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4 Star Complementary Food Menu Recommendation System Using the Mobile-Based Fuzzy Multiple Attribute Decision Making (FMADM) Method

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Abstract

In order to fulfill the nutritional needs for the toddler's growth, complementary foods must be sufficient in the age category of six to twenty-four months while still paying attention to the continuity of breastfeeding. One thing that must be considered in choosing complementary foods is the Recommended Dietary Allowances (RDA) which is categorized by age, weight, and food texture, which is adjusted to the toddler age category. In terms of fulfilling all aspects of choosing complementary foods, this study proposes the design of a 4-star daily menu recommendation system for toddlers which refers to the intake of daily calorie needs for toddlers, namely carbohydrates, animal protein, vegetable protein, and vitamins/minerals using the FMADM method (Fuzzy Multiple Attribute Decision Making). The FMADM method used is the Electre method. In this study, the authors succeeded in building the desired recommendation system using the Electre method that can be accessed via mobile devices which produces a daily menu based on the number of mealtimes, based on the age and weight of toddlers by observing the user's tendency to the texture and composition of food and its nutritional content in the recommendation system.

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1. Introduction

Breast milk is one of the first nutritional intakes consumed by a baby. However, when the baby has become an infant or even a toddler, which is entering the age of 6 months to 24 months, breast milk is no longer enough to meet their nutritional needs so complementary foods are needed [1]. Provision of complementary foods aims to complement the breast milk nutrients, which is increasingly needed as the toddler grows [2].

Complementary foods itselves are semi-solid foods in the form of porridge, ground or mashed foods, baby cereals, and various other special baby foods. In making of complementary foods must consider the Recommended Dietary Allowances (RDA) based on the body weight, age, and food texture that is appropriate for the age of toddlers. This can be obtained from the type of food menu that contains four proper nutritional elements called the 4-star complementary food menu, namely: carbohydrates by 35%, animal protein by 25%, vegetable protein by 10% and minerals or vitamins by 25%.

The nutritional knowledge possessed by the mother is a factor that influences the provision of complementary foods for toddlers. Nutritional knowledge on food is only based on the experience of the parents and from several articles. Giving complementary foods that are not appropriate for their age can affect the digestive performance of toddlers, because it is not yet time to receive complementary foods, causing toddlers to experience diarrhea, allergies, respiratory infections to growth disorders [3] [4]. In addition, the inappropriate timing and intake of nutrients in food when giving complementary foods to the age of the baby, will result in stunted which will be seen at the age of two years above [5][6].

Meanwhile, with the development of technology and information in mobile-based, it can be used to find a menu of 4-star complementary food recommendations that are suitable and appropriate to be given to toddlers based on the benefits and in accordance to their age.

Related to the research topics described above, several researchers have also carried out by [7] using the TOPSIS method, in the following year research on the same topic was carried out by [8] using the Forward Chaining method, [9] using the Anthropometric method, and [10] using the Naïve Bayes method, and then making an information system related to MPASI carried out by [11][12]. Those Research, in their systems is not mobile-based yet.

K-Means is a non-hierarchical data clustering method that attempts to partition existing data into one or more skilled and classic clusters in data grouping [13][14][15]. K-Means clustering lies in the partitioning clustering method which often used in data mining [16].

The Electre method is part of the FMADM (Fuzzy Multiple Attribute Decision Making) method which is used as a calculation in the recommendation system that was built. FMADM is a method that will determine the weight value of each attribute to be ranked in the selection of existing alternatives [17][18][19]. Meanwhile, the Electre method which was first developed by Benayoun, Roy et al (1966) uses a comprehensive evaluation approach by trying to create a ranking of the number of each alternative described on several criteria [20][21]. In the Electre method, an alternative is said to dominate other alternatives if one or more criteria is exceeded (compared to other criteria) and it is equal to the remaining criteria [22]. So Electre can be used for cases with many choices, but there are only a few criteria involved [21] [23].

