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Optimization using Genetic Algorithm in Food Composition

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Abstract: This paper aims to process daily food consumption based on the Guideline to Healthy Food or the principle of Healthy 4 Perfect 5 (H4P5). The Guideline to Healthy Food does not include the portion and size of daily food consumption, therefore it is perfected into the Guidelines to Balanced Nutrition (GBN). GBN is performed by consuming three servings of protein vegetables, three servings of animal protein, eight servings of carbohydrates, five servings of vegetables, five servings of fruits, and eight servings of water. Each part of the portion has a proportional size and dose based on GBN. The portions are measured by food composition using the optimization process using a Genetic Algorithm (GA). Optimization by a using Genetic Algorithm yielded three outputs, namely, first, the initial objective function (0) compared to the generative objective function (1) produces a value of 6.13: 4.72 (there is an increase in chromosomes, because, the smaller the value, the better the chromosome is). Second, probability mutation is 50% of mutation rate, crossover probability is 5%, the maximum generation is 36, the maximum fitness point is 0.240806, and the size of the population is 6. Third, optimization using the Genetic Algorithm in food composition produces one food model, one consumption model, and one composition model. Thus, the result of this research (food model, consumption model, and composition model) can be a recommendation for food consumption patterns (normal condition) and a reference for national food consumption policies.

Keywords: Optimization, Genetic Algorithm, Food Composition

1. Introduction

Optimization is a set of problems in mathematics to obtain a unique and optimum value. It is used for computational problems with algorithms that are based on mathematical models [1]. One of the mathematical models is a combination model. This combination uses mathematical equations for combinations of food composition based on balanced nutrition [2]. Balanced nutrition is food containing nutrients from food sources as energy-producing substances (carbohydrates and fats), food sources as regulator substances (vegetable and animal protein), and food sources as protective substances (water, vitamin, and minerals). The function of balanced nutrition is to maintain and strengthen endurance, maintain balanced body weight, increase disease resistance, and improve healthy life quality. Based on normal portions and general standards in all groups in Indonesia, the compositions of food with balanced nutrition for daily consumption are 2-3 servings of vegetable protein, 2-3 servings of animal protein, 3-8 servings of carbohydrates, 3-5 servings of vegetables, 3-5 servings of fruits, and 8 servings of water (2 liters). Each portion is based on minimum nutritional requirements [3].

TABLE I. FOOD SOURCE

Source	Comparison	
	Health 4 Perfect 5 Pattern	***Balanced Nutrition***
Energy-producing substances	Carbohydrate	Carbohydrate 50%
Energy-producing substances	Fat	Fat 30%
Regulator substances	Protein	Protein 15%
Protective substance	Vitamin &Mineral	Vitamin & Mineral 5%
Pattern	4 health as a staple food and milk as a complement	Consumption of various food, healthy lifestyle, maintain ideal body weight, active sports

In this paper, Table 1 suggests some healthy messages. First, the Healthy Eating Guideline (HEG) with Healthy 4 Perfect 5 pattern emphasizes the message of food

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consumption on the importance of consumption of rice, side dishes, vegetables, fruits as staple foods. Secondly is the importance of consuming milk as a separate food or drink. Because of its nutritional content namely protein and minerals, it is beneficial to complement perfect food consumption. Third, there is no exact portion size of food to be consumed in one day in HEG. Fourth, the importance of drinking water (the quantity of water needed for consumption is not explained, neither is the quantity of mineral drinking water).

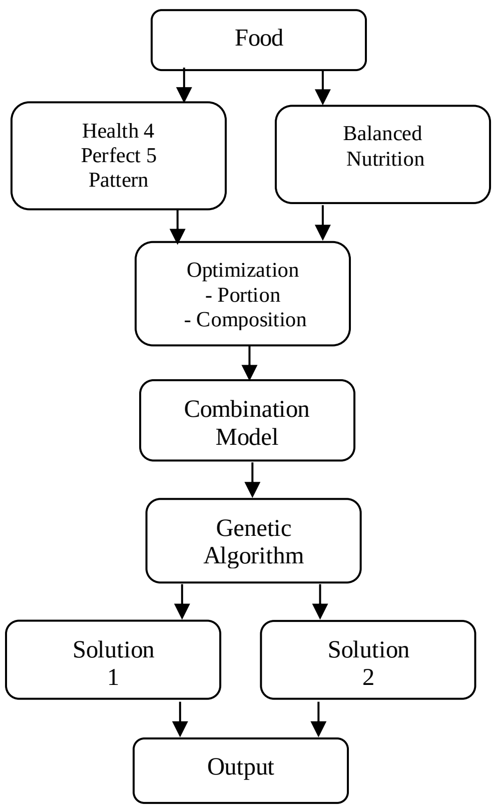

Figure 1. Structure of paper

Based on Figure 1, in this paper, the structure of the process consists of several elements. Firstly, the food element is a food data source element. Secondly, Healthy 4 Perfect 5 pattern as Guide 1 and Balanced Nutrition as Guide 2. Thirdly, optimization is a process for determining the portion and composition problems. Fourthly, a combination model in mathematical form. Fifthly, the Genetic Algorithm is a method of how to produce mathematical solutions. Sixthly, solution as output (alternative solution 1 and solution 2). Seventhly or lastly, output as optimal optimization (food menu, food nutrition, meal times, and food composition based on Food Model, Consumption Model, and Composition Model).

The Guideline of Balanced Nutrition is a healthy message by emphasizing the consumption of food with food composition containing nutrient elements that suits the needs of the body, using 7 principles, namely regularly eating a variety of foods, maintaining a clean lifestyle, exercising, and weight monitoring, drinking milk, (milk is included in the complementary/non-food group), replacing milk with other food/drinks with similar or equal nutritional value, measuring the portion of the amount/size/food that must be consumed for each type of food, and drinking mineral water with an explanation of drinking 2 liters of mineral water or 8 glasses per day. A composition framework is displayed in Figure 2.

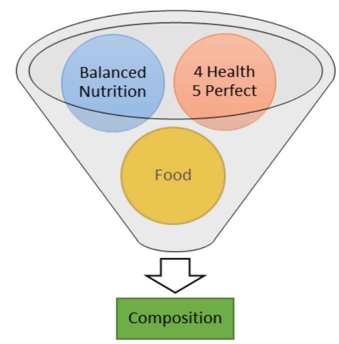

Figure 2. Composition framework

Optimization of food composition needs to be done to get the optimal solution for food consumed based on the Healthy 4 Perfect 5 pattern and Guidelines of Balanced Nutrition (GBN). The optimal solution is used to obtain the right food composition. The right food comes from the right menu, balanced nutrition, a regular schedule, and proportional food composition. The food framework is displayed in Figure 3.

