Artificial Bee Colony – Based for Dietary Recommendation in Daily Nutrition Requirements

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***Abstract*—Healthy lifestyle is an important requirement for people, which is obtained from balanced nutrition. Imbalanced nutrition increases risk of health problems. Balanced nutrition means the difference between nutrition needed and nutrition intake must be as minimum as possible. The condition in Indonesian, many people consume food with high carbohydrate; whereas nutrition consists of protein, carbohydrate, and fat. That nutrition obtains from five foods category, namely: main dish (MP), vegetable side dish (LN), meat (LH), vegetable (SY), and fruit (BH). Therefore, it needs a system to provide a suggestion for balanced nutrition. This research used Artificial Bee Colony (ABC) to obtain optimal nutrition, which contains five dimensions (MP, LH, LN, SY, BH). These dimension and variable are represented as food source, which will be optimized by bees. These bees are divided into employee bee (BN), onlooker bee (SN), and scout bee. BN will produce new food source, where if new food source has a better solution, it will replace the old one. SN performers based on the fitness value of each food source; if the food source has high probability, SN will produce new food source. While scout bee will determine a new food source, if the number of trials for releasing a food source is equal to the value of "limit". The performance of ABC evaluated using twelve data of men and female. The result shows that ABC achieve 99.90% in giving a recommendation for portion and type of foods a day.**

Keywords—Optimization; Daily Nutrition; Food Recommendation; Computational Intelligence; Artificial Bee Colony;

I. INTRODUCTION

A healthy lifestyle is an important requirement for people, which is obtained from balanced nutrition. However, most of the people do not know how to obtain balanced nutrition for daily consumption. Based on research of Riskedas, Indonesian are lack of fruit and vegetable consumption [1]. In their research, 93.25% of people above 10 years old consume fruit and vegetable in under of suggestion [2]. It is because Indonesian consumed foods and drinks high in sugar, salt, and fat; it makes body fat and leads to obesity [3].

Approximately 1.9 billion people worldwide are overweight and over 600 million of them are obese [4]. These conditions increase the risk of health problems, such as hypertension, type-2 diabetes, coronary heart disease, gallbladder disease, certain cancers, dyslipidemia, stroke, osteoarthritis, and sleep apnea; where more than half of deaths in Indonesia are caused by these diseases [3], [5]. Therefore, it is important to arrange composition and serving suggestion to obtain balanced nutrition. Balanced nutrition mean fueling ourselves with right things, right amount, and in the right time, to achieve a healthier body and immune to disease [3]. Food recommendation is one of the solutions to obtain optimal nutrition. A good recommendation can be achieved using appropriate optimization method.

Previous researchers proposed several techniques in food recommendation, where their recommendation have different goals for instances; ontology mechanism, personal ontology filter, and food fuzzy mechanism for diabetic patient [6]; self-organizing map and *k*-mean clustering for diabetic patient [7]; genetic algorithm, rule-based reasoning, and case-based reasoning in personal diet recommendation for cancer patient [8]; type-2 fuzzy logic system and genetic fuzzy markup language to reduce the risk of various chronic diseases [9]; and genetic algorithm for health purpose [10]. To obtain optimal nutrition, previous researchers used Computational Intelligence (CI) approach; it is applied to optimize portion and type of foods. CI is applied, there are many possibilities for portion and type of foods to be optimized at the same time.

CI is sub-branch of Artificial Intelligence (AI); usually, it is used to solve a complex real-world problem such as optimization problem. One of the most popular optimization technique is Artificial Bee Colony (ABC). Day by day the number of researches being interested in ABC algorithm increases rapidly; there were many publications about ABC from 2005 until 2012 [11]. Research in 2009 & 2011, Karaboga compared between ABC with Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Differential Evolution (DE), Evolution Strategy (ES), and other techniques. As the result, the performance from ABC was better than other techniques; although it uses fewer control parameters, the algorithm still had good results [12], [13]. Therefore, ABC is applied in this research to optimize nutrition and provide food recommendations to get balanced nutrition.