The selection of the Electre method is based on its ability to determine the weight value for each attribute, namely the weight of the toddler, the age of the toddler, and gender, by means of a sorting or ranking process in selecting the best alternative from a set of alternatives produced. The alternative is the best complementary food menu that refers to predetermined criteria and nutritional adequacy rates which are

presented in the form of a mobile-based application. So that with your mobile device, you can easily find recommendations for complementary foods that are suitable and varied every day.

2. Research Methods

The methodology is carried out to provide a clear picture of the flow and structure of the research, from preparation, problem analysis, until the implementation, which is described in one flow diagram, so making it easier for the researchers and the users to understand the system being built. The methodology used in this study is the Methodology of Expert System. The method steps are namely:

2.1 Problem Definition

At this stage, the preliminary process of this research is carried out. This stage has 2 processes, namely:

1. Kakas Selection

Selection of Kakas is useful to determine how the application will be built, in this process it is related to determining the programming language and methods in used. The method used is the Electre method which is a group of FMADM methods. The stages of the Electre method implemented in the system that was built were following [20] [21] [23] [24] [25][26]:

a. Preparing the decision matrix

The first step is to prepare a decision matrix, which is used as a standard based on criteria and alternatives

b. Normalizing the decision matrix

At this stage, each attribute is processed into a comparable value. Before normalizing this matrix, it is necessary to determine the weight of the criteria based on the given alternatives. In this study, alternatives were categorized into four menu choices based on the age of six months under five based on the 4-star complementary food menu.

Table 1. Determination of Criteria and Alternative Values Based on The Rda Content of Each Menu

Menu	Alternative	Menu Name	Criteria			
			C1 = Carbohydrate (35%)	C2 = Animal Protein (30%)	C3 = Vegetable Protein (10%)	C4 = Vitamin & Mineral (25%)
1	A1	Organic White Rice + Ground Beef + Peeled Green Beans + Organic Carrots	Not Enough (3)	Not Enough (3)	Too Much (5)	Not Enough (3)
2	A2	Organic White Rice + Chicken Fillet + Tempe + Tomato	Not Enough (3)	Not Enough (3)	Too Much (5)	Not Enough (3)
3	A3	Potato + Egg + Tempe + Carrot	Not Enough (3)	Not Enough (3)	Too Much (5)	Enough (4)
4	A4	White Rice + Tuna + Japanese Tofu + Carrot	Too Much (5)	Too Much (5)	Not Enough (3)	Not Enough (3)

Furthermore, the normalization of the matrix is determined based on the formula

$$X = \begin{bmatrix} 3 & 3 & 5 & 3 \\ 3 & 3 & 5 & 3 \\ 3 & 3 & 5 & 4 \\ 5 & 5 & 3 & 3 \end{bmatrix} \qquad R = \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} \\ r_{21} & r_{22} & r_{23} & r_{24} \\ r_{31} & r_{32} & r_{33} & r_{34} \\ r_{41} & r_{42} & r_{43} & r_{44} \end{bmatrix}$$

$$r_{11} = \frac{x_{11}}{\sqrt{x_{11}^2 + x_{21}^2 + x_{31}^2 + x_{41}^2}} = \frac{3}{\sqrt{3^2 + 3^2 + 3^2 + 5^2}}$$

$$r_{11} = \frac{3}{\sqrt{52}} = 0{,}4160$$

The calculation will be performed to all matrix values up to r44.

c. Weighting of the Normalized matrix

At this stage, each column in the R matrix is multiplied by the weight (wj) determined by the decision maker. So, the weighted normalized matrix is V = R.W. Meanwhile,

the preference weight used in this study is the Weight

(W) = (4, 4, 4, 4)

V = R . W

$$= \begin{bmatrix} 0.4160 & 0.4160 & 0.5455 & 0.4575 \\ 0.4160 & 0.4160 & 0.5455 & 0.4575 \\ 0.4160 & 0.4160 & 0.5455 & 0.6100 \\ 0.6934 & 0.6934 & 0.3273 & 0.4575 \end{bmatrix}$$