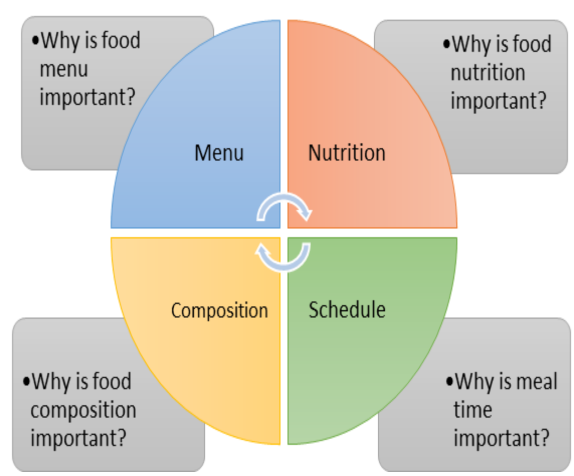

Figure 3. Food framework

First, why is the diet important? In planning a food menu, it is very important to select the right food menu. A healthy diet must meet the amount and variety of nutritious foods and the types of nutrients needed by the body. A nutritious diet is needed for optimal growth and the acquisition of nutrients to strengthen the immune system. The food menu must be based on the Healthy 4 and Perfect 5 pattern which consists of rice, side dishes, vegetables, fruit, and milk while an improved diet is based on the Guidelines of Balanced Nutrition, namely vegetable protein, animal protein, carbohydrates, vegetables, fruit, and water.

Second, why is food nutrition important? The answer is because nutrition can help growth, improve the function of body organs, and provide protection from the risk of diseases. Moreover, the nutritional imbalance can trigger malnutrition which in turn can result in slow growth (stunting). The components of balanced nutrition are carbohydrates, protein, fat, vitamins, minerals, fiber, and water.

Third, why is eating time important? A good mealtime is defined as a meal schedule with a regular schedule at the right time. Eating at the wrong time can affect health. Skipping meals also affects the balance of bodily functions as the human body works according to biological working hours which affects mealtime. Delaying meal times can affect digestion and metabolic disorders. Therefore, the best way to manage your eating schedule is to know when to eat and what portions to support the activities that will be carried out. A good eating schedule consists of breakfast (at 05:00 - 09.00 in the morning), morning mini-meal or snack (10:00 morning), lunch (12:00 - 13:00 noon), afternoon mini-meal or snack (15:00 - 16:00 afternoon), and dinner (7:00 - 80:00 pm).

Fourth, why is the composition important? Food composition is very important for the body. The food must meet the number of calories, portion of food, type of food, amount of nutrition, nutritional value, amount of consumption, and the amount of energy needed by the body. Most importantly the food is consumed according to the right eating schedule. Food consumption is based on GBN, which consists of 3 servings of vegetable protein, 3 servings of animal protein, 8 servings of carbohydrates, 5 servings of vegetables, 5 servings of fruit, and 8 servings of water.

2. RELATED WORK

One popular computational algorithm for optimization problems is the Genetic Algorithm [4]. A Genetic Algorithm has been proposed by many researchers on food problems. Among the researches are combination menus on cholesterol prevention [5], food composition for patients with diabetes mellitus [6], food composition for patients with high blood pressure 7], food composition for hypertensive patients [8], nutritional status can be influenced by balanced nutritional behavior [9], media promotion the tagline “My Dishes” [10], and the influence of media on web-based and Android nutrition education [11]. The guideline of balanced nutrition is also very important to determine the combination of the composition of food consumed. This combination problem requires the right solution with GBN as it is very necessary for a nutritious diet. Nutritious food menus are needed for food nutrition standards and food nutrition must be by food composition. Food composition needs to be consumed on the right eating schedule. Combinations of a nutritious and varied diet need to be made because food nutrition requires a variety of foods with optimal composition. More importantly, optimal food composition needs to be consumed at the right time. Thus, this optimization is needed to produce an optimal composition with the right combination for food consumption. Food consumption with optimal composition and the right combination can improve the quality of life of healthy people and reduce the risk of illness. This strategy can be one way to improve public health for approximately 260 million of Indonesia’s population. Because there has not been a clear or proper composition of the guideline of healthy food and there is no optimal scheduling in the guidelines of balanced nutrition, optimization is highly needed. The proposed method is by optimization using a Genetic Algorithm to obtain a clear food composition and optimal scheduling. Therefore, this method is expected to be a recommendation for food consumption patterns and can be a reference for national food consumption policies.

The main contributions of this work are summarized as follows:

- The paper presents a novel genetic algorithm based on the food consumption algorithm. The idea presented in the paper is very useful for the society where most of the peoples are unable to take a healthy diet.
- The authors implemented in the form of 3 models: the Consumption Model, the Food Model, and the Composition Model.
- The paper presented a novel method for maintaining a healthy diet plan. The genetic algorithm has been used to design a novel model for a healthy diet plan.
- In this paper, optimization was applied using a genetic algorithm for food processing scenarios. The result of this research can be a recommendation for food consumption patterns.
- This paper presented using a genetic algorithm to optimize food composition based on guidelines of healthy food and balanced food. This study somehow showed interesting finds for a new guideline and can be recommended for Indonesian people in normal condition (excluded pregnant, baby, children, and older) and also depend on their activities (excluded working hard, bodybuilder athletes, and food addiction).

3. PROPOSED METHOD

The proposed method consists of five elements are the data model, optimization, Genetic Algorithm, food composition, and solution.

A. Data Model

The daily food consumption data model is explained by the mathematical model in equation (1).

$$3a + 3b + 8c + 5d + 5e + 8f = 24 \quad (1)$$

Where *a* is the portion of consumption of vegetable protein, *b* is the portion of animal protein, *c* is the portion of carbohydrate consumption, *d* is the portion of vegetable consumption, *e* is the portion of fruit consumption, and *f* is the portion of water consumption, and 24 the time of hours in one day ((24 hours to achieve 100%).

