education and knowledge and baby's food intake are factors that can affect the nutritional status of toddlers at the Oebufu auxiliary health center[12]

This problem can be overcome by providing education to parents regarding foods that are suitable for consumption by babies according to the baby's condition. In order to identify and suggest foods that are suitable for consumption by babies, an intelligent system is needed in which expert knowledge is acquired, in this case a baby nutritionist. To provide food recommendation decisions in this study, the Fuzzy Tsukamoto inference expert system was used. Fuzzy Tsukamoto is used to combine many rules based on facts from expert knowledge that each rule is represented using Fuzzy sets[13]. Facts in the form of the baby's age, weight, gender, consumption of breast milk or formula milk will be the input values used to determine the status of the baby's set of conditions. Then, food suggestions for the baby are determined by the baby's condition status in the output set.

Previous research related to this problem includes the Application of an Expert System for Selection of Food Based on Nutritional Needs Using the Forward Chaining Method[14], A Comparison Tsukamoto and Mamdani Methods in Fuzzy Inference System for Determining Nutritional Toddlers[15], Decision Support System for Determining the Nutritional Status of Toddlers Using the Fuzzy Tsukamoto Method[16], Education on Feeding Infants and Children to Fulfill Children's Nutrition Intake[17].

METHOD

The method used in this research is in the form of several stages of the research framework:

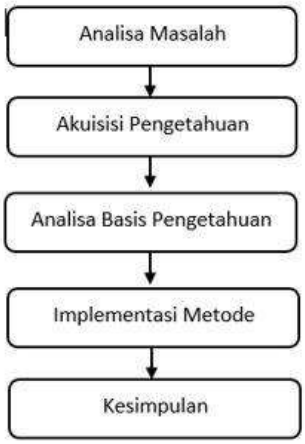

Image 1. Research Framework

In the early stages, an analysis of the nutritional needs of infants 0-5 years will be carried out. Furthermore, the acquisition of expert knowledge, in this case a nutritionist, is carried out in the form of any food that is suitable for babies with the conditions that have been

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analyzed. Next, a table and calculation of the baby's condition will be made which will be implemented using the Fuzzy Tsukamoto method. Conclusions can be drawn from the calculation of a particular case.

Analysis of Infant Nutritional Needs.

Infants aged 0-5 years have a risk of malnutrition because of several things, namely at this golden age there is very rapid development and growth so that toddlers need more nutrients to meet their needs. Then the second reason is that during toddlerhood there is usually a decrease in appetite due to a lot of physical activity and is prone to infection because toddlers always put objects in their mouths to learn to recognize something.

The importance of knowing and paying attention to the provision of nutrients to infants is something that parents should be aware of. Basically, the nutrients that babies need are as follows:

1. Energy
   Energy is very important for babies to do activities. In addition, energy is also useful for the growth and development of the baby. The energy sources are Carbohydrate and fats
2. Proteins
   The need for protein in infants is higher than in adults because protein plays an important role in infant growth, maintenance and repair of body tissues, making digestive enzymes, making immune substances (antibodies) that function to protect the body so it is protected from infectious diseases, and forming cells new cells to support the growth process of all organs of the body and brain development.
3. Fiber
   Fiber is part of carbohydrates and vegetable proteins that are not broken down in the small intestine. Fiber is very important for preventing constipation and other intestinal disorders
4. Vitamin and minerals
   Vitamins are complex organic substances that are needed in very small amounts for many important processes carried out in the body. Minerals are organic substances needed by the body for various functions.

Application of the Tsukamoto Fuzzy Method

Tsukamoto's Fuzzy Method is an extension of single thought. In this method, each IF-THEN rule must be represented by a fuzzy set that has a membership function. As a result, the inference output from each rule will be given certainty based on the D-Predicate[15]. In the Fuzzy Tsukamoto method there must be a relationship between the rules in the form of cause and effect, besides that there must be a relationship between input and output so that the relationship between action and condition can be seen. The following is an overview of Fuzzy Tsukamoto's inference[16].

