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KAWANKULINER: PERSONALISED FOOD RECOMMENDATION APP USING BMR AND TDEE FOR OPTIMAL DAILY NUTRITION

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ABSTRACT

People often have difficulty in determining the type of food that is suitable for the composition of their body. This is due to the many types of food available, as well as the lack of information about the nutritional content of each type of food. By fulfilling the daily calorie and macro-nutrient needs required by the body, its metabolism can be maintained, preventing various health problems such as malnutrition. Based on the results of the Basic Health Research in 2018 malnutrition is one of the most serious problems in Indonesia. Several studies related to calculating calorie estimates using the BMR approach with the utilization of technology have been conducted. However, these studies were limited to only displaying the amount of daily calorie needs that were not accompanied by what foods were needed to meet these daily needs. The purpose of this research is to build an app to help individuals understand their daily calorie needs based on their Basal Metabolic Rate (BMR) and total daily expenditure energy (TDEE), using smart scale to provide body composition information and spoonacular API to provide food recommendations that match their energy needs and give them recipes on how to make their food meanwhile waterfall model is used as a software development method. The test results show that the app meets the functional and usability requirements well, with a high accuracy rate of 99.86% for calories, protein, fat, and carbohydrates. In terms of user response, 13 respondents had a very positive response, and considered the app useful for making it easier to get information about their calorie and macro-nutrient needs, as well as provide food recommendations based on their daily needs.

2020 ACM Computing Classification Codes:

Introduction

Food is one of the basic needs for every human being. Proper food consumption will ensure the health for the body, while improper food consumption can cause bad things such as health problems [1,2,3,4,5] and environmental problems [6,7,8]. Therefore, it is important for each individual to consume the right foods that match their daily calorie needs.

People often have difficulty in determining the type of food that is suitable for their body structure and weight. This is due to the many types of food available, as well as the lack of information about the nutritional content of each type of food [9,10]. By fulfilling the calorie and macro-nutrient needs required, the body's metabolism can be maintained, preventing various health problems such as malnutrition [11]. Based on the results of the Basic Health Research in 2018, malnutrition in Indonesia includes 17.7% undernutrition in adults, 10.2% undernutrition, and 27.3% stunting. While obesity in adults is at 21% so that in total the number of nutritional problems in Indonesia is still fairly high [12,13]. People must learn to consume food according to their daily calorie needs, especially in terms of macro nutrients, so that the nutrients consumed are neither less nor more than needed.

Based on the results of a questionnaire distributed randomly in Bandung city to people from different age groups and backgrounds, it was found that out of 35 respondents, more than half of them did not know their body weight composition (54.3%) or body composition percentage (78.9%). As a result, they found it difficult to manage their weight effectively. In addition, only a small proportion knew their daily calorie requirements (8.6%) and daily nutrient requirements (11.4%), which could lead to nutritional imbalances and energy deficiencies in their diets. More than half of the respondents also had difficulty deciding on a diet that suited their nutritional needs (74.3%) and did not pay attention to the nutritional content of food (68.6%), which resulted in an unbalanced nutritional intake and raised the potential for malnutrition. Only 20% of respondents had a nutritionally balanced diet, most did not (22.9%) or did not even know if their food choices were healthy (57.1%). This shows that people did not know their daily nutritional requirement according to their daily activity requirements.

The method for calculating daily nutritional needs involves energy requirements for the Basal Metabolic Rate and total daily energy expenditure required for daily activities. Basal Metabolic Rate (BMR) is the amount of energy needed by the body at rest to maintain basic functions such as breathing, blood circulation, cell growth and maintaining body temperature [14]. Total Daily Energy Expenditure (TDEE) is the total amount of energy needed by the body based on the amount of daily activity, where the energy needs vary depending on how much physical activity is carried out. Several studies related to calculating calorie estimates using the BMR approach have been conducted [15-17]. However, these studies were limited to only displaying the amount of daily calorie needs and were not accompanied by what foods were needed to meet these daily needs. Other studies [18] have been conducted involving diet programmes in line with calorie needs and the types of disease suffered, but the food recommendations do not specifically include macronutrient needs. Research conducted by Agustia [19] includes elements of macronutrient needs and recommends foods that do not exceed these daily nutritional needs in the form of augmented reality, but in this study the data is still static, private and limited in accuracy because it does not consider the daily physical activity factor.