$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 4 & 0 & 0 \\ 0 & 0 & 4 & 0 \\ 0 & 0 & 0 & 4 \end{bmatrix}$$

$$V = \begin{bmatrix} 1.6641 & 1.6641 & 2.1822 & 1.8300 \\ 1.6641 & 1.6641 & 2.1822 & 1.8300 \\ 1.6641 & 1.6641 & 2.1822 & 2.4400 \\ 2.7735 & 2.7735 & 1.3093 & 1.8300 \end{bmatrix}$$

d. Determining the set of concordance and discordance index

Concordance Set Step

C12 = {j, v1j ≥ v2j} = {1,2,3,4}
C13 = {j, v1j ≥ v3j} = {1,2,3}
C14 = {j, v1j ≥ v4j} = {3,4}
C21 = {j, v2j ≥ v1j} = {1,2,3,4}
C23 = {j, v2j ≥ v3j} = {1,2,3}
C24 = {j, v2j ≥ v4j} = {3,4}
C31 = {j, v3j ≥ v3j} = {1,2,3,4}
C32 = {j, v3j ≥ v2j} = {1,2,3,4}
C34 = {j, v3j ≥ v4j} = {3,4}
C41 = {j, v4j ≥ v1j} = {1,2,4}
C42 = {j, v4j ≥ v2j} = {1,2,4}
C43 = {j, v4j ≥ v3j} = {1,2}

Discordance Set Steps

D12 = {j, v1j < v2j} = {}
D13 = {j, v1j < v3j} = {4}
D14 = {j, v1j < v4j} = {1,2}
D21 = {j, v2j < v1j} = {}
D23 = {j, v2j < v3j} = {4}
D24 = {j, v2j < v4j} = {1}
D31 = {j, v3j < v3j} = {1,2}
D32 = {j, v3j < v2j} = {}
D34 = {j, v3j < v4j} = {1,2}
D41 = {j, v4j < v1j} = {3}
D42 = {j, v4j < v2j} = {3}
D43 = {j, v4j < v3j} = {3,4}

e. Setting the concordance matrix and discordance index

Concordance matrix

c12 = w1 + w2 + w3 + w4 = 4 + 4 + 4 + 4 = 16
c13 = w1 + w2 + w3 = 4 + 4 + 4 = 12
c14 = w3 + w4 = 4 + 4 = 8
c21 = w1 + w2 + w3 + w4 = 4 + 4 + 4 + 4 = 16
c23 = w1 + w2 + w3 = 4 + 4 + 4 = 12
c24 = w3 + w4 = 4 + 4 = 8
c31 = w1 + w2 + w3 + w4 = 4 + 4 + 4 + 4 = 16
c32 = w1 + w2 + w3 + w4 = 4 + 4 + 4 + 4 = 16
c34 = w3 + w4 = 4 + 4 = 8
c41 = w1 + w2 + w4 = 4 + 4 + 4 = 12
c42 = w1 + w2 + w4 = 4 + 4 + 4 = 12
c43 = w1 + w2 = 4 + 4 = 8

So, the concordance matrix is:

$$\begin{bmatrix} - & 16 & 12 & 8 \\ 16 & - & 12 & 8 \\ 16 & 16 & - & 8 \\ 12 & 12 & 8 & - \end{bmatrix}$$

Discordance matrix

$$d12 = \frac{\max\{0\}}{\max\{(1.6641-1.6641);(1.6641-1.6641);(2.1822-2.1822);(1.8300-1.8300)\}} = \frac{\max\{0\}}{\max\{(0);(0);(0);(0)\}} = 0$$

This process will be continued until the discordance matrix value is d43.