The result of the calculation of this method is done by finding the Z value that depends on the previous predicted values. The defuzzification formula is as follows[18]:

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$$Z = \frac{apred1 * z1 + apred2 * z2 + apred3 * z3}{apred1 + apred2 + apred3} \quad (1)$$

The Fuzzy Tsukamoto method in this case was used to first classify the nutritional status of infants which consisted of 5 parts, namely the group of malnutrition, undernutrition, good nutrition, over nutrition, and obesity.

RESULTS AND DISCUSSION

In this section, a discussion will be carried out on providing recommendations for baby food menus according to the nutritional adequacy rate based on the grouping results that have been obtained. grouping the condition of babies with the Fuzzy Tsukamoto method.

1. Membership table

This table is taken from the anthropometric standards for children by the Ministry of Health in 2020.

Table 1. Membership

Code	Ages (mo)	Weight (kg)	Height (cm)	Description
A1	0-5	2-3	40-45	Less
		4-7	50-65	Normal
		8-10	>70	Excess
A2	6-11	5-6	60-63	Less
		7-9	70-75	Normal
		11-13	>81	Excess
A3	12-23	6-7	65-70	Less
		8-13	75-90	Normal
		14-16	>95	Excess
A4	24-36	8-9	75-80	Less
		12-14	85-100	Normal
		18-20	>110	Excess
A5	37-60	9-11	80-90	Less
		14-18	95-115	Normal
		20-27	>120	Excess

2. Fuzzification

The fuzzification process is carried out on the variables of age, weight, and height to produce nutritional status in decisions on the baby's nutritional status so that appropriate food menus can be recommended.

3. Table of recommendations for baby food menu

To provide recommendations for baby food, a food menu table is made :

Table 2. Food Table

Code	T01
P01 = Tim Rice/ Rice	100gr
P02 = Potato/ Cassava/ Sweet Potato	2 med. Piece/1 slice/1 piece
L01 = Chicken/ Fish/ Buffallo meat/ Fresh shrimp	1 med. Slice
L02 = egg/ Cow meat	1/1 med. Slice
L03 = Duck	1 med. Slice
K01 = Mung beans/ Soybeans/ Red beans/ Peanuts/tofu/tempe	2 tbl. Spoon/2 ½ tbl. Spoon/2 tbl. Spoon/2 tbl. Spoon/1/2 med. Slice
S01= Spinach/ Water spinach/ Snaps/ Chives/ Long beans/ Broccoli/ Pumpkin/ Carrot	100gr
S02 = Red spinach	100gr
Katuk leaves/ Melinjo/ Bean sprouts/ Papaya leaves/ Cassava leaves	
B01 = fruits	1 med. Slice
G01 = sugar	1 tbl. Spoon
U01 = Yoghurt/ Skimmed milk	2/3cup/4 tbl. Spoon
U02= Cheese/ Goat milk/ Cow milk	1 small slice/3/4 cup/1cup
U03 = Buffalo milk	½ cup
M01 = Avocado/ Almond/ Olive oil	1/7/1 tea spoon

4. Recommendation

a. Malnutriton

All of baby malnutrition 0-60 month inpatient treatment should be carried out

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by administering F100 and F75 from a health worker with the dose adjusted by the medical team based on the baby's condition.

A1 = Breastfeeding or Formula Milk

A2 = Breast milk or Formula Milk 4-6 times a day or 600-900 ml + Pureed food/drink with complete combination (choice according to taste): P01 or P02 + L03 or (L01 + L02) + S02 + juice combination B01 with G01 + snacks K01 with dose of T01 for 3 meals a day.

A3 = Breast milk or Formula Milk 4-5 times a day or 700-800 ml + Food/drink with a complete combination (choice according to taste): P01 or P02 + L03 or (L01 + L02) + S02 + juice combination B01 with G01 + snacks K01 with a dose of 1 + ½ *T01 for 3 meals a day.

A4 = Food/drink with complete combination (choice according to taste): U02 + P01 or P02 + L03 or (L01 + L02) + S02 + juice combination B01 with G01 + snacks K01 + M01 with a dose of 2 * T01 for 3 meals a day.