Each country has different in foods category, where Indonesia have five foods category, namely: main dish (MP), vegetable side dish (LN), meat (LH), vegetable (SY), and fruit (BH) [3]. Food recommendation in Indonesia already proposed by Wulandhari & Kurniawan (2016) , they proposed food recommendation based on energy requirement; and energy intake which is obtained from raw food data. Besides energy,

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our body needs protein, carbohydrate, and fat to function optimally and remain healthy. Therefore, this research propose food recommendation based on protein, carbohydrate, and fat. By using ABC, that provide food recommendation to obtain balanced nutrition.

II. NUTRITION NEEDED AND SUGGESTED MODELING

Nutrition are divided into two categories, namely: Macronutrients and Micronutrients. Nutrition are substances need for growth, metabolism, and for other body functions. Macronutrients are nutrition that provide calories or energy, which is needed in large amounts. There are three broad classes of macronutrients, namely: carbohydrate, protein, and fat [3], [14]. Beside macronutrients, our bodies also need water (6-8 glasses a day) and micronutrients. Micronutrients are nutrition that is needed in smaller amounts, including vitamins and minerals. It helps reactions to produce energy and increase body growth and development [15], [16].

In this research, we will focus on macronutrients. Macronutrients can obtain from rice, meat, vegetables, and fruit. In Indonesia, they have five foods category (MP, LN, LN, SY, BH) [3]; each category has contribution in nutrition fulfillment. Therefore, nutrition suggested (NS) can is written as the following equation:

$$\mathrm{NS} = (x_1 * \mathrm{MP}) + (x_2 * \mathrm{LN}) + (x_3 * \mathrm{LH}) + (x_4 * \mathrm{SY}) + (x_5 * \mathrm{BH}) \quad (1)$$

where,

x_1, x_2, x_3, x_4, x_5 : Numbers of serving portion
MP : Nutrition of main dish
LN : Nutrition of vegetable side dish
LH : Nutrition of meat
SY : Nutrition of vegetable
BH : Nutrition of fruit

Each individual has difference nutrition needed (NN) for nutrition fulfillment; the difference between nutrition needed and suggested must minimum to obtain optimal nutrition. Nutrition needed can determine based on the Basal Metabolic Rate (BMR) and activity level. The value of BMR obtain using Revised Harris Benedict Equation [17]:

Men

$$BMR = 88.362 + (13.397 \text{ x weight}) + (4.799 \text{ x height}) - (5.677 \text{ x age}) \quad (2)$$

Women

$$\mathrm{BMR} = 447.593 + (9.247 \text{ x weight}) + (3.098 \text{ x height}) - (4.330 \text{ x age}) \quad (3)$$

where weight in kilogram, height in centimeter, and age in years.

The next step, calculate BMR value with activity level to obtain total daily energy requirements. Activity level divided into five categories, namely: little or no exercise, light exercise, moderate exercise, heavy exercise, very heavy exercise. This step is calculated by the equation as follow:

$$ER = BMR * Activity\ Factor \quad (4)$$

where *ER* is energy requirements and *AL Factor* is activity level factor of each individual.

TABLE I. HARRIS-BENEDICT PRINCIPLE

Activity Level	Activity Factor
Little or no exercise	BMR x 1.2
Light exercise (1–3 days/week)	BMR x 1.375
Moderate exercise (3–5 days/week)	BMR x 1.55
Heavy exercise (6–7 days/week)	BMR x 1.725
Very heavy exercise (twice/day, extra heavy workouts)	BMR x 1.9

In this step, we have obtained daily energy requirement. The next step is divide energy requirement into amount energy needed for each nutrition (carbohydrate, protein, and fat). Based on Institute of Medicine [18] ranges for the percentage of energy which should come from carbohydrate, protein, and fat using equation:

Amount of energy needed for carbohydrate

$$\mathrm{EC} = \mathrm{ER} * \text{Carbohyrdate Percentage} \quad (5)$$

Amount of energy needed for protein

$$\mathrm{EP} = \mathrm{ER} * \text{Protein Percentage} \quad (6)$$

Amount of energy needed for fat

$$EF = \mathrm{ER} * \text{Fat Percentage} \quad (7)$$

where EC is energy needed for carbohydrate, carbohydrate percentage is carbohydrate factor, EP is energy needed for protein, protein percentage is protein factor, EF is energy needed for fat, fat percentage is fat factor. Macronutrients Proportions divided into three categories, namely: 1-3 years, 4-18 years, ≥19 years (see Table 2); where combination between carbohydrate, protein, and fat must reach 100%. This research used 60% for carbohydrate, 15% for protein, and 25% for fat.

