Optimization of Food Ingredients Composition for Outpatients with Heart Disease Using Cosine PSO

Imam Cholissodin, I Gusti Ayu Putri Diani, and Suprapto

***Abstract*—**One of the most important organs in the body is heart. Heart pumps blood around the body. Many people can suffer heart disease caused by unhealthy lifestyle. According to the report of the World Health Organization (WHO), deaths caused by cardiovascular disease around 17.7 million or approximately 45% deaths. Take care of food consumption is important in order to be healthy for people who suffered from heart disease. This research will be conducted on composing food ingredients for patients who suffered heart disease whose can continue their treatment in their home. Optimizing the composition of the food ingredients for heart disease outpatients in this research will be using particle swarm optimization algorithm which the results will be displayed in the program is data such as age, weight, height, along with recommended of food ingredients and minimum price of each food ingredients. This algorithm consists stages of initialize particles, calculating fitness value, define pbest and gbest value, calculating velocity and position of the particles. The results from this research, it is found that the nutritional needs of this program and actual patient's data have a difference as much 4.67%. And reduce the expenses as much 14.68% from patient's actual expenses per day.

***Keywords*—** cardiac diet, food ingredients, heart disease, optimization, outpatient heart disease, particle swarm optimization.

I. INTRODUCTION

HEART is an organ in the body that pumps blood. Heart pumps blood which brings a lot of oxygen and food to the rest of the human body including to the coronary arteries, and blood which carried less oxygen will be heading to the lungs to pick up oxygen [8]. Many types of heart disease, such as coronary artery disease, heart failure, and others. Heart disease is one of the diseases suffered by most people [1].

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According to reports in 2017 by World Health Organization (WHO), by 2015, an estimated 40 million deaths occurred due to Non-Communicable Diseases (NCDs), equivalent to 70% of the total number of 56 million deaths globally. Most of the deaths caused by NCDs, one of them is heart disease that cause17.7 million deaths or approximately 45% of all deaths from NCDs. For people suffering from heart disease, lifestyle and food consumption needs to be maintained seriously. The difficulty of regulating the food consumed by patients where food must meet nutritional needs without interfering and worsening the state of the heart.

Food given to the patients should be limited to recommended food ingredients, food ingredients which are not recommended and how to process it. The food given divided based on the level of severity of the disease where these categories are divided into 4 different types of diets as follows Cardiac Diet 1, 2, 3 and Cardiac Diet 4 [2]. This research will be conducted on giving of food ingredients for patients who suffered heart disease whose patients can continue their treatment at home but are still not allowed to eat certain foods and food eaten remain to be monitored. Cardiac Diet 4 is chosen due to the composition of food ingredients given to patients can vary.

At one of the hospitals, heart disease outpatients are only given the weight of food ingredients in 1 day with the frequency of eating 3 times (morning, day, and night). In order to get the food which suitable with the patient's condition, then patients must return to the hospital to perform an examination and recalculate the nutritional needs the patient's needed so it takes time and cost. This research made to facilitate the selection of food ingredients to suit the patient's needs and can generate a variety of food ingredients without return to the hospital to get a list of the weight of food ingredients.

Similar problem with the composition of food ingredients has been done before by using particle swarm optimization algorithm to optimizing the nutritional needs of the family [4], and using genetic algorithm to optimizing the cost for fulfillment of nutrition requirements [6] and also optimizing the cost and the fulfillment of nutrition requirements for elderly [9]. Other related works using particle swarm optimization algorithms have been used by Mickael Tuegeh for scheduling the electric power operating system in 2009.

This research will display the result of optimizing using particle swarm optimization such as a list of food ingredients and the prices of each ingredient based on a calculation of the patient's nutritional needs. The nutritional needs obtained from the patient's data such as age, weight, and height. The composition of the food ingredients is recommended that can vary as long as 11 days. Particle Swarm Optimization algorithms used in this research was first introduced by James Kennedy and Russell Eberhart in 1995. This algorithm inspired based on the behavior of social animals such as fish or a flock of birds that swim together and have many similarities with evolutionary computing such as genetic algorithms. The advantage of this algorithm is that particle swarm optimization algorithm calculation have simpler concept compared to other calculation techniques [11].