This research paper aims to improve the accuracy of daily calorie need estimates and macro nutritional information, which include carbohydrates, fats and proteins to provide personalised food recommendations on the spoonacular API using the Basal Metabolic Rate (BMR) calculation from Miffilin-St Jeor [14,19] and Total Daily Energy Expenditure (TDEE) [18,20]. In order to measure body weight more accurately, a smart scale [21] is used to take measurements automatically. Another capability of the smart scale can provide body composition information which can provide better food recommendations. In addition, the application can provide recipes from the selected foods so that users can provide these foods themselves.

It is expected that this research can contribute to helping people get food recommendations that match their daily macronutrient needs so that they can support a healthy diet, avoid overconsumption or malnutrition and encourage users to avoid food waste which can reduce the carbon footprint and keep the environment healthy.

Methodology

The research stages carried out consist of 6 phases (as shown in Figure 1), namely problem formulation, analysis of daily calorie and macro nutritional needs, analysis of food recommendations, software development, result analysis, and drawing conclusions.

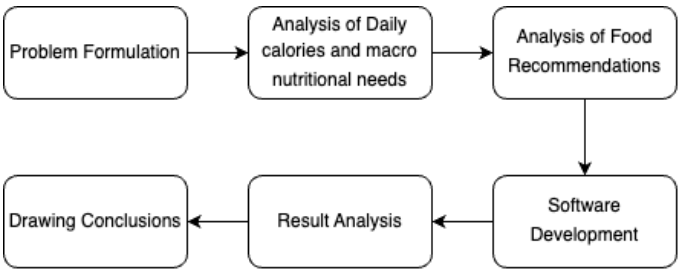

Figure 1: Research stage

The problem formulation is the process of analysing the problem being studied to find a solution, namely by using data collection methods such as literature study in which data can be obtained from books, journals, research reports, and other sources related to the research topic. Another data collection method is the distribution of questionnaires to respondents via an online form.

The Second phase is an analysis of the daily calorie and macro nutrient needs. At this stage, data will be taken from the smart scale device, such as body weight and body composition. Body weight is used to calculate a person's weight whether it is in an ideal condition or not. The body mass index refers to the WHO western pacific region [22]. The body mass index (BMI) formula is:

The body mass index categories information can be seen in Table 1.

$$Body\ Mass\ Index = \frac{Weight}{Height^2} \quad (1)$$

Table 1: Body Mass Index classification

Category	Body Mass Index
Underweight	< 18,5
Normal weight	18,5 - 22,9
Overweight	23 - 24,9
Obesity	25 - 29,9
Obesity II	≥ 30

Other data taken from the smart scale is a person's body composition data, the data to be analysed includes bone mass, muscle mass and percentage of body water. Bone mass is an important component of body weight composition that plays a role in the strength and structure of the body's skeleton. Muscle mass is an important component of body weight composition that is related to strength and function and percentage of body water content reflects the amount of water present in the body and is important for maintaining hydration balance and optimal physiological function. The method used in the smart scale uses BIA (Bioelectrical Impedance Analysis) [23].

Daily Calorie Needs Analysis

In this study, the method used to estimate a person's daily calorie needs is the Basal Metabolic Rate (BMR) Method using the Mifflin-St Jeor formula. This method considers gender, weight, height, and age as factors in the BMR calculation. It can be seen in the following formula:

$$Man\ BMR = [10 \times Weight(kg)] + [6.25 \times Height(cm)] - [5 \times Age(years)] + 5 \quad (2)$$

$$Woman\ BMR = 10 \times Weight(kg)] + [6.25 \times Height(cm)] - [5 \times Age(years)] - 161 \quad (3)$$

After BMR is obtained, calculations are carried out involving total daily energy expenditure (TDEE). If BMR is the caloric requirement to keep the organs functional during the day, TDEE is the amount of energy required to carry out the basic functions of the body for daily activities and exercise. To calculate the TDEE value multiply the activity multiplier from McArdle et al. [24] by BMR. The activity level table along with the TDEE calculation formula based on the Katch-McArdle multiplier can be seen in Table 2.