B. Optimization

Optimization is performed using the Genetic Algorithm in food composition. One application of the Genetic Algorithm is solving combinations with mathematical models. This optimization aims to get an optimal value of the solution for a problem that has many solutions. The optimization model is illustrated in the framework displayed in Figure 4.

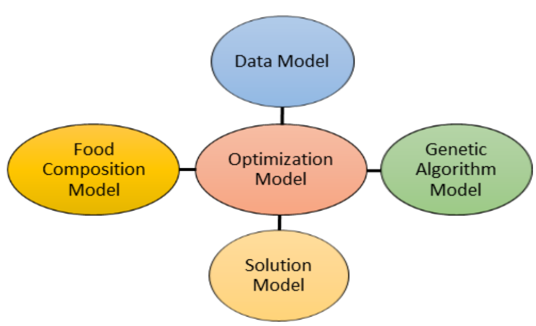

Figure 4. Optimization framework

A framework is used to find a solution to the problem of food composition. The framework consists of Optimization, Data, Genetic Algorithm, Food Composition, and Solutions. Data models are based on mathematical models. The optimization uses the Genetic Algorithm. The food composition is based on optimization. Output is a model for optimal solutions.

C. Genetic Algorithm

Based on Flowchart [12], the Genetic Algorithm can solve combinatorial optimization problems for simple solutions. A solution produced in the Genetic Algorithm is called a Chromosome. Chromosome collection is called Population. A chromosome is formed from a component called a Gene. Genes can have values in the form of numeric numbers, binaries, symbols, characters depending on the problem you want to solve. Chromosomes will evolve continuously called Generation. In each generation, chromosomes are evaluated on the success rate of the solution to the problem to be solved (objective function) with a measure called Fitness. To select chromosomes that will be retained for the next generation, a process called Selection is carried out.

The chromosomes selection process with a high Fitness Point has a great chance to be re-elected in the next generation. The new chromosome called Offspring is formed by cross-breeding in a generation called Crossover. The number of chromosomes undergoing crossover is determined by a parameter called the Crossover Rate. The process of changing one or more gene values in a chromosome with a random number is called the Mutation Rate. A solution produced from several generations with chromosomes with the value of gene convergence. Convergence value is the optimal solution (best solution) from the Genetic Algorithm. Optimization using the Genetic Algorithm is done to solve the problem of combination using a computer (computing) based on the paper [13]. The process of computing the Genetic Algorithm is described in the form of the flowchart shown in Figure 5.

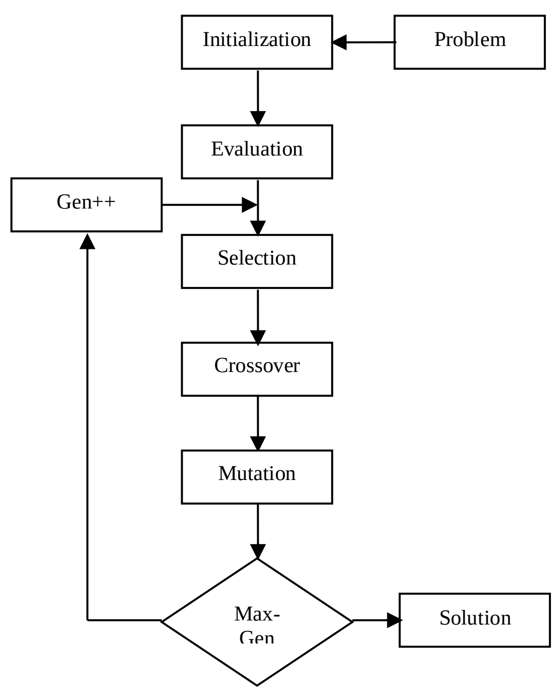

Figure 5. Flowchart

D. Food Composition

Food composition is based on Balanced Nutrition Guidelines for daily food consumption. Various types of food, various menu choices, time of consumption, and the portion are based on normal calorie needs per person per day. Daily food intake is adjusted to the number of calories and nutritional value to the needs of people under normal conditions (except for infants, toddlers, children, pregnant women, sick people, and elderly people). Food composition will be converted into mathematical models.

E. Solution

The solution is produced from several generations with chromosome genes whose value converges as optimal solutions from several combinations. An optimal solution is generated in a Genetic Algorithm called Best Chromosome with a process called Encoding. The returning process called Decoding will produce the convergence value into the best value as a solution.

4. RESULT AND DISCUSSION

A. Data Model

The Data Model is used to create mathematical models. Based on Table 2, these components are converted into mathematical models. The model used for solving combination problems is based on equation (1). The food component consists of vegetable protein with portions three times and is symbolized by symbol *a*. this means that the consumption of a variety of foods containing vegetable protein, the consumption schedule is five times a day (morning, morning mini-meal or snack, lunch, afternoon mini-meal or snack, and dinner). Consumption is valid for 1 day or 24 hours. This consumption pattern applies normally to every individual in a healthy condition. The same thing was done for animal protein (symbol b), carbohydrates ((symbol c), vegetables (symbol d), fruit (symbol e), and water (symbol f). Consumption of food in the size of one meal, foods that contain protein, carbohydrates, vegetables, fruits, and vitamins and minerals contained in a variety of foods. The data model is displayed in Table 2.

TABLE II. DATA MODEL

Component	Formulation	
	Portion	*Notation*
Vegetable Protein	3	a
Animal Protein	3	b
Carbohydrate	8	c
Vegetable	5	d
Fruit	5	e
Water	8	f
One day consumption	24 (hours)	

B. Optimization

Optimization is done by finding the best solution from many alternatives. Optimization can produce more than one solution.

C. Genetic Algorithm

Genetic Algorithms are used to solve combinatorial optimization problems shown in Table 3.

TABLE III. DIMENSION OF GENETIC ALGORITHM

No	Dimension	Technique
1	Problem	Data Model Variable Chromosome Coding Chromosome
2	Initialization	Initialization Chromosome
	Evaluation	Objective Function
3	Selection	Probability Chromosome Roulette Wheel Model
4	Crossover	Crossover Rate
5	Mutation	Mutation Rate
6	Iteration	Objective Function
7	Solution	Decoding Chromosome

Table 3 shows the computational process using a Genetic Algorithm with 7 dimensions (Problems, Initialization, Evaluation, Selection, Crossover, Mutation, and Solution).

