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Optimum Nutrition Intake from Daily Dietary Recommendation for Indonesian Children Using Binary Particle Swarm Optimization Algorithm

Fanny*[a], Lili Ayu Wulandhari[a], Sani Muhamad Isa[b]

[a]*Computer Science Department, School of Computer Science, Bina Nusantara University, Jakarta, Indonesia 11480*
[b]*Computer Science Department, Binus Graduate Program – Master of Computer Science, Bina Nusantara University, Jakarta, Indonesia 11480*

Abstract

Optimum nutrition intake in daily dietary habit has a significant role for children growth. Nevertheless, the mistakenness in the fulfillment of nutrition still concerned. It happens because an individual does not have much knowledge about the energy content of food and food combination to meet the nutrition requirement. The objectives of this research are to facilitate an individual to obtain the optimum nutrition intake from their daily dietary habit. This paper proposes a Binary Particle Swarm Optimization (BPSO) algorithm to find the optimum combination of food portion and food option for an individual daily dietary habit. The food data is obtained from *'Tabel Komposisi Pangan Indonesia'* book which contains more than 1600 kind of Indonesian food. The results show that BPSO provides an optimum nutrition intake accuracy of 99.14%. Moreover, the nutritionist is already validated that this experiment is succeed in recommending a variation of daily dietary habit that meet an optimum nutrition intake for an individual. Based on this result it can be conducted that BPSO can provide the better accuracy of optimum nutrition intake than Genetic Algorithm (GA), while GA can only provide an optimum nutrition intake accuracy of 97.87%.

*Keywords:*Optimum nutrition, Energy requirement, Energy intake, Dietary habit recommendation, Binary Particle Swarm Optimization

* Corresponding author. Tel.: +62-21-543-5830 ext 2316; fax: +62-21-530-1668.
*E-mail address:*fanny.sa@binus.edu

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1. Introduction

Indonesia is one of the Indonesia is one of the largest agriculture countries in Southeast Asia with high diversity and richness of natural resources that is potential to be a modern country. Despite its richness, Indonesian still have a problem in health, intelligence, and productivity, which can be determined by the level of Human Development Index (HDI)[1,2]. Based on United Nations Development Programme (UNDP) report, Indonesia's HDI level is ranked 108th of 187 countries assessed in 2013[3]. While to develop into a modern country, the population should not have a low level of HDI.

Therefore, these problems become the biggest challenge for Indonesia to develop as a modern country. The main factors that strongly influence Indonesia's HDI are lack of nutrition and health status of Indonesian, proven by low level of life expectancy at birth [1]. The medical survey reports that child mortality in Indonesia reaches 40 per 1000 births with more than half is caused by malnutrition[4]. Besides mortality, there are some other effects of malnutrition such as body and brain growth retardation, immunity, and intelligence or IQ as well[5,6]. Studies show that children who have poor nutrition will have lower IQ performance and working memory than children who have good nutrition[6,7]. While over-nutrition also has some damaging effect, mainly it can cause overweight and obesity that trigger the emergence of the degenerative disease like diabetes, and heart disease[5].

Recently, information about nutrition and dietary habit for children can only be obtained from nutritionist, which takes time and cost. Therefore, the technology is required to give the information about optimum nutrition intake from the dietary habit quickly and accurately. According to this condition, this research will propose a technique that can suggest dietary habit, which conceives balanced nutrition for normal children (not overweight or underweight) and children with allergy.

2. Literature Review

2.1. Recent Work

There are several previous researches about food recommendation. One of the researches, which provide a food recommendation for children dietary intake, is in India. This research is using ID3 algorithm in order to give a food recommendation and the result of this research is good[8]. However, this research cannot be applied in Indonesia because Indian food has a different food structure with Indonesian food, which in Indonesian food has main dishes, vegetable dish, meat, vegetable, and fruits. Moreover, this research is limited for child age 7 to 9 years only. Moreover, India's and Indonesia's dietary habit is different as well. Besides, in 2016, Wulandhari and Kurniawan are already done a research using Indonesian food data. That research is using genetic algorithm method in computational intelligence approach to give a balance nutrition for health[9]. However, even the result of this research is good, this research has several limitations. This research provides a food recommendation for general user and cannot be used specifically for children; either for normal or children with allergy.