Table 2: Katch-McArdle multiplier for calculating TDEE

Activity level	Formula
Sedentary	BMR x 1.2 (All day sitting in the office, driving at home. Walks around the office/home at most. No exercise at all or once a month).
Slightly active	BMR x 1,375 (Does moderate exercise 1-3 times per week for 30-60 minutes. This could be brisk walking, leisurely cycling, light yoga Lots of standing and walking during daily activities).
Moderately active	BMR x 1.55 (Does moderate exercise 6-7 times per week for 60+ minutes. Can be running, swimming, aerobic exercise, soccer, badminton. Lots of moving and standing during daily activities).
Very active	BMR x 1,725 (Does vigorous exercise every day or 2 times a day. Can be long distance running, weightlifting, intensive gymnastics, team sports. Work requires a lot of movement and strenuous physical activity).
Extra active	BMR x 1.9 (Doing heavy exercise 2 or more times a day. Professional athletes, very heavy physical labourers such as construction workers. Almost all time is spent in intensive physical activity).

Nutritional Needs Analysis

Nutrients are needed by the body, nutrients are divided into macro nutrients such as proteins, carbohydrates, fats, and micronutrients such as vitamins and minerals. In this study, the nutritional needs analysed only include macro nutrients. The nutritional needs of each individual is different depending on gender, age, weight, height, activity level, and health conditions. In general, a person's daily nutritional needs can be calculated using the following nutritional needs formula according to the Institute of Medicine (IOM) [25]:

$$Carbohydrate = \frac{65\% * Daily\ Calorie\ Needs}{4} \quad (4)$$

$$Protein = \frac{15\% * Daily\ Calorie\ Needs}{4} \quad (5)$$

$$Fats = \frac{20\% * Daily\ Calorie\ Needs}{9} \quad (6)$$

The Third phase is analysis of food recommendation. Food recommendations are obtained by connecting the input data of a person's food nutrition needs with a list of foods obtained through the spoonacular API. Spoonacular API is a web service that can be accessed by the application to retrieve nutritional data and food recipes. Food recommendations is divided into 3 eating sessions, which are breakfast, lunch and dinner. There are many percentages of the distribution of food portions for the

three sessions, in this study the distribution of macro-nutrient needs uses a percentage of 30% for breakfast, 40% for lunch and 30% for dinner [26].

The fourth stage is software development. To build the software the waterfall approach is used. In this phase, the integration process is carried out how the smart scale as an automatic measurement tool and the spoonacular API as a food recommender are connected to the application. The output is that the system is expected to provide food recommendations according to the characteristics of the user's needs where the type of macro-nutrient food can be selected by the user, besides that the selected food will provide detailed information in the form of nutritional content and how to make it.

The Fifth phase is Result Analysis. A series of tests were conducted involving several users to see the results of the recommendations after measurements using the smart scale and application were taken. The method for calculating the comparison between manual and system measurements is calculated using the relative error method to calculate the accuracy.

$$Relative\ Error\ = \left| \frac{Predicted\ Value - True\ Value}{True\ Value} \right| x\ 100\% \quad (7)$$

$$Accuracy\ = 100\% - Relative\ Error \quad (8)$$

After the results are analysed, the sixth phase is carried out by drawing conclusions from the research that has been done.

Result and Discussion

Architecture System

The system architecture can be seen in Figure 2. The architecture illustrates how the smart scale, application and spoonacular API are integrated to be able to provide food recommendations based on daily macronutrient needs.

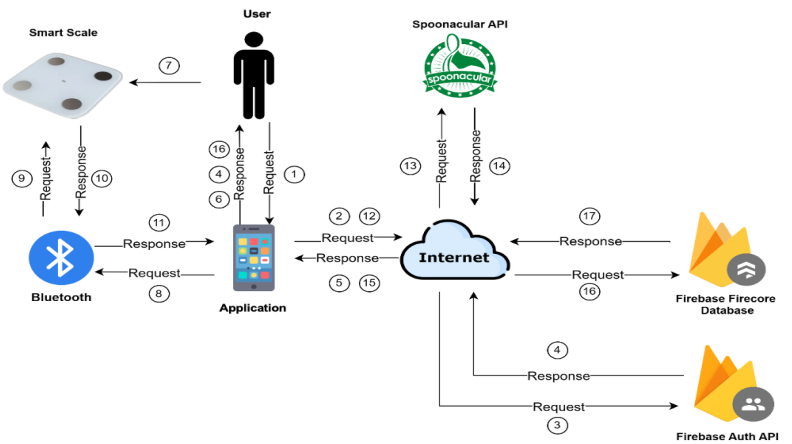

Figure 2: Architecture system

The following is an explanation of the system workflow:

Steps 1 to 5 show the user authentication and account data retrieval process where the process is as follows: When the user logs into the application, it initiates an account authentication request to the Firebase Auth API via the internet to verify the user's identity. The Internet acts as an intermediary, forwarding the authentication request from the application to the Firebase Auth API. If the authentication is successful, the Firebase Auth API responds with the user's account data, which the app receives over the internet. This process provides the app with essential information about the user.

Steps 6 to 11 show the user data Entry and smart scale integration process where the process is as follows: After logging in, the user fills in personal data such as age, height, gender, and activity level, which the app requires to calculate calorie and nutrition requirements. Additionally, the user uses a smart scale to measure body weight, data necessary for the app to determine body composition. The application performs a connection request to the smart scale via Bluetooth, enabling the app to connect with the smart scale. Bluetooth then acts as a communication intermediary, connecting the smart scale with the app and allowing the smart scale to send weight composition data via Bluetooth. The Bluetooth connection forwards this data to the app.

Steps 12 to 16 show the calorie and nutrient calculation with food data retrieval process where the process is as follows: Once the app processes the weight composition data, it calculates the user's calorie and nutrient requirements and requests corresponding food data from the spoonacular API via the Internet. The Internet forwards this request from the app to the spoonacular API, which responds with food data in JSON form. The Internet again acts as an intermediary, forwarding the response from the spoonacular API to the application. Subsequently, the application displays a list of recommended foods to the user.

Finally Steps 17 to 18 show the food recommendation history retrieval process where the process is as follows: The application requests food recommendation history data from the Firebase Firestore Database via the Internet. The Firebase Firestore Database responds with the food recommendation history data, which is transmitted to the application over the Internet.

Application Testing

Testing of the system was carried out in 3 ways, the first test was carried out to find out the differences in daily macronutrient needs between males and females along with recommended foods, so testing was carried out by entering the users' attributes bearing the same weight, age and activity level. The second test was conducted to find out how accurate the apps calculations were when compared to the manual calculation method, in this second test 13 users were involved with different characteristics such as height, age, gender and activity level. The third test was usability testing to find out how easy the app is to use. In this test, a series of tests were carried out to see whether the interactions and displays on the system made it easier for users to get the information they were looking for.

Comparison of Gender Daily Calorie Needs

The results of the first test can be seen in Tables 3 and 4. Table 3 shows male macronutrient needs and Table 4 shows female macronutrient needs with same attribute which are age: 22 years old, weight: 60 kg, activity level: slightly active, and Height: 160 cm. The results of the test show that the level of macronutrient needs of male users are greater than that of female users. The list of recommended foods for men is much more than that of women. The same recommended foods for both men and women for breakfast recommendations can be seen in Table 5, lunch recommendations can be seen in Table 6 and dinner recommendations can be seen in Table 7.

Table 3: Male macronutrient needs

Nutrient	Daily Need	Breakfast	Lunch	Dinner
Calorie	2041 kkal	612,3 kkal	816,4 kkal	612,3 kkal
Protein	76,5 g	22,95 g	30,6 g	22,9 g
Fats	45,3 g	13,59 g	18,12 g	13,59 g
Carbohydrate	331 g	99,3 g	133,6 g	99,3 g

Table 4: Female macronutrient needs

Nutrient	Daily Need	Breakfast	Lunch	Dinner
Calorie	1827 kkal	548,1 kkal	730,8 kkal	548,1 kkal
Protein	69 g	20,7 g	27,6 g	20,7 g
Fats	41 g	12,3 g	16,4 g	12,3 g
Carbohydrate	297 g	89,1 g	118,8 g	89,1 g