Step 1: Chromosome Variables

The variables of chromosomes are shown in Table 4.

TABLE IV. ELEMENT

Element	Notation	Description
Population Size	Pop. size	6
Random Number	R[i]	[0..30]
Variable Chromosome	Chr[i]	a,b,c,d,e,f
Probability Crossover	Pc	50% or 0,5
Probability Mutation	Pm	5% or 0,05
Maximum Generation	Max-Gen	36

Step 2: Chromosome Initialization with the position of Chr[i] generated by Random Number R[i]

$$Chr[1] = [a,b,c,d,e,f] = [2{,}50; 1{,}50; 1{,}35; 0{,}40; 0{,}80; 0{,}50]$$
$$Chr[2] = [a,b,c,d,e,f] = [1{,}75; 2{,}45; 0{,}40; 0{,}80; 0{,}60; 0{,}60]$$
$$Chr[3] = [a,b,c,d,e,f] = [1{,}30; 1{,}70; 0{,}30; 1{,}85; 1{,}50; 0{,}20]$$
$$Chr[4] = [a,b,c,d,e,f] = [2{,}65; 2{,}50; 0{,}50; 0{,}80; 0{,}40; 0{,}25]$$
$$Chr[5] = [a,b,c,d,e,f] = [1{,}25; 1{,}75; 0{,}60; 0{,}60; 0{,}80; 1{,}55]$$
$$Chr[6] = [a,b,c,d,e,f] = [1{,}70; 1{,}30; 0{,}20; 1{,}50; 1{,}90; 0{,}30]$$

Step 3: Chromosome Evaluation based on Objective Function f[i]

- *Solution→Objective Function =f[Chr]*

$$Chr[1] = Abs\begin{pmatrix} 3*2{,}50+3*1{,}50+ \\ 8*1{,}35+5*0{,}40+ \\ 5*0{,}80+8*0{,}50 \end{pmatrix} - 24 = Abs(32{,}80) - 24 = 8{,}80$$

$$Chr[2] = Abs\begin{pmatrix} 3*1{,}75+3*2{,}45+ \\ 8*0{,}40+5*0{,}80+ \\ 5*0{,}60+8*0{,}60 \end{pmatrix} - 24 = Abs(27{,}60) - 24 = 3{,}60$$

$$Chr[3] = Abs\begin{pmatrix}3*1{,}30+3*1{,}70+\\8*0{,}30+5*1{,}85+\\5*1{,}50+8*0{,}20\end{pmatrix}-24 = Abs(29{,}75)-24 = 5{,}75$$

$$Chr[4] = Abs\begin{pmatrix}3*2{,}65+3*2{,}50+\\8*0{,}50+5*0{,}80+\\5*0{,}40+8*0{,}25\end{pmatrix}-24 = Abs(27{,}45)-24 = 3{,}45$$

$$Chr[5] = Abs\begin{pmatrix}3*1{,}25+3*1{,}75+\\8*0{,}60+5*0{,}60+\\5*0{,}80+8*1{,}55\end{pmatrix}-24 = Abs(33{,}20)-24 = 9{,}20$$

$$Chr[6] = Abs\begin{pmatrix}3*1{,}70+3*1{,}30+\\8*0{,}20+5*1{,}50+\\5*1{,}90+8*0{,}30\end{pmatrix}-24 = Abs(30{,}00)-24 = 6{,}00$$

- *Average →f [i] from Chr[i]*

$$Avg \to f[0] \to Chr[i] = \frac{8{,}80+3{,}60+5{,}75+3{,}45+9{,}20+6{,}00}{6} = 6{,}13$$

Step 4: Chromosome Selection based on Fitness Function f[i] and P[i].

- $Fitness\ Function \to f[i] = \frac{1}{(f[i]+1)}$

$$f[1] = \frac{1}{(8{,}80+1)} = \frac{1}{9{,}80} = 0{,}102041$$

$$f[2] = \frac{1}{(3{,}60+1)} = \frac{1}{4{,}60} = 0{,}217391$$

$$f[3] = \frac{1}{(5{,}75+1)} = \frac{1}{6{,}75} = 0{,}148148$$

$$f[4] = \frac{1}{(3{,}45+1)} = \frac{1}{4{,}45} = 0{,}224719$$

$$f[5] = \frac{1}{(9{,}20+1)} = \frac{1}{10{,}20} = 0{,}098039$$

$$f[6] = \frac{1}{(6{,}00+1)} = \frac{1}{7{,}00} = 0{,}142857$$

- $Total = 0{,}102041 + 0{,}217391 + 0{,}148148 + 0{,}224719 + 0{,}098039 + 0{,}142857 = 0{,}933196$
- $Probability \to P[i] = \frac{f[i]}{total f[i]}$

$$P[1] = \frac{0{,}102041}{0{,}933196} = 0{,}109346 \qquad P[2] = \frac{0{,}217391}{0{,}933196} = 0{,}232954$$

$$P[3] = \frac{0{,}148148}{0{,}933196} = 0{,}158754 \qquad P[4] = \frac{0{,}224719}{0{,}933196} = 0{,}240806$$

$$P[5] = \frac{0{,}098039}{0{,}933196} = 0{,}105058 \qquad P[6] = \frac{0{,}142857}{0{,}933196} = 0{,}153084$$

- $Max = 0{,}240806$
- $Cumulative \to C[i]$

$C[1] = 0{,}109346$
$C[2] = 0{,}109346 + 0{,}232954 = 0{,}342299$
$C[3] = 0{,}109346 + 0{,}232954 + 0{,}240806 = 0{,}501053$
$C[4] = 0{,}109346 + 0{,}232954 + 0{,}240806 + 0{,}240806 = 0{,}741859$
$C[5] = 0{,}109346 + 0{,}232954 + 0{,}240806 + 0{,}240806 + 0{,}105058 = 0{,}846916$
$C[6] = 0{,}109346 + 0{,}232954 + 0{,}240806 + 0{,}240806 + 0{,}105058 + 0{,}153084 = 0{,}999997 \to 1{,}000000$

- *Random Number R[i] based on Roulette Wheel Model (generate a random number using Excel software)*