Therefore, this research proposes Binary Particle Swarm Optimization approach to provide a close optimum result of nutrition adequacy in the dietary habit recommendation for normal or children with allergy. The nutrition needs for each child per day is calculated using Total Energy Expenditure (TEE) equation. To support this equation, some data are required; which covers age, weight (in kilogram), gender, and level of physical activity.

Binary Particle Swarm optimization algorithm is used in this research because it is proven effective in solving an optimization problem. It is proven in several areas such as optimize the network architecture, timetabling, and scheduling[10,11,12]. Moreover, it is also proven in other areas like traveling salesman problem, optimize the mixture of growing production strain ingredients[10], and managing the use of highly concentrated chargers to minimize the strain of power grid[13].

2.2. Human Nutrition

Human Nutrition is the process where the body gain and use nutrients from foods to maintain body functional human[14]. Some biological model shows that there is a relationship between nutrition and health. Therefore, the study of human nutrition tries to find the social and biological factors on how human maintain their optimum health and

body function, how the influence of food consumption by their quality and quantity and what the body gain from food, and how nourishment affects health as well[14].

In order to meet optimum nutrition intake for human, Food and Agriculture Organization (FAO) and World Health Organization (WHO) define the energy requirement for humans. A balanced energy requirement (food energy needed) required to get optimal nutrition and health which can be attained when dietary energy intake (EI) is equal to energy requirement (ER)[15]. Since 1981, joint FAO/WHO/UNU consultation has made an experiment in how to estimate energy requirement for children and adolescents. They prove that it can be measured from Total Energy Expenditure (TEE) and energy needs for growth[16] as shown in Equation 1.

$$TotalER = (TEE + Energy\ needs\ for\ growth) \tag{1}$$

In predicting TEE for children and adolescents, weight become a single indicator because it played a bigger role than age while ignoring age as an indicator does not increase the estimation error. The equation for predicting TEE (kcal/day) for boys shown in equation 2 and for girls shown in equation 3 with the lowest estimation error has been found[17].

$$TEE = 310.2 + 63.3 * w - 0.263 * w^2 \tag{2}$$

$$TEE = 263.4 + 65.3 * w - 0.454 * w^2 \tag{3}$$

where *w* is weight in kilogram. Moreover, energy needs for growth is estimated by multiplying mean weight gain at each year of boys or girls from WHO (shown in Table 1) by the average of energy deposited in growing tissues (8.6 kJ or 2 kcal per gram of weight gain) [16].

Table 1. Mean Weight Gain.

Age	Boys (*gram/day*)	Girls (*gram/day*)
1 - 2	6.6	6.6
2 - 3	5.5	6.0
3 - 4	5.8	5.2
4 - 5	5.5	4.7
5 - 6	5.5	4.9
6 - 7	6.0	6.3
7 - 8	6.6	8.2
8 - 9	7.7	10.1
9 - 10	9.0	11.0
10 - 11	10.7	12.3
11 - 12	12.3	12.3
12 - 13	14.2	12.6
13 - 14	15.9	11.5
14 - 15	16.2	9.3
15 - 16	14.8	6.0
16 - 17	11.5	2.2
17 - 18	7.1	0

The equation of energy needs for growth shown in Equation 4.

$$Energy\ needs\ for\ growth = 2 * Mean\ weight\ gain \tag{4}$$

Energy intake is energy content of food that supplied by the main sources of dietary energy; there are carbohydrates, protein, fat, and alcohol. Carbohydrates and protein offer 16.8 kJ of energy for each gram; fat offers 37.8 kJ of energy for each gram and alcohol offer 29.4 kJ of energy for each gram [14]. The energy intake for children must be fulfilled 10% by protein, 20% by fat, and 70% by carbohydrate as shown in Equation 5, 6, and 7.