TABLE II. RECOMMENDED MACRONUTRIENTS PROPORTIONS

Age	Carbohydrate Percentage	Protein Percentage	Fat Percentage
1-3 years	45-65%	5-20%	30-40%
4-18 years	45-65%	10-30%	25-35%
≥19 years	45-65%	10-35%	20-35%

The last step, divide amount of energy needed for each nutrition into nutrition needed [19]. When burned (metabolized), each nutrition provides different energy. This step is calculated by the equation as follow:

Carbohydrate

$$\text{Carbohydrate} = \mathrm{EC} / 4 \quad (8)$$

Protein

$$\text{Protein} = \mathrm{EP} / 4 \quad (9)$$

Fat

$$Fat = \mathrm{EF} / 9 \quad (10)$$

where the result of carbohydrate, protein, fat in Gram. In this step, we have nutrition needed for daily requirements, where in nutrition needed have carbohydrate, protein, and fat.

$$\mathrm{NN} = \text{Carhbohydrate} + \text{Protein} + \text{Fat} \quad (11)$$

III. Artificial Bee Colony in Optimizing Nutrition Needed

Artificial bee colony created by Dervis Karaboga [20]; this algorithm was observed from behavior of honey bees to take the process of foraging. The bees are divided into three categories, namely: employee bee (BN), onlooker bee (SN), scout bee. Detailed pseudo-code of the ABC algorithm is given below:

1: Initialize food source $\boldsymbol{X_{ij}}$, $i \in \{1,..,BN\}$, $j \in \{1,..,D\}$
2: Evaluate food source by using equation (12)
3: t=1
4: **REPEAT**
5: Produce new solutions $\boldsymbol{V_{ij}}$ for the employed bees by using equation (13) and evaluate them using equation (12)
6: Apply the greedy selection process for the employed bees.
7: Calculate the probability value $\boldsymbol{P_i}$ for the solution $\boldsymbol{X_{ij}}$ by equation (14)
8: Produce the new solutions $\boldsymbol{V_{ij}}$ for the onlookers from the solutions $\boldsymbol{X_{ij}}$ depending on $\boldsymbol{P_i}$ by using equation (13) and evaluate them using equation (12).
9: Apply the greedy selection process for the employed bees.
10: Determine the abandoned solution for the scout, if trial have reach limit, then replace it with a new randomly produced solution $\boldsymbol{X_{ij}}$.
11: Memorize the best solution achieved so far
12: t = t + 1
13: **UNTIL** t = max iteration

At initialization stage, the food sources are randomly selected and their nectar amounts are determined. Then, these bees come into the hive and share the nectar information. In our case, each food source has five dimensions; where each dimension has two variables, namely: portion and type of foods (see Figure 1). For their value are randomly chosen, where portion ∈ {1,..,10} and type of foods ∈{1,..,N}; N is amount of data for each category, where MP ∈{1,..,110}, LN ∈{111,..,216}, LH ∈{217,..,437}, SY ∈{438,..,587}, BH ∈{588,..,667}; example, index of MP is 2, then MP is *Nasi*. In this stage, we obtained portion and type of foods. Then, evaluate food source using equation:

$$MIN(fitness = \text{abs}(\sum_{j=0}^{n}(NN_j - NS_j))) \quad (12)$$

where,
$fitness_i$ is the minimum value or the closest value between nutrition needed and nutrition suggested.

n =3 (carbohydrate, protein, fat).