Table 5: Breakfast food recommendation

Food	Calorie	Protein	Fats	Carbohydrate
Easy Blueberry Muffin	468,2 kkal	9,3 g	8,3 g	87,5 g
Berry Banana Smoothies	457,1 kkal	20.6 g	9.9 g	68.5 g
Blueberry Lemon Pancakes	456,2 Kkal	16,5 g	9,1 g	73,9 g
Pumkin French Toast	452,2 Kkal	15,6 g	9,1 g	64,4 g
Strawberry Shortcake Pancakes	424,9 Kkal	19,2 g	6,8 g	60,2 g

Table 6: Lunch food recommendation

Food	Calorie	Protein	Fats	Carbohydrate
Pasta With Chickpea and Kale	609,1 kkal	23,7 g	7,5 g	101,7 g
Thai Pasta Salad	557,7 kkal	19,8 g	16,4 g	85,0 g
Farfalle with fresh tomatoes	557,0 kkal	16,1 g	14,8 g	84,4 g
Smoky Black bean Soup	554,9 kkal	23,3 g	7,5 g	80,5 g
Vegetarian Falafels	552,0 kkal	21,6 g	10,4 g	82,2 g
Cuban Black Beans	543,9 kkal	19,1 g	8,4 g	80,7 g

Dragon Salad	530,4 kkal	17,9 g	17,9 g	74,4 g
Masala-Tofu-Burger	494,9 kkal	18,7 g	10,5 g	74,7 g
Baked Rigatoni	480,5 kkal	24,6 g	10,0 g	66,5 g
Penne Arrabiata	466,6 kkal	16,4 g	8,9 g	101,3 g

Table 7: Dinner food recommendation

Food	Calorie	Protein	Fats	Carbohydrate
Moroccan Chickpea Stew	456,6 kkal	20,1 g	7,3 g	66,9 g
Cauliflower Chickpea Stew	455,3 kkal	13,6 g	7,8 g	74,0 g
Curried Chickpea and Vegetables	447,9 kkal	15,4 g	11,2 g	60,7 g
Easy Homemade Rice and Beans	445,7 kkal	19,1 g	4,1 g	66,8 g
Instant Pot Quinoa Grain Bowl	415,6 kkal	16,0 g	9,7 g	58,4 g
Red Kidney Bean Jambalaya	392,8 kkal	18,1 g	6,5 g	53,1 g
Roasted Endive Salad with Prosciutto	387,7 kkal	13,9 g	10,3 g	44,6 g
Broccoli and Chickpea Rice Salad	354,8 kkal	15,1 g	9,8 g	42,3 g

Comparison of Manual Calculation and Application

The results of the second test were carried out to find out how accurate the system provides calculation results, which compared the results of the calculation of the value of macronutrient requirements in the system with manual calculations. This test involves 13 users with varied input data where user input data can be seen in Table 8.

Table 8: Data user

Weight (kg)	Height (cm)	Activity Level	Age	Gender
68,95	170	Slightly active	22	Male
40,95	164	Slightly active	22	Female
42,75	150	Moderately active	46	Female
64,55	165	Slightly active	60	Male
57,95	160	Sedentary	62	Male
75,15	160	Moderately active	23	Female
73,7	169	Very active	60	Male
69,85	155	Slightly active	56	Female
64,75	172	Sedentary	23	Male
46,15	169	Slightly active	22	Male
69,9	164	Moderately active	25	Female
64,3	150	Slightly active	57	Female
76,9	175	Slightly active	63	Male

The results of manual testing can be seen in table 9 and the results of system testing can be seen in Table 10.