$$ER1 = TotalER * 10\% \quad (5)$$

$$ER2 = TotalER * 20\% \quad (6)$$

$$ER3 = TotalER * 70\% \quad (7)$$

In Indonesia, the Health Ministry of Indonesia said that to get a balanced nutrition, the daily food consumed must fulfil the food variation, namely main dishes, vegetable side dishes, meat, vegetable, and fruit [2]. So, the equation of energy intake (EI) from food in Indonesia can be written as shown in Equation 8.

$$EI_i = (p_1 * n_{i1}) + (p_2 * n_{i2}) + \cdots + p_m * n_{im} \quad (8)$$

where, *m* is total of food type, *p* stands for portion and *n* stands for nutrition. To meet the optimum nutrition intake from each child, the optimization method is needed to provide the optimum combination of portion and food option for their daily dietary habit recommendation.

3. Methods

Binary Particle Swarm Optimization (BPSO) is used in this research to provide a daily dietary habit recommendation for children in Indonesia that already meet the optimum nutrition intake. BPSO is developed by Kennedy & Eberhart (1997) to solve the basic PSO problem in handle a discrete-valued variable[18].

In binary particle swarm optimization, each particle represents positions in binary space. Each component of a particles position is binary value 0 or 1 which 0 means 'not used' and 1 means 'used'. Each particle's component can change from 0 to 1 or 1 to 0 depends on the velocity. The velocity of the particle also travels in dimensional space, which is in the range [-Vmax, Vmax]. This velocity represents the probability of the particles position. The binary particle swarm optimization algorithm is commonly same as basic particle swarm optimization. The difference is in velocity update equation and the determination of position value, which based on velocity maximum value.

The BPSO algorithm is described as follows:

- Initialize the initial velocity randomly (V_i^0), for $i = 1,2,...,P$. P is number of particles.
- Set position for each particle (X_i^0), where:

$$if\ (V_i^0 = \max(V_i^0)), then\ X_i^0 = 1, else\ X_i^0 = 0 \quad (9)$$

- Set iteration (t) to 1, $t = 1$.
- Find $pBest_i$ value for each particle and $gBest$ value:

$$if\ f(X_i) < pBest_i, then\ pBest_i = X_i, else\ pBest_i = pBest_i \quad (10)$$

$$f(X_i) = \min(|ER_1 - EI_1| + |ER_2 - EI_2| + \cdots + |ER_n - EI_n|) \quad (11)$$

where n is the total of nutrition type.

$$gBest = \min(pBest_i) \quad (12)$$

- Update the velocity and position for each particle using the following equation:

$$V_i^{(t+1)} = V_i + c1 * r1(pBest_i - X_i) + c2 * r2\ (gBest - X_i) \quad (13)$$

$$if\ (V_i^{(t+1)} = \max(V_i^{(t+1)})), then\ X_i^{(t+1)} = 1, else\ X_i^{(t+1)} = 0 \quad (14)$$

where, $V_i \in 1, 2, ..., P$.

- Update iteration (t) value, $t = t + 1$.

- Repeat step 4 until iteration is equals to maximum iteration.

The representation of BPSO algorithm to this case is shown in Tables 2 and 3, where p is total of food type (variation), q is total of food data per food type, and r is total portion ($P \in (0.5, 1.0, 1.5, \ldots, 3.0)$).

Table 2. Example of Particle's Velocity.

PRM	F_{11}	F_{12}	...	F_{21}	F_{22}	...	F_{pq}
P_1	3	8	...	5	-4	...	...
P_2	-4	-4	...	2	0	...	...
...	...	...	...	...	...	...	...
P_r	...	...	...	...	...	...	...