f. Determining the dominant concordance and discordance matrix

Concordance dominant matrix
The threshold value (c) is

$$C = \frac{\sum_{k=1}^{m}}{m(m-1)}$$

= 16 + 12 + 8 + 16 + 12 + 8 + 16 + 16 + 8 + 12 + 12 + 8 / 4 (4-1) = 12

F matrix elements:

$$f_{kl} = \begin{cases} 1, jika\ c_{kl} \geq \underline{c} \\ 0, jika\ c_{kl} < \underline{c} \end{cases}$$

Concordance dominant matrix result:

$$F = \begin{matrix} - & 1 & 1 & 0 \\ 1 & - & 1 & 0 \\ 1 & 1 & - & 0 \\ 1 & 1 & 0 & - \end{matrix}$$

Discordance dominant matrix
The threshold value (c) is

$$d = \frac{\sum_{k=1}^{m}}{m(m-1)}$$

= 0 + 0 + (-1.27) + 0 + 0 + (-1.27) + 0 + 0 + (-1.27) + (-0.78) + (-0.78) + (-0.54) / 4 (4-1)
= 0.4947

Determine the elements of the matrix G:

$$g_{kl} = \begin{cases} 1, jika\ d_{kl} \geq \underline{d} \\ 0, jika\ d_{kl} < \underline{d} \end{cases}$$

the dominant discordance matrix is:

$$G = \begin{matrix} - & 0 & 0 & 1 \\ 0 & - & 0 & 1 \\ 0 & 0 & - & 1 \\ 1 & 1 & 1 & - \end{matrix}$$

g. Determining the aggregate dominant matrix

E = F x G

$$\begin{bmatrix} - & 1 & 1 & 0 \\ 1 & - & 1 & 0 \\ 1 & 1 & - & 0 \\ 1 & 1 & 0 & - \end{bmatrix} x \begin{bmatrix} - & 0 & 0 & 1 \\ 0 & - & 0 & 1 \\ 0 & 0 & - & 1 \\ 0 & 0 & 0 & - \end{bmatrix}$$

$$= \begin{bmatrix} - & 0 & 0 & 0 \\ 0 & - & 0 & 0 \\ 0 & 0 & - & 0 \\ 1 & 1 & 0 & - \end{bmatrix}$$

h. Eliminating the less favorable alternatives

Each alternative from the selection sequence is described in Matrix E. If ekl = 1 then alternative Ak is more optimal than A. So the row that has the least number of ekl=1 in matrix E can be eliminated.
Based on step f, it is calculated that the aggregate value has the highest value and is considered the best alternative in providing recommendations.
The best alternative in the MPASI recommendation for 6 months of age is the fourth menu, namely

Carbohydrates	: White Rice
Animal Protein	: Tuna
Vegetable Protein	: Japanese Tofu
Vitamins & Minerals	: Carrot

2. Expert Knowledge

The transfer of a person's expertise into a system is called an expert system. Expert System is an artificial intelligence system, which is built on the basis of in-depth expertise in a particular field of study/obtained from experts and specialists in that field [27][28] [29]. The expert who was asked for data and information in this study was dr. Krisnanto Wibobo, SP.A, M.Sc who served at an hospital named RSIA Andini Pekanbaru

2.2 System Build

This stage is the system-building process of a 4-star complementary food menu recommendation by incorporating the stages of the Electre method into the system that was built. The system was made based on android with android studio programming and MySQL database so that it is easy to access.

2.3 Testing

This stage will use Black box testing to see the functionality of the system being built, so that there are no error features that hinder the evaluation process.

2.4 Evaluation

This stage is used to evaluate the system by asking several respondents to use a 4-star recommendation system, so as to produce recommendation data which is then verified by the experts regarding its correctness.

2.5 Documentation

Tahap ini mendokumentasikan hasil penelitian dalam bentuk laporan dan publikasi lainnya sehingga dapat bermanfaat sebagai bahan referensi dan pertimbangan bagi peneliti lain.

3. Results and Discussion

3.1 Use Case Diagram System

The following is the use case system used, where there are 2 actors, namely Admin and System Users. Admin has the authority to manage/edit/add/delete existing data on needs, recipes, and rules for the complementary foods. Meanwhile, users can only view the complementary food recipes and select the recipes through the criteria provided by the system.