Table 9: Result of application calculation

User	Calorie Needs	Protein	Fats	Carbohydrate
1	2273	85	51	369
2	1608	60	36	261
3	1680	63	37	273
4	1900	71	42	309
5	1529	57	34	249
6	2287	86	51	372
7	2584	97	57	420
8	1686	64	37	274
9	1935	73	43	314
10	1695	64	38	275
11	2224	83	49	361
12	1560	58	35	253
13	2135	80	47	347

Table 10: Result of manual calculation

User	Calorie Needs	Protein	Fats	Carbohydrate
1	2265	85	50	369
2	1600	60	36	261
3	1510	57	34	273
4	1900	71	42	309
5	1529	57	34	249
6	2287	86	51	372
7	2584	97	57	420
8	1686	63	37	274
9	1935	73	43	314
10	1695	64	38	275
11	2229	84	50	361
12	1560	59	35	253
13	2135	80	47	347

To calculate the accuracy, the relative error is calculated between manual testing and system testing. After each subject is measured, the accuracy value is obtained, the value will be averaged based on the number of subjects measured to get the average accuracy. Table 11 shows the average results of accuracy measurements between manual calculations and calculations with the application.

Table 11: Average accuracy result

Attribute	Average Accuracy
Calorie	99,05 %
Protein	98,85 %
Fats	99,01 %
Carbohydrate	99,05 %

Usability Testing

To find out how well the application makes it easy for users to get information, usability testing will be carried out. Figure 3 shows the graphical user interface (GUI) of the application and figure 4 is a list of recommended foods from the spoonacular API based on the user's daily macronutrient needs.