Table 2 shows the example of one particle's velocity. For initialization, velocity is set randomly in range [$-V_{max}$, V_{max}] and from the velocity value, the particle's position can be obtained from the max (V_i) value.

Table 3. Example of Particle's Position.

PRM	F_{11}	F_{12}	...	F_{21}	F_{22}	...	F_{pq}
P_1	0	1	...	1	0	...	...
P_2	0	0	...	0	0	...	...
...	...	...	...	...	...	...	...
P_r	...	...	...	...	...	...	...

Table 3 shows that from the velocity value in Table 2, the position of the particle is in food number 2 for food type 1 (main dishes) and in the 1st portion (0.5), and for food type 2 (vegetable side dishes), the position is in food number 1 in the 3rd portion (1.5), and so on until the total of food data type. It means that each particle will have position with n number of 1 which stands for the total of food type. The position of each particle will travel in the search space based on the change of velocity until the maximum iteration is met.

4. Results

For the experiment, this research collects data of children and Indonesia food data. The children data is including age, weight, gender, and level of physical activity (PAL) to calculate the energy requirement for each child. Besides, the data of allergy and carbohydrate desired (CS) for the main course is needed for data processing. And for the food data, this research collects about 1600 kinds of Indonesian food data from *'Tabel Komposisi Pangan Indonesia'* book[19].

After the food data is collected, this data will be processed to remove some data and parameters that are not relevant to this research and to group food data into five categories (main dishes, vegetable side dishes, meat, vegetable, and fruit) according to the nutrition balanced guidelines from [2]. From processing process, it is obtaining around 200 data to be used for the experiment and the unique ID is assigned to each data to distinguish it by food

categories. Table 4 shows the example of food data and the nutrition contained in each food (in gram) per 100 grams.

Table 4. Experiment Data.

ID	Name	Category	Protein	Fat	Carbohydrates
1	Rice	Main dishes	3	0.3	39.8
19	Fried tofu	Vegetable dishes	9.7	8.5	2.5
42	Fish curry	Meat	16.5	3.3	2.5
65	Boiled kale	Vegetable	2.5	0.6	3.1
99	Apple	Fruit	0.3	0.4	14.9

For the variable and parameter value used for BPSO algorithm, this experiment using 70 particles and 10 maximum iterations as the stopping criteria. The variable of V_{max} is set to 8, $c1$ and $c2$ is set to 2.

The determination of parameter and variable values that used in this research is based on trial. V_{max} determination experiment shown in Table 5 and Fig. 1a. and for particles and maximum iteration values determination shown in Table 6 and Fig. 1b.

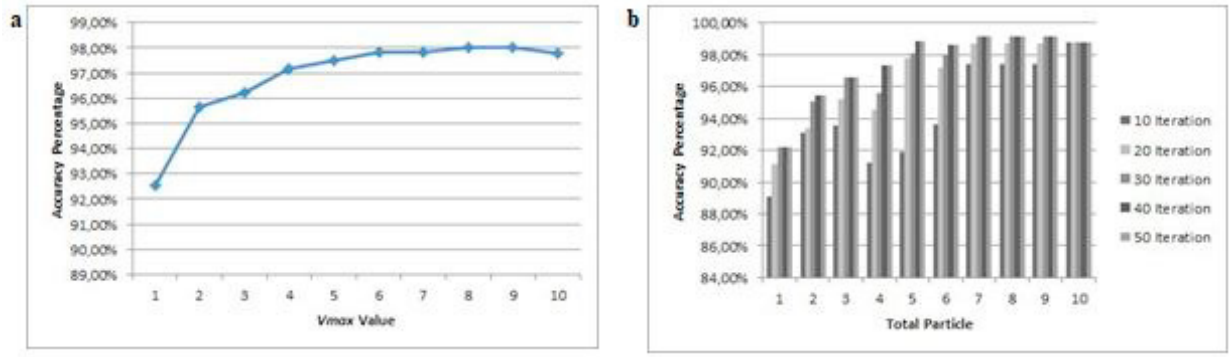

Fig. 1. (a) V_{max} Value Determination; (b) Particle and Max Iteration Determination.