Fig. 1. Food Sources

Stage two, each employee bee goes to food source and chooses a new food sources by means of visual information from neighborhood. Each employee bee will be doing mutation for portion and type of foods (see Figure 2). In order to produce a new food sources from the old one, the ABC uses the following expression:

$$V_{ij} = X_{ij} + \emptyset_{ij}\,(X_{ij} - X_{kj}) \quad (13)$$

where,
V_{ij} is new food source.
X_{ij} is current food source.
X_{kj} is another food source
$i \in \{1,..,BN\}$.
$k \in \{1,...,BN\}$ are randomly chosen.
$j \in \{1,...,D\}$ are randomly chosen.
D is number of dimension. In this research have 5 dimension (MP, LN, LH, SY, BH).
$\emptyset_{ij}$ is random number between [-1, 1]. It is to control the production of neighborhood food positions around X_{ij} and the modification food position by the bee.

Fig. 2. Mutation in Food Sources

Each employee bee will be doing mutation for portion value and type of foods. In this step, each employee has obtained new food source; if a new food source has a better solution, it will replace the old one; Otherwise, trials = trials + 1; trials value used in scout bee phase.

Stage three, an onlooker goes to food source depending on probability of food source (P_i), calculated by following expression:

$$P_i = \frac{fitness_i}{\sum_{n=1}^{SN} fitness_n} \quad (14)$$

where,
P_i is probability of food source.
$fitness_i$ is the minimum value or the closest value between nutrition needed and nutrition suggested.
SN is amount of onlooker bee.

If the probability of food source has higher than random number in interval (0,1), then onlooker bee will be doing mutation for portion and type of foods (same with step in employee bee). If a new food source has a better solution, it will replace the old one; Otherwise, trials = trials + 1. The last step is scout bee. This step is controlled by a control parameter called "limit". The number of trials for releasing a food source is equal to the value of "limit" which is an important control parameter of ABC [12], [21]. The limit calculated by following expression:

$$limit = SN * D \quad (15)$$

where D is number of dimension problem and SN is number of employee or onlooker bee. When the food source reaches the limit, employee and onlooker bee will abandon the food source. In this step, a new food source is randomly determined by scout bee and replaced with the abandoned one. For their value are randomly chosen, where portion $\in \{1,..,10\}$ and type of foods $\in \{1,..,N\}$; N is amount of data for each category.

IV. Experiment and Result

A. Data Collection and Preparation

For Indonesian foods data collected from *Tabel Komposisi Pangan Indonesia* [22]. Foods data have several information like foods ID, foods name, data sources, and food nutrients. The data that will be used are foods name and food nutrients. The scope of nutrients for this research is macronutrient; from several food nutrients, the nutrients will be used are protein, carbohydrates, and fat. After data collection, the next step is data preparation; where it is makes data can be used on our modeling.

There are two step to data preparation, namely: data cleaning and data grouping. Data cleaning are process of checking and removing inaccurate records from database (example: missing data). The next step, grouping the data based on foods category; where the data have five categories, namely: MP, LN, LH, SY, and BH. Afterward, the foods data will consist of type foods, food name, total protein, total carbohydrate, total fat, and the amount of food that will be served (see Table 3).

For this experiment, we used 12 data sets; The experiments are conducted by several parameters, for instance: gender, age, height, weight, activity level, and special condition as input data. If the data has a special condition (vegetarian), then LH category will be disabled. In order to analyze the result, each of data will repeat 10 times and the results of experiments shown average of portion and percentage of nutrition fulfillment.

TABLE III. Example of Foods Data

Food ID	Type	Food Name	Composition Nutrition / 100 gram		
			Protein (g)	Fat (g)	Carbo (g)
1	MP	Ketupat ketan	4	4.6	38.6
2	MP	Nasi	3	0.3	39.8
72	LN	Kacang hijau	20.8	2.1	64.6
74	LN	Kacang kedelai	40.4	16.7	24.9
110	LH	Daging kambing	16.6	9.2	0
115	LH	Daging kornet	16	25	0
210	SY	Daun pare	2.7	1	8.4
216	SY	Daun pepaya	8	2	11.9
250	BH	Apel	0.3	0.4	14.9
255	BH	Jambu biji	0.9	0.3	12.2

B. Parameter Settibg of ABC

At this step, we will determine several parameters which affect the performance of artificial bee colony, namely: number of bee, food source, limit. This experiment, we used "Data1" as a sample (see Table 6). In Table 4, we compared several number of bee to obtain the best bee. In order to analyze the result, each of experiments in this section was repeat 10 times; then we average the fitness function. Number of food source is equal to number of employee bee [20] and for number of limit obtain from expression (10). In this experiment, we used 400 iterations as maximum iterations.