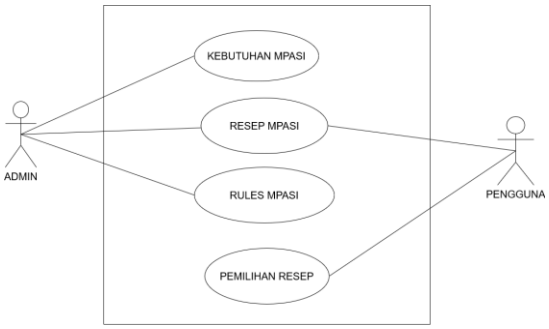

Figure 1. Use case diagram

3.2 Result

The application display in the study is divided into 2 parts, the first part is the Administrator who is in charge of inputting master data, in the form of complementary food menu data, nutritional needs data, and nutritional value data of each food. The second part is the public part or application that is intended for general users, in this case, the community.

a. Rules Page

In this section the admin inputs the variables used in calculating the Electre method which is also used as a rule in decision making for the 4 Star complementary food menu recommendation system. The inputted variables include:

1. In this complementary food system, the recommended age for toddlers is between 6 months to 24 months.
2. The ideal weight for toddlers is in accordance with the Indonesian toddler weight standards.
3. Measurement of the estimated energy requirement EER value from the total energy requirement, which comes from breast milk and complementary foods as a reference in menu recommendations [5]

Table 2. Value Measurement of Estimated Energy Requirement (EER)

Age	EER Value
6-8 month	(89 x body weight [kg] – 100) + 56 (kcal *energy deposition*)
9-11 month	(89 x body weight [kg] – 100) + 22 (kcal *energy deposition*)
12-24 month	(89 x body weight [kg] – 100) + 20 (kcal *energy deposition*)

4. Ideal calorie requirement (Kcal), maximum and minimum according to the formula

Calculation of kcal in Table 3 per times complementary food

Table 3. Average energy obtained from breast milk (WHO/Unicef,2008)

Age	Energy
6-8 month	413 kcal/day
9-11 month	379 kcal/day
12-24 month	346 kcal/day