Table 5. V_{max} Value Determination.

V_{max}	Accuracy
1	92.53%
2	95.67%
3	96.23%
4	97.17%
5	97.51%
6	97.82%
7	97.81%
8	**98.03%**
9	**98.03%**
10	97.79%

Table 6. Particle and Max Value Determination.

Population Size	Maximum Iteration				
	10	**20**	**30**	**40**	**50**
10	89.10%	91.15%	92.23%	92.23%	92.23%
20	93.08%	93.42%	95.10%	95.48%	95.48%
30	93.58%	95.19%	96.60%	96.60%	96.60%
40	91.22%	94.54%	95.57%	97.36%	97.36%
50	91.86%	97.76%	98.11%	98.87%	98.87%
60	93.63%	97.20%	97.94%	98.63%	98.63%
70	97.38%	98.73%	99.13%	**99.15%**	**99.15%**
80	97.38%	98.73%	99.13%	**99.15%**	**99.15%**
90	97.38%	98.73%	99.13%	**99.15%**	**99.15%**
100	98.78%	98.78%	98.78%	98.78%	98.78%

The data for this experiment is varied and obtained randomly from the normal children data in Indonesia. Table 7 shows the experiment result for each children data including Physical actvity level (moderate, light, orvigorous), allergy, and carbohydratesource (riceor non-rice). The example of dietary habit recommendation shown in Fig. 2.

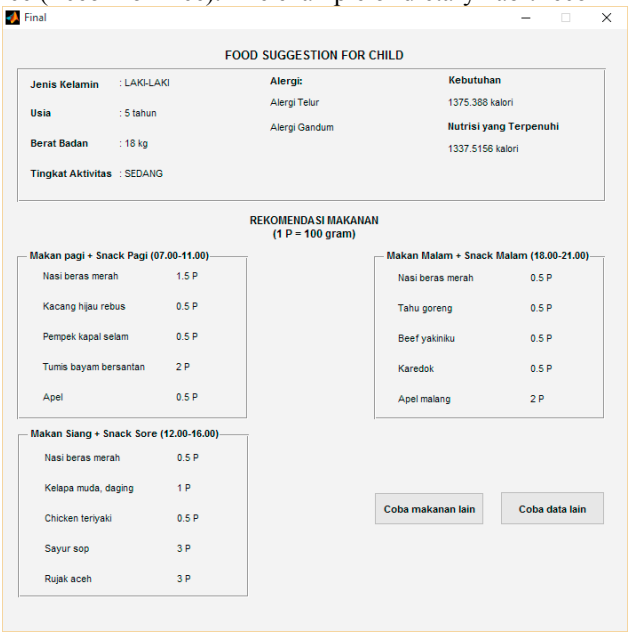

Fig. 2. Dietary Habit Recommendation Example.

It shows the portion and food option for each mealtime/day; breakfast from 07.00 AM - 11.00 AM, lunch from 12.00 PM - 04.00 PM, and dinner from 06.00 PM - 09.00 PM.

Table 7. Experiment Personal Data.

Data	Age	Weight (*kg*)	Gender	Physical Activity Level	Allergy	Carbogydrates Source
1	3	15.1	Boy	Moderate	No	Rice

2	4	15.2	Girl	Light	Wheat	Rice
3	5	17.82	Girl	Vigorous	No	Non-rice
4	6	18.8	Boy	Moderate	Egg	Non-rice
5	7	24.16	Girl	Moderate	No	Non-rice
6	8	22.24	Girl	Vigorous	Seafood	Rice
7	9	23.29	Boy	Moderate	No	Rice
8	9	23.29	Boy	Light	No	Rice
9	11	31.98	Girl	Moderate	Milk	Rice
10	11	34.46	Boy	Vigorous	Nuts	Rice
11	11	34.48	Boy	Moderate	Nuts	Non-rice
12	12	34.42	Boy	Moderate	No	Non-rice

The experimental results show that this research is succeed, proven from the accuracy of each nutrition type of this research is between the upper bound and lower bound, which is in range 80% and 110% (shown in the second until the fourth column of Table 8).