$R[1] = 0{,}740891\ nearby\ C[4] = 0{,}741859 \to Chr[1] = Chr[4]$
$R[2] = 0{,}855193\ nearby\ C[5] = 0{,}846916 \to Chr[2] = Chr[5]$
$R[3] = 0{,}999998\ nearby\ C[6] = 0{,}999997 \to Chr[3] = Chr[6]$
$R[4] = 0{,}119081\ nearby\ C[1] = 0{,}109346 \to Chr[4] = Chr[1]$
$R[5] = 0{,}342265\ nearby\ C[2] = 0{,}342299 \to Chr[5] = Chr[2]$
$R[6] = 0{,}501488\ nearby\ C[3] = 0{,}501053 \to Chr[6] = Chr[3]$

$Chr[1] = Chr[4] \to [2{,}60; 2{,}50; 0{,}50; 0{,}80; 0{,}40; 0{,}25]$
$Chr[2] = Chr[5] \to [1{,}25; 1{,}75; 0{,}60; 0{,}60; 0{,}80; 1{,}55]$
$Chr[3] = Chr[6] \to [1{,}70; 1{,}30; 0{,}20; 1{,}50; 1{,}90; 0{,}30]$
$Chr[4] = Chr[1] \to [2{,}50; 1{,}50; 1{,}35; 0{,}40; 0{,}80; 0{,}50]$
$Chr[5] = Chr[2] \to [1{,}75; 2{,}45; 0{,}40; 0{,}80; 0{,}60; 0{,}60]$
$Chr[6] = Chr[3] \to [1{,}30; 1{,}70; 0{,}30; 1{,}85; 1{,}50; 0{,}20]$

Step 5: Crossover based on Probability level $Pc \to 50\% = 0{,}500000$

$R[i]$	$Pc[i]$
$R[1] = 0{,}476543$	$Pc[1] = 0{,}500000$
$R[2] = 0{,}524538$	$Pc[2] = 0{,}500000$
$R[3] = 0{,}489123$	$Pc[3] = 0{,}500000$
$R[4] = 0{,}515263$	$Pc[4] = 0{,}500000$
$R[5] = 0{,}496175$	$Pc[5] = 0{,}500000$
$R[6] = 0{,}537852$	$Pc[6] = 0{,}500000$

- *Compare→* $R[i]\ with\ Pc[i]$

$R[1] < Pc[1] \to R[1]$	$R[2] > Pc[2]$
$R[3] < Pc[3] \to R[3]$	$R[4] > Pc[4]$
$R[5] < Pc[5] \to R[5]$	$R[6] > Pc[6]$

- *Determine parent by choice value→* $R[i] < Pc[i]$

$R[1] \to parent\ R[3] \to parent R[5] \to parent$
$Pc = 50\% * Number\ of\ Genes = 50\% * 6 = 3$

- *The cut point position uses a random number based on the number of the chromosome, in this case, means there are 3 chromosomes (range 1-3).*
- $Chr[1] >< Chr[3]\ with\ C[1] = 2$ *→(the position of the 2nd gen on Chr[3] exchange with Chr [1])*

$Chr[1] >< Chr[3] \to [2{,}65; 2{,}50; 0{,}50; 0{,}80; 0{,}40; 0{,}25]$
$exchange\ with\ [1{,}70; 1{,}30; 0{,}20; 1{,}50; 1{,}90; 0{,}30]$
$output [1{,}70; 2{,}50; 0{,}20; 1{,}50; 1{,}90; 0{,}30]$

- $Chr[3] >< Chr[5]\ with\ C[2] = 2$ *→(the position of the 2nd gen on Chr [2] exchange with Chr [5])*

$Chr[3] >< Chr[5] \to [1{,}70; 1{,}30; 0{,}20; 1{,}50; 1{,}90; 0{,}30]$
$exchange\ with\ [1{,}70; 2{,}45; 0{,}40; 0{,}80; 0{,}60; 0{,}60]$
$output [1{,}75; 1{,}30; 0{,}40; 0{,}80; 0{,}60; 0{,}60]$

- $Chr[5] >< Chr[1]\ with\ C[3] = 2$ *→(the position of the 2nd gen on Chr [1] exchange with Chr [3])*

$Chr[5] >< Chr[1] \to [1{,}75; 2{,}45; 0{,}40; 0{,}80; 0{,}60; 0{,}60]$
$exchange\ with\ [2{,}65; 2{,}50; 0{,}50; 0{,}80; 0{,}40; 0{,}25]$
$output [2{,}65; 2{,}45; 0{,}50; 0{,}80; 0{,}40; 0{,}25]$

- *Determine the Offspring (red font in box)*

Step 6: Mutation based on the level of probability of mutation → $Pm = 5\% = 0.05$

- $Total = Number\ of\ Genes * Population = 6 * 6 = 36$
- $Mutation = 5\% * Total = 0.05 * 36 = 1{,}8 = 2\ (rounded\ of)$
- $R[i] = [0..35]$

- *Gen position exchanged with R[i] → the position of selected genes by mutation*
  Selected = Chr[4] gen at the 3rd position
  Selected = Chr[6] gen at the 4th position
- *Before Mutation (a red font in the box)*
  $Chr[1] = [1,70; 2,50; 0,20; 1,50; 1,90; 0,30]$
  $Chr[2] = [1,25; 1,75; 0,60; 0,60; 0,80; 1,55]$
  $Chr[3] = [1,75; 1,30; 0,40; 0,80; 0,60; 0,60]$
  $Chr[4] = [2,50; 1,50; \boxed{1,35}; 0,40; 0,80; 0,50]$ → 3rd position
  $Chr[5] = [1,30; 1,75; 0,60; 0,60; 0,80; 1,55]$
  $Chr[6] = [1,30; 1,70; 0,30; \boxed{1,85}; 1,50; 0,20]$ → 4th position
- *After Mutation (a red font in the box)*
  $Chr[1] = [1,70; 2,50; 0,20; 1,50; 1,90; 0,30]$
  $Chr[2] = [1,25; 1,75; 0,60; 0,60; 0,80; 1,55]$
  $Chr[3] = [1,75; 1,30; 0,40; 0,80; 0,60; 0,60]$
  $Chr[4] = [2,50; 1,50; \boxed{0,25}; 0,40; 0,80; 0,50]$ → 3rd position
  $Chr[5] = [1,30; 1,75; 0,60; 0,60; 0,80; 1,55]$
  $Chr[6] = [1,30; 1,70; 0,30; \boxed{0,70}; 1,50; 0,20]$ → 4th position