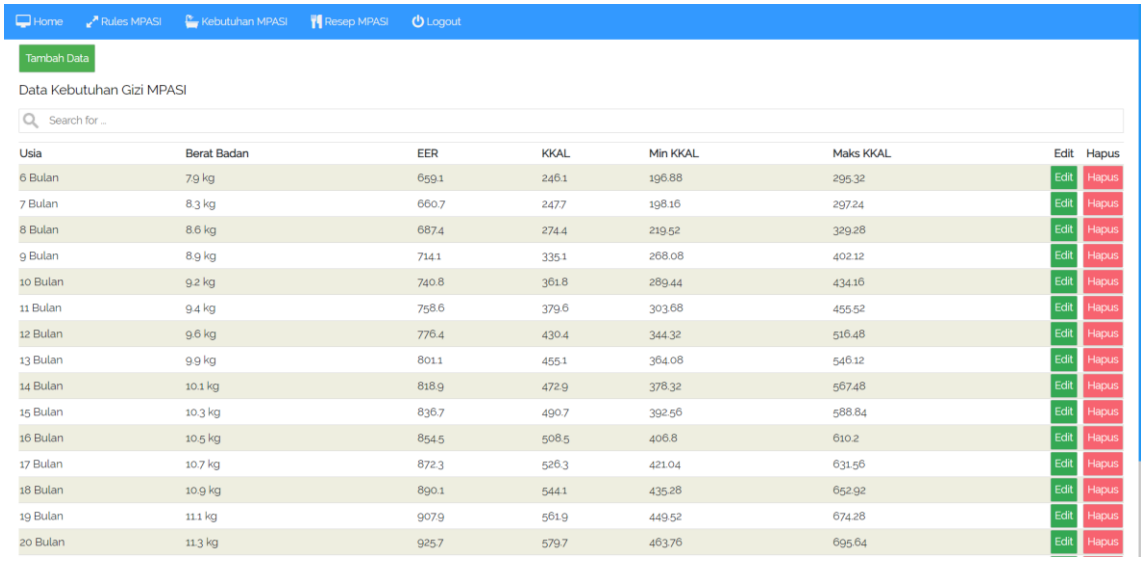

Figure 2. Rules Page

b. Nutritional Needs Page

As explained in the introduction, the 4-star complimentary food contains 35% carbohydrates, 25% animal protein, 10% vegetable protein, and 25% vitamins and minerals obtained from vegetables and fruit.

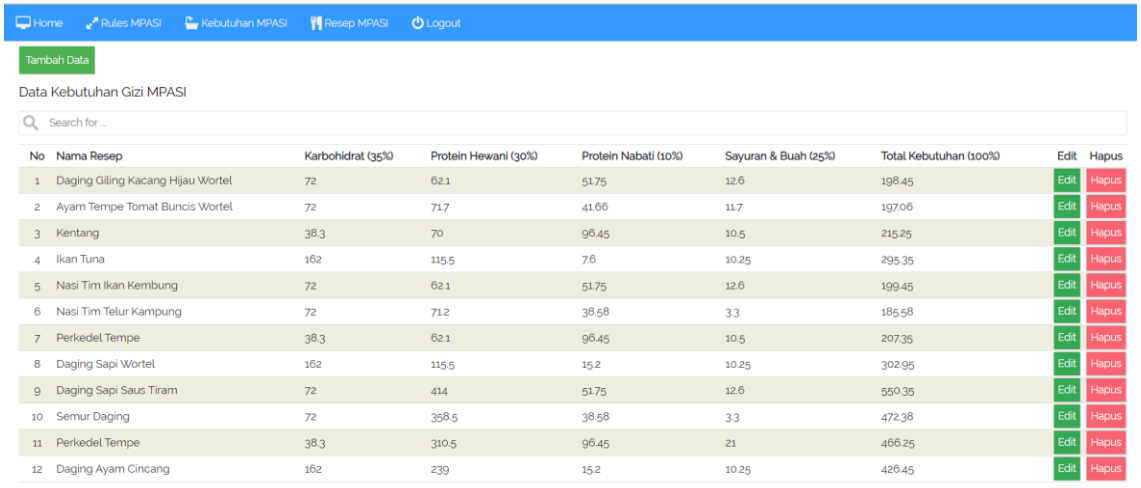

Figure 3. Nutritional needs page

c. Menu Option Page

This page is the determinant of the 4-star complementary food menu recommendations that are in accordance with the nutritional content. This variable is also

determined as a variable in the analysis using the Electre method.