Table 8. Experiment Data.

Data	Protein (Intake/Requirement)	Fat (Intake/Requirement)	Carbohydrates (Intake/Requirement)	Accuracy
1	134.66/133.76 = 100.67%	262.68/267.52 = 98.19%	935.85/936.32 = 99.95%	99.15%
2	117.96/116.47 = 101.28%	227.52/232.94 = 97.67%	814.40/815.30 = 99.89%	98.76%
3	183.25/181.82 = 100.79%	359.16/363.63 = 98.77%	1271.19/1272.72 = 99.88%	99.28%
4	158.38/160.52 = 98.67%	313.30/321.04 = 97.59%	1121.61/1123.64 = 99.82%	98.69%
5	211.69/212.25 = 99.74%	405.85/424.49 = 95.61%	1482.74/1485.72 = 99.8%	98.38%
6	226.96/225.45 = 100.67%	447.25/450.90 = 99.19%	1577.99/1578.14 = 99.99%	99.50%
7	195.17/194.51 = 100.34%	390.38/389.02 = 100.35%	1361.72/1361.58 = 100.01%	99.76%
8	167.67/165.33 = 101.41%	325.35/330.67 = 98.39%	1160.93/1157.34 = 100.31%	98.89%
9	288.46/284.06 = 101.55%	559.09/568.12 = 98.41%	1985.24/1988.43 = 99.84%	98.90%
10	323.71/325.27 = 99.52%	652.10/650.54 = 100.24%	2275.52/2276.88 = 99.94%	99.74%
11	287.62/283.01 = 101.63%	550.50/566.01 = 97.26%	1980.45/1981.04 = 99.97%	98.53%
12	290.85/282.90 = 102.81%	562.80/565.79 = 99.47%	1979.88/1980.28 = 99.98%	98.88%

Where, PI is protein intake, PR is protein requirement, FI is fat intake, FR is fat requirement, CI is carbohydrate intake, CR is carbohydrate intake, and the accuracy in the fifth column is obtained from Equation 15.

$$Accuracy = 100\% - ((|ER - EI| / ER) * 100\%) Accuracy = 100\% - (\frac{|ER-EI|}{ER} * 100\%) \quad (15)$$

The result of this research is also compared with the result of the previous research using Genetic Algorithm (GA). To reach the optimum nutrition intake, BPSO provide a better result than GA. Where in BPSO, the average accuracy of nutrition intake is 99.14% while using GA, the average accuracy of nutrition intake is 97.87%.

Besides from the accuracy, the nutritionist expert has validated that the dietary habit recommendation from this research is valid. This dietary habit recommendation is also already meeting the nutrition needs of protein, fat, and

carbohydrates and already cover the food variance in Indonesia (main dishes, vegetable side dishes, meat, vegetable, and fruit).

5. Disscussion

This paper presents the daily dietary habit recommendation for children in Indonesia using Binary Particle Swarm Optimization algorithm (BPSO). This research shows that BPSO can provides a daily dietary habit recommendation for each child that already meet the close optimum nutrition intake. Proven from the average accuracy of nutrition intake of 99.14% while GA can only provide an optimum nutrition intake accuracy of 97.87%. Moreover, the result of this research is already validated by nutritionist expert.

For the future work, this research will be developed to be used for underweight and overweight children so that they can get back to normal. Moreover, this research will also be developed to cover all minor nutrition type like water, fiber, calcium, phosphor, potassium, sodium, copper, zinc, carotene, thiamine, niacin, and vitamin C.

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