TABLE IV. Setting Parameter for Number of Bee

Number of Bee	Average Fitness
10	6.081704
20	3.830785
30	2.836348
40	2.297758
50	2.288378
60	2.296201
70	2.026895
80	1.699724
90	1.626298
100	1.775342

Number of Bee	Average Fitness
110	1.50864
120	1.655181
130	1.708797
140	1.36633
150	1.520046
160	1.316895
170	1.333606
180	1.459522
190	1.422288
200	1.41503

From the result in Table 4, it appears the amount of the bee as much as 160 have a better result if we compared with another number of bees. In this research, we used 160 bees. For iteration, we used 300 iterations; After several testing, ABC have obtained the optimal solution before 300 iterations. This experiments run for 10 times. For parameter setting of ABC for food source is 80 and limit is 400 as shown in Table 5. After obtained the optimal parameter setting of ABC, this parameter will use to testing to another data.

TABLE V. Parameter Setting of ABC

Experiment	Parameter
Bee (BN+ SN)	160
Food Source	80
limit	400
Iterations	300
Experiment	10

C. Experiment and Result

The experiments are provided from 12 data sets (Data1-Data12). These data obtained from questionnaire, where it was taken on February 20th, 2016. In this step, we will input several information such as name, age, gender, height, weight, exercise levels and special condition (see Figure 3).

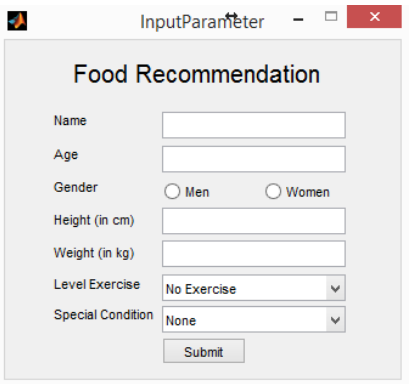

Fig. 3. Input Parameter

After inputted several parameters, ABC algorithm will be searching the optimal portion and type of foods between nutrition needed and nutrition suggested for a day, where portion $\in \{1,..,10\}$ and foods type from category of foods (MP, LH, LN, SY, BH), $\in \{1,..,N\}$; N is amount of data for each category, where MP $\in \{1,..,110\}$, LN $\in \{111,..,216\}$, LH $\in \{217,..,437\}$, SY $\in \{438,..,587\}$, BH $\in \{588,..,667\}$; example: index of MP is 2, then MP is *Nasi*. As the result, it will give several information such as nutrition needed, nutrition suggested, and food recommendation for breakfast + snack, lunch + snack, and dinner.

The result of experiment shown in Table 7; it shows the portion of foods for a day. From the result, we can obtain information, where male has higher food servings than female (see Table 4.5); vegetarian people has higher food servings than non-vegetarian, they do not consume meat for daily nutrition, then they could obtain optimal nutrition from another foods category, namely: MP, LN, SY, and BH. ABC can provide acceptable portion and type of foods with the tolerance of error 80% - 110%. In this research, we only testing 12 data, because with 12 data are showed ABC can give ideal portion and type of foods to obtain balanced nutrition with average accuracy 99.90%. The result has validated by Dr. dr. Dwi Susilowati MSc, IBCLC, SpGK (a nutritionist), where the recommendation of portion and type of foods is valid.