Step 7: Solution → Chr[i]

- $Chr[i] \to f[i] \to Chr[i]$

$$Chr[1] = Abs\begin{pmatrix} 3*1,70+3*2,50+ \\ 8*0,20+5*1,50+ \\ 5*1,90+8*0,30 \end{pmatrix} - 24 = Abs(28,60) - 24 = 4,60$$

$$Chr[2] = Abs\begin{pmatrix} 3*1,25+3*1,75+ \\ 8*0,60+5*0,60+ \\ 5*0,80+8*1,55 \end{pmatrix} - 24 = Abs(33,20) - 24 = 9,20$$

$$Chr[3] = Abs\begin{pmatrix} 3*1,75+3*1,30+ \\ 8*0,40+5*0,80+ \\ 5*0,60+8*0,60 \end{pmatrix} - 24 = Abs(24,15) - 24 = 0,15$$

$$Chr[4] = Abs\begin{pmatrix} 3*2,50+3*1,50+ \\ 8*0,25+5*0,40+ \\ 5*0,80+8*0,50 \end{pmatrix} - 24 = Abs(24) - 24 = 0$$

$$Chr[5] = Abs\begin{pmatrix} 3*1,30+3*1,75+ \\ 8*0,60+5*0,60+ \\ 5*0,80+8*1,55 \end{pmatrix} - 24 = Abs(29,35) - 24 = 5,35$$

$$Chr[6] = Abs\begin{pmatrix} 3*1,30+3*1,70+ \\ 8*0,30+5*0,70+ \\ 5*1,50+8*0,20 \end{pmatrix} - 24 = Abs(24) - 24 = 0$$

- $Average \to f(1)$

$$Chr[i] = \frac{4,60+9,20+0,15+0+5,35+0}{6} = 3,22$$

- $Compare \to f(0): f(1) = 6,13: 3,22 \to f(1) < f(0)$
  There is an increase in genes. The test was performed again with the decoding process if the best combination has been obtained, then the iteration is stopped. Return to step Chromosomes Variables to Mutation until the maximum generation is reached (in this case, the solution has been obtained).

D. Food Composition

Food composition, food sources, food variation, portions of daily consumption, and size of one meal for daily consumption are shown in Table 5.

TABLE V. FOOD COMPOSITION

Component	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Vegetable Protein	2,5 tablespoons soybeans (25g)	2 medium slice Tempe (50g)	2 large slice Oncom (50g)	1 large slice tofu (100g)
Animal Protein	2 medium pieces anchovy (25g)	2 pieces chicken eggs (60g)	1 medium piece beef (50g)	1glass milk (200g)
Carbo Hydrate	1 medium slice cassava (200g)	4 slice white bread (80g)	0,75 cup rice (100g)	1 large seed taro (200g)
Vegetable	yam leaves (100g)	spinach (100g)	tomato (100g)	cabbage (100g)
Fruit	0,5 pieces mango (50g)	2 pieces orange (100g)	1 medium slice papaya (100g)	8 pieces rambutan (50g)
Water	2 glasses of water	2 glasses of water	2 glasses of water	2 glasses of water

E. Solution

Solution based on initialization, selection, crossover, mutation, and solution is shown in Table 6.

TABLE VI. INITIALIZATION

Chr[i]	3a	3b	8c	5d	5e	8f
[1]	2,50	1,50	1,35	0,40	0,80	0,50
[2]	1,75	2,45	0,40	0,80	0,60	0,60
[3]	1,30	1,70	0,30	1,85	1,50	0,20
[4]	2,65	2,50	0,50	0,80	0,40	0,25
[5]	1,25	1,75	0,60	0,60	1,80	0,55
[6]	1,70	1,30	0,20	1,50	1,90	0,30

Table 6 presents initialization with chromosome regulation and gene position in the initial population.

TABLE VII. SELECTION

Chr[i]	3a	3b	8c	5d	5e	8f
[1]	2,65	2,50	0,50	0,80	0,40	0,25
[2]	1,25	1,75	0,60	0,60	0,80	1,55
[3]	1,70	1,30	0,20	1,50	1,90	0,30
[4]	2,50	1,50	1,35	0,40	0,80	0,50
[5]	1,75	2,45	0,40	0,80	0,60	0,60
[6]	1,30	1,70	0,30	1,85	1,50	0,20

Table 7 presents the selection by chromosome arrangement and gene position. All genes changes (blocks).

TABLE VIII. CROSSOVER

Chr[i]	3a	3b	8c	5d	5e	8f
[1]	1,75	2,50	0,20	1,50	1,90	0,30
[2]	1,25	1,75	0,60	0,60	0,80	1,55
[3]	1,75	1,30	0,40	0,80	0,60	0,60
[4]	2,50	1,50	1,35	0,40	0,80	0,50
[5]	1,30	1,75	0,60	0,60	0,80	1,55
[6]	1,30	1,70	0,30	1,85	1,50	0,20
Crossover Chr[1], Chr[3], Chr[5]						

Table 8 shows crossovers with chromosome arrangement and changes in gene position (blocks). On chromosome 5, 5 gene positions are similar to the initialization process.

TABLE IX. MUTATION

Chr[i]	3a	3b	8c	5d	5e	8f
[1]	1,75	2,50	0,20	1,50	1,90	0,30
[2]	1,25	1,75	0,60	0,60	0,80	1,55
[3]	1,75	1,30	0,40	0,80	0,60	0,60
[4]	2,50	1,50	1,35	0,40	0,80	0,50
[5]	1,30	1,75	0,60	0,60	0,80	1,55
[6]	1,30	1,70	0,30	1,85	1,50	0,20
Mutation Chr[4] Gen 3, Chr[6], Gen 4						

Table 9 presents mutations in the order of the chromosomes arrangement and the position of the altered gene (blocks). At position 5, the genes are the same as the initialization process. On chromosome 4, gen 3 (light blue block) mutations are performed.