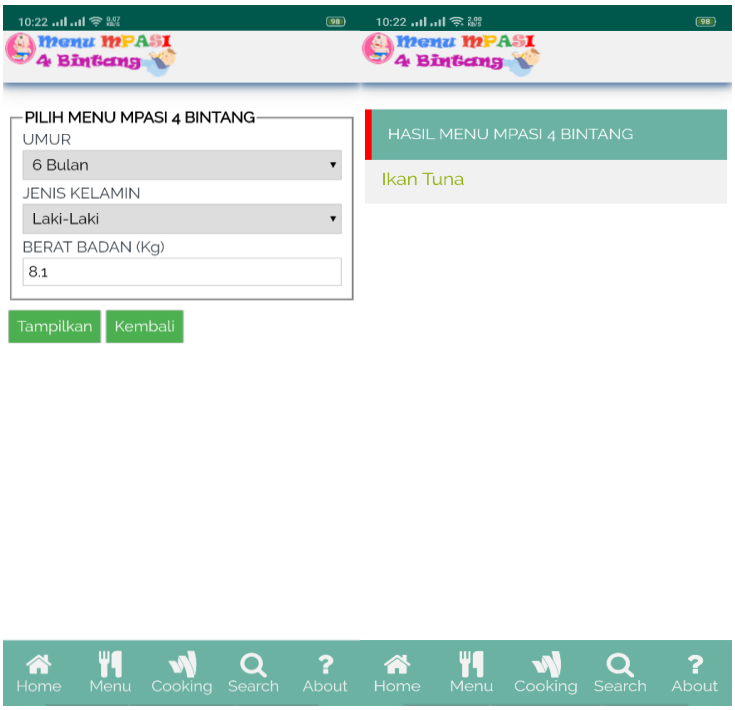

Figure 4. Menu options page

d. Menu Details Page

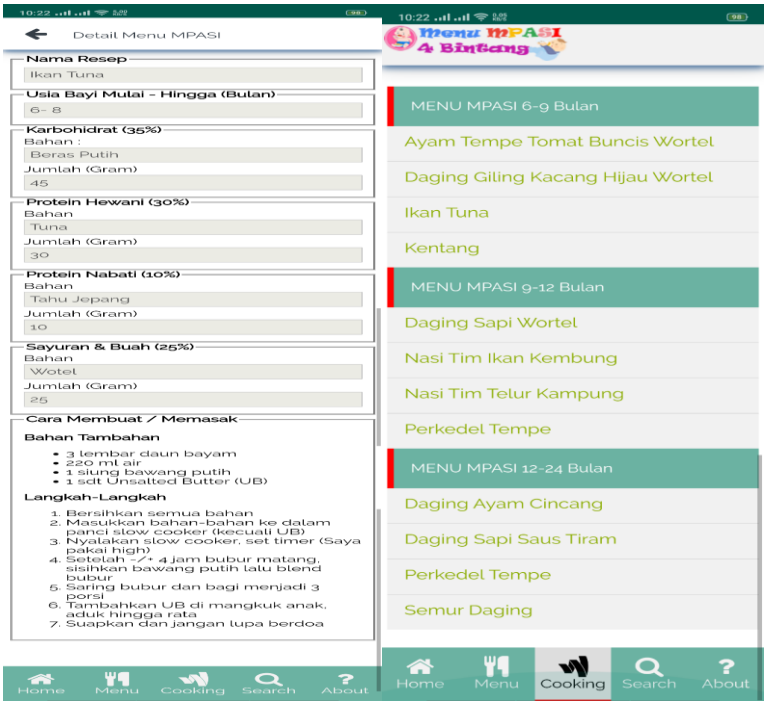

Figure 7. Selected menu details page

3.3 Testing

before implementation, the next step is to conduct testing, testing is carried out so that the resulting system or application can be known for its shortcomings so that improvements can be made to the system or application [30][31]. At this stage, testing is carried out on the system that has been built using Black Box Testing, where testing is carried out on system functions while operating whether it can run as expected or not.

4. Conclusion

Through the implementation of Electre which is a multi-criteria-based decision-making analysis method into implementation, it can be said that the system has been able to prove results in recommending complementary food menus. In the case of the proposed 4-star complementary food menu recommendation, with 4 candidate variables in the form of a 4-star complementary food menu recipe for 6 months of age, namely A1 = Recipe 1, A2 = Recipe 2, A3 = Recipe 3 and A4 = Recipe 4. These 4 stars provide 4 criteria as a step in selecting candidates for Carbohydrates (35%), Animal Protein (30%), Vegetable Proteins (10%) and Vitamins & Minerals (25%). In this case, the author gives weight to the four criteria is [4,4,4,4]. After doing the selection using the Electre method, the 4th Recipe was chosen for a recommendation for complementary food 4 stars aged 6 months, namely Carbohydrates: White Rice, Animal Protein: Tuna, Vegetable Protein: Japanese Tofu, Vitamins & Minerals: Carrots

Meanwhile, for further development, it is recommended that the system that is built can consider foods that are liked by toddlers to foods that cause allergies for toddlers.

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