II. THEORETICAL BASIS

A. Heart Disease Diet

Heart disease diet is given to patients who are suffered from heart disease. There are 4 types of diet for heart disease which are Cardiac Diet 1 given to patients with acute heart disease who are in the stage of hospitalization, Cardiac Diet 2 given to patients who have been able to overcome the acute phase, Cardiac Diet 3 is a displacement from the Cardiac Diet 2 where the patient's condition not too heavy, and Cardiac Diet 4 given food for patients with mild conditions or patients who are undergoing Cardiac Diet 4 are heart disease outpatients. In this research, food composition optimization is given to patients with Cardiac Diet 4 or heart disease outpatients. Outpatients can consume food in the form of regular food, unlike Cardiac Diet 1 to Cardiac Diet 3 where the food consumptions still in the form of soft or liquid [2].

B. Nutritional Needs Calculations

Nutritional needs such as energy, carbohydrates, proteins, and fats obtained from the calculation of Ideal Body Weight (IBW) and calculation of basal value. The parameters used for the calculation of the nutritional needs are weight, height, age, and gender of the patient. Calculation for IBW:

$$IBW = (H - 100) \times 90\% \tag{1}$$

Explanation:
IBW : Ideal Body Weight
H : Height
Nutritional needs calculation:

$$Energy = Basal \times ActivityFactor \times StressFactor \tag{2}$$

Explanation:
Activity Factor : 1.3
Stress Factor : 1.1
The calculation for basal value is different for men and women and using weight in kilogram (kg). The following is the formula for calculation of basal values:

$$Men = 30kcal \times Weight \tag{3}$$

$$Women = 25kcal \times Weight \tag{4}$$

Fats, Proteins, and Carbohydrates calculations:

$$Fats = \frac{25\% \times Energy}{9} \tag{5}$$

$$Proteins = 0.8 \times IBW \tag{6}$$

$$Carbohydrates = \frac{(Energy - ((Fats \times 4) + (Proteins \times 9)))}{4} \tag{7}$$

C. Particle Swarm Optimization Algorithm

Particle swarm optimization algorithm categorized into swarm intelligence algorithms and this optimization technique based on the population that was originally developed by Kennedy and Eberhart in 1995. This is driven by the social behavior of a flock of birds or fish that swim together [10]. Particle swarm optimization included in metaheuristic algorithms and can be widely applied to solve many problems such as combinatorial problems. This algorithm initializes a random population of particles and finds the best position of the particle with the best fitness value [3][5]. Velocity vij and the position of the particle to xij by dimension j updated with Equation [12]:

$$v_{(i,j)}^{(t+1)} = \omega \times v_{(i,j)}^{(t)} + c1 \times rand1_{(i,j)} \times Pbest_{(i,j)}^{(t)} - x_{(i,j)}^{(t)} + c2 \times rand2_{(i,j)} \times Gbest_{(i,j)}^{(t)} - x_{(i,j)}^{(t)} \tag{8}$$

Explanation:
v_{ij} : Velocity from i particles by *j* dimension
ω : Inertia weight
c_i : Factors that control social & cognitive components
$rand_{ij}$: 2 random values between 0 to 1
Pbest : Position with the best fitness value on i particles
Gbest : Best *Pbest* value from all particle populations
t : Number of iterations

$$x_{(i,j)}^{(t+1)} = x_{(i,j)}^{(t)} + v_{(i,j)}^{(t+1)} \tag{9}$$

Explanation:
xij: Position of i particles

ω or inertia weights were introduced by Eberhart and Shi in 1998 and used to help balancing between local and global search and could be a good parameters control.

$$\omega = \omega max - \frac{(\omega max - \omega min)}{Itermax \times Iter} \tag{10}$$