TABLE X. SOLUTION

Chr[i]	3a	3b	8c	5d	5e	8f
[1]	1,75	2,50	0,20	1,50	1,90	0,30
[2]	1,25	1,75	0,60	0,60	0,80	1,55
[3]	1,75	1,30	0,40	0,80	0,60	0,60
[4]	2,50	1,50	0,25	0,40	0,80	0,50
[5]	1,30	1,75	0,60	0,60	0,80	1,55
[6]	1,30	1,70	0,30	0,70	1,50	0,20

Table 10 presents solutions to the regulation of chromosomes and the position of altered genes (blocks). On chromosome 5, 5 gene positions are similar to the initialization process. On chromosome 4, gen 3 (light blue block), and chromosome 6 gen 4 (light blue block) is the result of mutation:

$$Chr(1) = [3a + 3b + 8c + 5d + 5e + 8f] - 24 \rightarrow 28{,}60 - 24 = 4{,}6$$
$$Chr(2) = [3a + 3b + 8c + 5d + 5e + 8f] - 24 \rightarrow 33{,}20 - 24 = 9{,}2$$
$$Chr(3) = [3a + 3b + 8c + 5d + 5e + 8f] - 24 \rightarrow 24{,}15 - 24 = 0{,}15$$

$$Chr(4) = [3a + 3b + 8c + 5d + 5e + 8f] - 24 \rightarrow 24 - 24 = 0$$
$$Chr[4] = optimal \rightarrow Solution\ 1$$

$$Chr(5) = [3a + 3b + 8c + 5d + 5e + 8f] - 24 \rightarrow 29{,}35 - 24 = 5{,}35$$
$$Chr(6) = [3a + 3b + 8c + 5d + 5e + 8f] - 24 \rightarrow 24 - 24 = 0$$
$$Chr[6] = optimal \rightarrow Solution\ 2$$

Decoding Solution 1

$$(3 * 2{,}50 + 3 * 1{,}50 + 8 * 0{,}25 + 5 * 0{,}40 + 5 * 0{,}80 + 8 * 0{,}50) = 7{,}50 + 4{,}50 + 2{,}00 + 2{,}00 + 4{,}00 + 4{,}00 = 24$$

Decoding Solution 2

$$(3 * 1{,}30 + 3 * 1{,}70 + 8 * 0{,}30 + 5 * 0{,}70 + 5 * 1{,}50 + 8 * 0{,}20) = 3{,}90 + 5{,}10 + 2{,}40 + 3{,}50 + 7{,}50 + 1{,}60 = 24$$

TABLE XI. FORMULATION AND DECODING

Component	Formulation		Solution 1	Solution 2
	Portion	*Notation*	*Decoding 1*	*Decoding 2*
Vegetable Protein	3	a	2,50	1,30
Animal Protein	3	b	1,50	1,70
Carbo hydrate	8	c	0,25	0,30
Vegetable	5	d	0,40	0,70
Fruit	5	e	0,80	1,50
Water	8	f	0,50	0,20

Table 11 presents the formula and decoding of food composition based on solution 1 and solution 2.

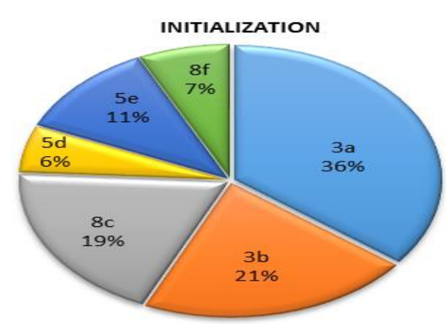

Figure 6. Graphic of initialization

Figure 6 shows the initialization graph based on percentages and composition. The consumption for vegetable protein (3a) is 36%, consumption of animal protein (3b) is 21%, carbohydrate consumption (8c) is 19%, vegetable consumption (5d) is 6%, fruit consumption (5e) is 11%, and water consumption (8f) is 7%.

Figure 7 shows a choice graph based on percentage and food composition. The consumption for vegetable protein (3a) is 37%, consumption of animal protein (3b) is 35%, carbohydrate consumption (8c) is 7%, vegetable consumption (5d) is 11%, fruit consumption (5e) is 6%, and water consumption (8e) is 4%.

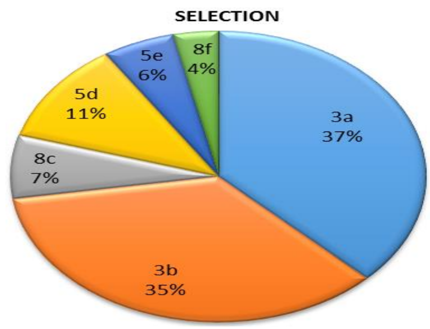

Figure 7. Graphic of selection

Figure 8 shows a crossover chart based on food percentages and composition. The consumption for vegetable protein (3a) is 22%, consumption of animal protein (3b) is 31%, carbohydrate consumption (8c) is 2%, vegetable consumption (5d) is 18%, fruit consumption (5e) is 23%, and water consumption (5f) is 4%. The percentage of the crossover is the same as the percentage of mutation.

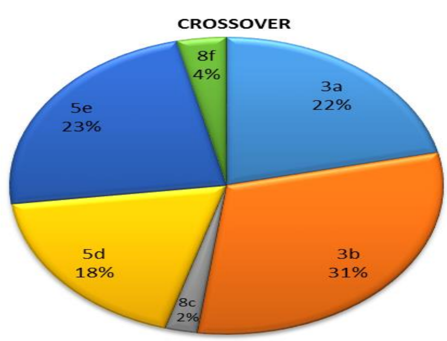

Figure 8. Graphic of crossover

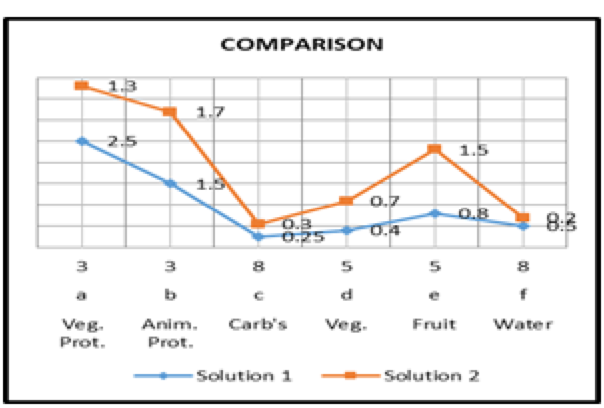

Figure 9. Graphic of comparison

Figure 9 shows the comparison of solution 1 and solution 2, food composition and portions in one meal for one-day consumption. Based on Solution 1, vegetable protein (3a = 2.5), animal protein (3b = 1.5), carbohydrate (8c = 0.25), vegetable (5d = 0.4), fruit (5e = 0.8), and water (8f = 0.5) to achieve balanced nutrition in food consumption. Based on Solution 2, vegetable protein (3a = 1.3), animal protein (3b = 1.7), carbohydrate (8c = 0.3), vegetable (5d = 0.7), fruit (5e = 1.5), and water (8f = 0.2) to achieve balanced nutrition in food consumption. Solution 1 and Solution 2 can be recommendation for the society where most of the peoples are unable to take a healthy diet and apply to Indonesian people in normal condition (peoples can choose Solution 1 or Solution 2 based on their condition).