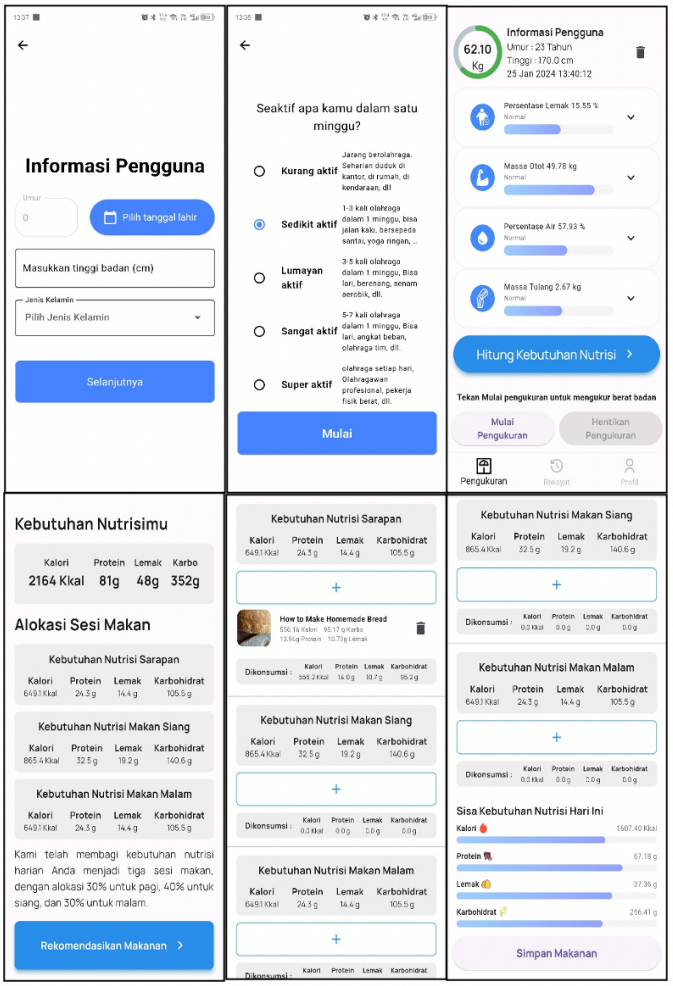

Figure 3: GUI application

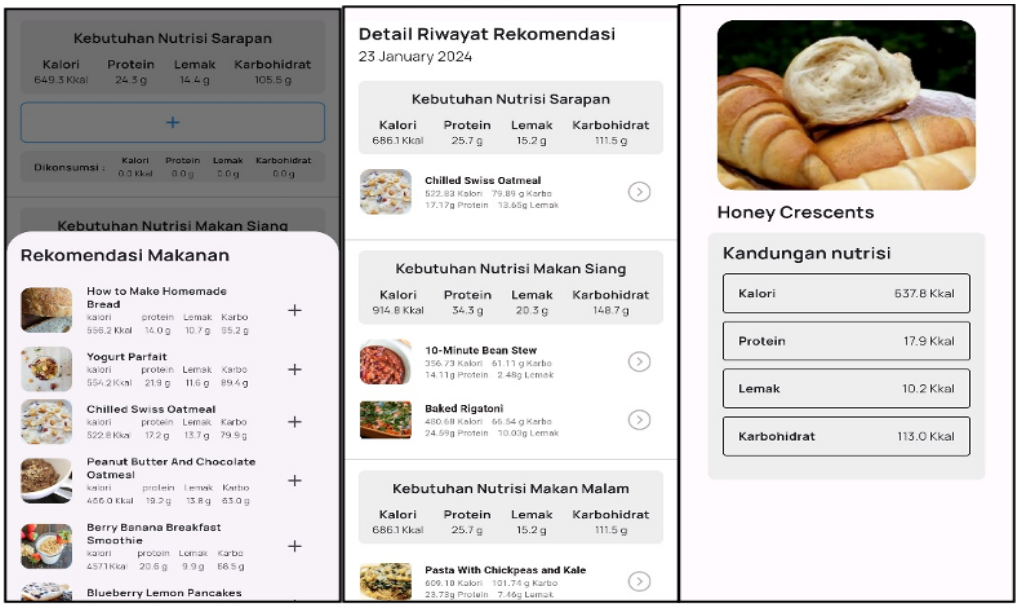

Figure 4: Food recommendation

In usability testing process, the steps involve give a series of pre-prepared tasks, which users can execute while interacting with the application under test. These tasks were given to 13 respondents who had never used this application before. The test was conducted to measure the extent to which the application can provide a good interface in fulfilling the user's information needs. The tasks to be performed by the user are as follows:

1. Task 1: The user is asked to take a weight measurement using the smart scale on the Weight Measurement page.
2. Task 2: The user is asked to view information on his nutritional needs such as calories, protein, fat, carbohydrates for each meal session.
3. Task 3: The user is asked to select one of the food recommendations provided by the system on the Food Recommendations page.
4. Task 4: The user is asked to adjust the food they choose to the nutritional needs of each meal session so as not to exceed the recommended one.
5. Task 5: The user is asked to view the history of food recommendations on the Food Recommendation History page.

Once the user has completed all the tasks, the next step is to evaluate the extent of their success. This evaluation is done by detailing the user's recorded results while completing the tasks. The assessment is given uniformly, where the user gets a score of 1 if successful and a score of 0 if there are obstacles or confusion that hindered the completion of the task. The results of the task assessment analysis from the user execution recordings can be seen in Table 12.

Table 12: Usability testing results

User	Task 1	Task 2	Task 3	Task 4	Task 5
User 1	1	1	1	1	1
User 2	1	1	1	1	1
User 3	1	1	1	1	1
User 4	1	1	1	1	1
User 5	0	1	1	1	1
User 6	1	1	1	0	1
User 7	1	1	1	1	1
User 8	1	0	1	0	1
User 9	1	1	1	1	1
User 10	1	1	1	0	1
User 11	1	1	1	1	1
User 12	1	1	1	1	1
User 13	0	1	1	1	1
Percentage of success	**85%**	**92%**	**100%**	**77%**	**100%**

Conclusions

The results of testing for gender with the same height, weight, activity level and age values show that the calorie requirement for men is much greater. The test results on how accurate the results given by the app and manual calculations show the numbers average accuracy on calorie is 99.05%, protein is 98.85%, fats is 99.01% and carbohydrate is 99.05% this shows the results issued by the application are close to the same value as the results manually. Based on the table of usability testing results conducted on 13 users with 5 different tasks, it can be concluded that in general users can complete the tasks given well. The highest success rate was achieved in Tasks 3 i.e. Select one of the food recommendations provided by the application and 5 i.e. View the history of food recommendations, where all 13 users successfully completed it (100%). While the lowest success rate was on Task 4, where only 10 out of 13 users were successful (77%) due to the difficulty in determining the food that suits their calorie and nutritional needs. Although most users can use the app well, there are still some tasks that need to be improved so that all users can complete them.

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Conflict of Interest Statement

The authors state that they have no conflicts of interest. The funding sources did not influence the study's design, data collection, analysis, interpretation, manuscript writing, or decision to publish the findings.

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