V. Conclusions

The main contribution of this study is to get optimal portion and type of food to obtain optimal solution, which is give food recommendation for Indonesian food. The optimal solution obtains from fitness function, which is the difference between nutrition needed and nutrition suggested must minimum as possible. This research presents artificial bee colony algorithm to get portion and type of food for daily nutrition needed. The result shows, ABC can provide acceptable portion and type of foods with the tolerance of error 80% - 110% and the average of accuracy is 99.90%. The result has validated by Dr. dr. Dwi Susilowati MSc, IBCLC, SpGK (a nutritionist), where the recommendation of portion and type of foods is valid. The result shows ABC can give ideal portion and type of foods to obtain balanced nutrition especially in Indonesia.

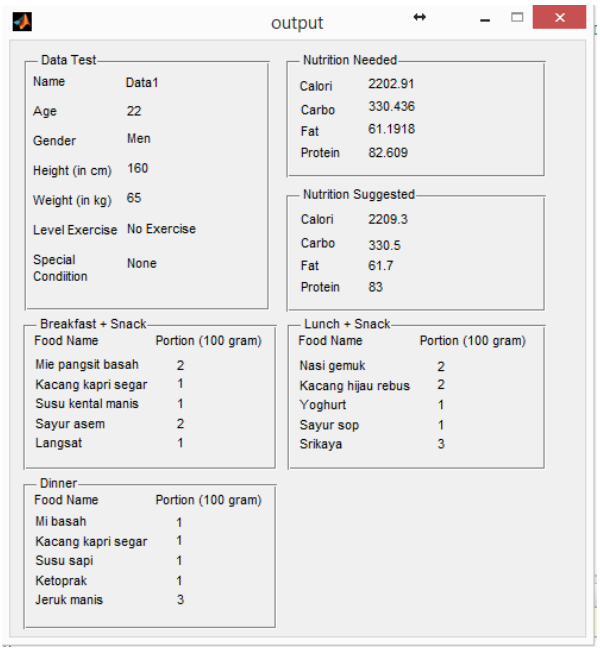

Fig. 4. Recommendation for Data1

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TABLE VI. DATA TESTING

Data Name	Gender	Age	Height	Weight	Activity Level	Special Condition
Data1	Men	22	160	65	1 - 3 Days	None
Data2	Men	35	169	82	No Exercise	None
Data3	Men	49	165	61	3 - 5 Days	None
Data4	Women	22	158	50	No Exercise	None
Data5	Women	32	155	52	3 - 5 Days	None
Data6	Women	52	155	49	No Exercise	None
Data7	Men	25	173	87	1 - 3 Days	Vegetarian
Data8	Men	36	160	70	No Exercise	Vegetarian
Data9	Men	46	157	49	1- 3 Days	Vegetarian
Data10	Women	21	160	75	1- 3 Days	Vegetarian
Data11	Women	38	158	60	1- 3 Days	Vegetarian
Data12	Women	41	160	65	3 - 5 Days	Vegetarian

TABLE VII. AVERAGE SERVINGS FOR A DAY

Data Name	AVERAGE SERVINGS FOR A DAY / 100 GRAM					FULFILMENT (%)			Accuracy
	x_1	x_2	x_3	x_4	x_5	Protein	Fat	Carbohydrate	
Data1	6	4	4	5	5	99.92%	99.92%	100.01%	99.94%
Data2	4	4	6	5	5	99.96%	99.96%	100.02%	99.97%
Data3	5	4	5	7	6	100.07%	99.83%	100.00%	99.92%
Data4	4	4	4	5	4	99.95%	100.02%	100.02%	99.97%
Data5	5	4	4	5	5	99.90%	99.99%	99.97%	99.95%
Data6	4	4	4	5	5	99.77%	100.40%	100.00%	99.79%
Data7	6	5	0	9	6	99.84%	100.05%	99.93%	99.91%
Data8	5	5	0	5	5	100.12%	99.80%	99.98%	99.89%
Data9	5	4	0	6	5	100.41%	100.17%	100.07%	99.78%
Data10	5	5	0	6	6	100.05%	99.96%	100.00%	99.97%
Data11	5	5	0	5	5	99.84%	100.20%	100.03%	99.87%
Data12	5	5	0	7	5	100.03%	100.33%	100.03%	99.87%
Average	5	4	2	6	5	99.99%	100.05%	100.01%	99.90%