TABLE XII. FOOD MODEL

Food Nutrition		**Food Menu**	
Health 4 Perfect 5 Pattern	Balanced Nutrition	Health 4 Perfect 5 Pattern	Balanced Nutrition
Carbohydrate	Vegetable Protein	Staple Food	Carbohydrate
Fat & Protein	Animal Protein	Meat or Fish	Protein
Vegetable	Carbohydrate	Vegetable	Fat
Fruit	Vegetable	Fruit	Vitamin & Mineral
Milk (Protein & Mineral)	Fruit	Milk	Fiber
Food Composition		**Meal Time**	
Health 4 Perfect 5 Pattern	Balanced Nutrition	Health 4 Perfect 5 Pattern	Balanced Nutrition
-	50% Carbohydrate	Breakfast (05.00 – 09.00)	Breakfast (05.00 – 09.00)
-	30% Fat	Lunch (12.00 – 13.00)	Morning Interlude (10.00)
-	15% Protein	Dinner (19.00 – 20.00)	Lunch (12.00 – 13.00)
-	5% Vitamin & Mineral		Afternoon Interlude (15.00 – 16.00)
			Dinner (19.00 – 20.00)

Table 12 shows food nutrition, diet, food composition, and meal times as food models. The main components of food nutrients are carbohydrates, protein, vegetables, and fruits. The main components of food diets are carbohydrates, protein, fiber, vitamins, minerals, and water. The main components of food compositions are carbohydrates, fats, protein, vitamins, and minerals. The main components of mealtimes are breakfast, lunch, and dinner.

TABLE XIII. CONSUMPTION MODEL

Component	Formulation		Solution 1	Solution 2
	Portion	*Notation*	*Decoding 1*	*Decoding 2*
Vegetable Protein	3	a	2,50	1,30
Solution 1 = 3 x consumption for vegetable protein @2,50 servings Solution 2 = 3 x consumption for vegetable protein @1,30 servings				
Animal Protein	3	b	1,50	1,70
Solution 1 = 3 x consumption for animal protein @1,50 servings Solution 2 = 3 x consumption for animal protein @1,70 servings				
Carbohydrate	8	c	0,25	0,30
Solution 1 = 8 x consumption for carbohydrate @0,25 servings Solution 2 = 8 x consumption for carbohydrate @0,30 servings				
Vegetable	5	d	0,40	0,70
Solution 1 = 5 x consumption for vegetable @0,40 servings Solution 2 = 5 x consumption for vegetable @0,70 servings				
Fruit	5	e	0,80	1,50
Solution 1 = 5 x consumption for fruit @0,80 servings Solution 2 = 5 x consumption for fruit @1,50 servings				
Water	8	f	0,50	0,20
Solution 1 = 8 x consumption for water @0,50 servings Solution 2 = 8 x consumption for water @0,20 servings				

TABLE XIV. COMPOSITION MODEL

Consumption	Time & Portion (p)	Initialization	Mutation
3 x Vegetable Protein	Breakfast (1p) Lunch (1p) Dinner (1p)	36% Vegetable Protein	22% Vegetable Protein
3 x Animal Protein	Breakfast (1p) Lunch (1p) Dinner (1p)	21% Animal Protein	31% Animal Protein
8 x Carbohydrate	Breakfast (2p) Morning Snack (1p) Lunch (2p) Afternoon Snack (1p) 2 x Dinner (2p)	19% Carbohydrate	2% Carbohydrate
5 x Vegetable	Breakfast (1p) Morning Snack (1p) Lunch (1p) Afternoon Snack (1p) Dinner (1p)	6% Vegetable	18% Vegetable
5 x Fruit	Breakfast (1p) Morning Snack (1p) Lunch (1p) Afternoon Snack (1p) Dinner (1p)	11% Fruit	23% Fruit
8 x Water	Breakfast (2p) Morning Snack (1p) Lunch (2p) Afternoon Snack (1p) Dinner (2p)	7% Water	4% Water

Table 13 shows the application of solution 1 and solution 2 for consumption per day and Solution 1 and Solution 2 with 3 meals for daily consumption (morning, afternoon, and night) and mini-meal or snack consumption based on food consumption in Table 5.

Table 14 shows the composition and combination of daily food consumption. The consumption pattern is with 3-3-8-5-5-8 pattern (3 x consumption for vegetable protein, 3 x consumption for animal protein, 8 x consumption for carbohydrate, 5 x consumption for vegetables, 5 x consumption for fruit, and 8 x water consumption) based on food consumption in Table 5. The regular meal-times are breakfast, morning mini-meal or snack, lunch, afternoon mini-meal or snack, and dinner. This pattern applies to initialization (initial state) and mutation (final state). This pattern yields outputs, namely: Consumption Model, Food Model, and Composition Model.

5. CONCLUSION

Optimization using the Genetic Algorithm on Food Composition can be performed and can produce a combination with two solutions, namely optimal solution as a combination of food component that can meet daily food needs, consisting of the right menu, nutrition, time, composition with the computational process. In this computational process for the Genetic Algorithm, the mutation rate is 50%, the crossover rate is 5%, the maximum generate is 36, the maximum fitness point is 0.240806, and the population size is 6. This Genetic Algorithm used genotype 1 variables (integer), initialization (random value/random number), evaluation (objective function is converted to fitness point function), selection (roulette whee model), genetic operator (the real value of recombination), crossover (binary value of recombination), and mutation (real value). The optimal from this research implemented in the form of 3 models: the Consumption Model, the Food Model, and the Composition Model. The resulting model has a large impact on food composition patterns with an optimal composition of the main food in improving health and minimizing malnutrition in Indonesia. In future work, subsequent research will be optimization using Particle Swarm Optimization (PSO more stable for the result of the fitness) for alternative food compositions.

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