A5 = Food/drink with complete combination (choice according to taste): U02 + P01 or P02 + L03 or (L01 + L02) + S02 + juice combination B01 with G01 + snacks K01 + M01 with a dose of 3*T01 for 3 meals a day.

b. Normal

A1 = Exclusive breast milk or formula every 2-3 hours or approximately 946 ml in 24 hours.

A2 = Breast milk or Formula Milk 4-6 times a day or 600-800 ml + Pureed food/drink with a complete combination (choice according to taste): P01 or P02 + L01 or L02 + snacks K01 + S01 or S02 + B01 or a combination of 2 fruits + G01. With a dose of T01 for 3x meals a day.

A3 = Breast milk or Formula Milk 4 times a day or 700-800ml + Food/drink with a complete combination (choice according to taste): P01 or P02 + L01 or L02 + snacks K01 + S01 or S02 + B01 or a combination of 2 fruits + G01. With a dose of 1+1/2*T01 for 3 meals a day.

A4 = Food/drink with complete combination (choice according to taste): U02 + P01 or P02 + L01 or L02 + snacks K01 or M01 + S01 or S02 + B01 or a combination of 2 pieces + G01. With a dose of 2 * T01 for 3 meals a day.

c. Obesity

For obesity condition of baby 0-60 month It is better to consult a medical professional.

A1 = Exclusive breast milk or formula according to the baby's needs, which is every 2-3 hours

A2 = Breast milk or Formula Milk 4-6 times a day or 600-800 ml + Pureed food/drink with a complete combination (choice according to taste): P01 or P02 + L01 or L02 + snacks K01 + S01 or S02 + B01 or a combination of 2 fruits + G01. With a dose of ½ of T01 for 2x meals a day.

A3 = Breast milk or Formula Milk 4 times a day or 700-800 ml + Food/drink with a complete combination (choice according to taste): P01 or P02 + L01 or L02 + snacks K01 + S01 or S02 + B01 or a combination of 2 fruits + G01. With a dose of T01 for 2x meals a day.

A4 = Food/drink with complete combination (choice according to taste): U2+P01 or P02 + L01 or L02 + snacks K01 + S01 or S02 + B01 or a combination of 2 pieces + G01. With a dose of 1 + 1/2 * T01 for 3 meals a day.

A5 = Food/drink with complete combination (choice according to taste): U2 + P01 or P02 + L01 or L02 + snacks K01 + S01 or S02 + B01 or a combination of 2 pieces + G01. At a rate

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of 2 * T01 for 3 meals.

Implementation of the Tsukamoto Fuzzy Method

To implement this method, a sample of a baby named Putra Sanjaya was taken, aged 24 months, weight 9.1 kg and height 79 cm.

1. Age membership function:
   Age:
   $\mu_{a4}(x) = 1$

   Weight
   $$\mu_{b10}(x) = \frac{12 - 9{,}1}{12 - 9} = \frac{2{,}9}{3} = 0{,}9$$

   Height
   $$\mu_{c10}(x) = \frac{79 - 75}{81 - 75} = \frac{4}{6} = 0{,}6$$

2. Rule
   Because the age of the baby is in member A4, the rule that is taken is the rule that contains A4.
   - If age A4, less weight, less height, Then Malnutrition Status

$$\alpha\_pre1 = \mu_{a4} \cap \mu_{b10} \cap \mu_{c10}$$
$$min(1\,;\ 0{,}9\,;\ 0{,}6) = 0{,}6$$
$$\mu_{buruk} = \frac{0{,}3 - z}{0{,}3 - 0{,}2}$$
$$0{,}6 = \frac{0{,}3 - z}{0{,}3 - 0{,}2}$$
$$0{,}3 - z = 0{,}06$$
$$z = 0{,}24$$

   - If age A4, less weight, less height, Then Less Nutritional Status

$$\alpha\_pre2 = \mu_{a4} \cap \mu_{b10} \cap \mu_{c10}$$
$$min(1\,;\ 0{,}9\,;\ 0{,}6) = 0{,}6$$
$$\mu_{kurang} = \frac{z - 0{,}2}{0{,}3 - 0{,}2}$$
$$0{,}6 = \frac{z - 0{,}2}{0{,}1}$$
$$z - 0{,}2 = 0{,}06$$
$$z = 0{,}06 + 0{,}2$$
$$z = 0{,}26$$
$$0{,}6 = \frac{0{,}6 - z}{0{,}6 - 0{,}5}$$
$$0{,}6 - z = 0{,}6\ x\ 0{,}1$$
$$-z = 0{,}06 - 0{,}6$$
$$-z = -0{,}54$$
$$z = 0{,}54$$

   - **If** age A4, Normal weight, Normal height, **Then** Good Nutritional Status

$$\alpha\_pre3 = \mu_{a4} \cap \mu_{b11} \cap \mu_{c11}$$
$$min(1\,;\ 0\,;\ 0) = 0$$
$$\mu_{Baik} = \frac{z - 0{,}5}{0{,}6 - 0{,}5}$$
$$0 = \frac{z - 0{,}5}{0{,}1}$$
$$z - 0{,}5 = 0$$
$$z = 0{,}5$$

$$0 = \frac{0{,}8 - z}{0{,}8 - 0{,}7}$$
$$0{,}8 - z = 0$$
$$z = 0{,}8$$

   - **If** age A4, Overweight, Over height,

Then Over Nutritional Status

$$\alpha\_pre4 = \mu_{a4} \cap \mu_{b12} \cap \mu_{c12}$$
$$min(1\,;\ 0\,;\ 0) = 0$$
$$\mu_{Baik} = \frac{z - 0{,}7}{0{,}8 - 0{,}7}$$
$$0 = \frac{z - 0{,}7}{0{,}1}$$
$$z - 0{,}7 = 0$$
$$z = 0{,}7$$
$$0 = \frac{0{,}9 - z}{0{,}9 - 0{,}8}$$
$$0{,}9 - z = 0$$
$$z = 0{,}9$$

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- **If** age A4, less weight, less height, **Then** Obesity Nutritional Status

$$\alpha\_pre5 = \mu_{a4} \cap \mu_{b12} \cap \mu_{c12}$$
$$min(1\ ;\ \ 0\ ;\ \ 0) = 0$$
$$\mu_{Obesitas} = \frac{z - 0{,}8}{0{,}9 - 0{,}8}$$
$$0 = \frac{z - 0{,}8}{0{,}9 - 0{,}8}$$
$$z - 0{,}8 = 0$$
$$z = 0{,}8$$

3. Results
   The results of the membership fuzzification above are calculated using the Tsukamoto fuzzy formula:

$$Z = \frac{0{,}6 * 0{,}24 + 0{,}6 * 0{,}26 + 0 * 0{,}5 + 0 * 0{,}7 + 0 * 0{,}8}{0{,}6 + 0{,}6 + 0 + 0 + 0}$$
$$Z = \frac{0{,}19344}{1{,}2}$$
$$Z = 0{,}16$$

Based on the nutritional status decision table, with Z below 0.2, the nutritional status of Putra Sanjaya **is malnutrition**.

Recommendation : Food/drink with complete combination (choice according to taste): U02 + P01 or P02 + L03 or (L01 + L02) + S02 + juice combination B01 with G01 + snacks K01 + M01 with a dose of 2 * T01 for 3 meals a day.

If the condition is bad, then inpatient treatment should be carried out by administering F100 and F75 from a health worker with the dose adjusted by the medical team based on the baby's condition.

CONCLUSION

Based on the results of the study it can be concluded that the Fuzzy Tsukamoto method can be used to indicate the nutritional status of infants by means of fuzzification of age, weight and height which is then carried out inferences to trace according to the rule base. The results of the fuzzy method of classifying the nutritional status of infants are used to provide recommendations for food and drink that are good for the baby to consume according to their nutritional status based on the Nutrition Adequacy Rate.

THANK-YOU NOTE

Thank you and highest appreciation to all parties involved in the process of carrying out this research, especially to the Ministry of Research and Technology / National Research and Innovation Agency (KEMENRISTEKBRIN) which has assisted with funding through the "Beginner Lecturer Research" grant program so that novice researchers become more passionate again to create innovations in the field of technology for a better Indonesia.

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