Explanation:
$\omega_{max} - \omega_{min}$: Initial weight and final weight
Itermax : Number of maximum iterations
Iter : Number of current iterations

D. Cosine Particle Swarm

In Particle Swarm Optimization, the particles will gather into a point which is not yet to find the global optimum. Then, Clerc introduced the factor of K into this algorithm to get the best convergence value using Cosine. The formula of K in this Particle Swam Optimization is (Yonghe, et al. 2015):

$$K = \frac{\cos((\pi / G_{max}) \times T) + 2.5}{4} \quad (11)$$

Explanation:
G_{max} : The changing value of K
T : Number of iterations

Thus the formula of the update particle is:

$$v_{(i,j)}^{(t+1)} = K \times [\omega \times v_{(i,j)}^{(t)} + c1 \times rand1_{(i,j)} \times Pbest_{(i,j)}^{(t)} - x_{(i,j)}^{(t)} + c2 \times rand2_{(i,j)} \times Gbest_{(i,j)}^{(t)} - x_{(i,j)}^{(t)}] \quad (12)$$

E. Fitness Value

Fitness calculation used to evaluate the results of this research. The fitness value used to represent the quality and purpose of this research. The following is the calculation formula for fitness value:

$$Fitness = \frac{1}{Penalty + 1} + \frac{1}{Price} + Variations \quad (13)$$

Explanation:
Penalty: Value of nutritional that exceeds or less than the nutritional needs of the patient
Price: Total price on the food composition in a particle
Variations: Amount of variety of food in a particle

III. DESIGN AND IMPLEMENTATION

Design of this research use data lists of food ingredients, recommended portion sizes, price of each food ingredients and outpatient's whose suffered heart disease data. Initialize particles represented with random integers from 1 to 56. Then the numbers will be normalized into the index number of food ingredients list. Lists of food ingredients divided into 7 groups which are source of carbohydrates, source of animal protein, source of vegetarian protein, vegetables, fruits and sugar, milk, and oil/fat. The list contains the name of the food ingredients, household serving size (URT), nutrient contents each food ingredients such as calories, protein, fat, and carbohydrates. Particles representation can be seen in Table I.

TABLE I:
PARTICLES REPRESENTATION

Particles	Breakfast						
	C	A	V	VS	F	O	M
	1	2	3	4	5	6	7
X1	56	23	12	1	7	34	21

Explanation:
C : Source of carbohydrates
A : Source of animal protein
V : Source of vegetarian protein
VS : Vegetables
F : Fruits and sugar
O : Oil/fat
M : Milk

Recommended portion sizes are used to meet the nutritional needs of patient who are divided into several age groups according to the balanced nutritional guideline that will be multiplied by the size of the food weight according to the list of food ingredients to obtain the weight of the food ingredients that adjusts the nutritional needs according to the age of the patient. Stages of this research:

1) Data input are heart disease outpatient's data such as weight, height, age, and gender of the patient. For parameters used by PSO include ω_{max}, ω_{min}, c_1, c_2, the maximum iteration with variable name iterMax, the number of particles, number of the upper limit of random integers and number of days.
2) Initialize the random particle populations.
3) Looping as much as the maximum iteration.
4) Calculate the fitness value of each particle.
5) Update the velocity and position each particle.
6) Determine the value of the pbest and specify the best pbest value and set it as gbest.
7) Return to process of calculating the fitness value until the number of iterations reaches maximum.

IV. TESTING AND ANALYSIS

In this research, testing parameters did with 4 scenarios testing, i.e. testing based on the number of particles, testing based on the value of the ωmin and ωmax and testing based on a number of iterations.

A. Test Based on Number of Particles

A test based on the number of particles done in order to know the relationship of a number of particles with the fitness' value where the number of particles that are used in this test starts from 5 up to 50 with multiples of 5. The tests of each particle performed 10 times with the specified parameter i.e. ωmax value of 0.9, ωmin value of 0.4, c1 and c2 values of 2, the number of days are 11 days, the number of iterations of 50 and upper limit of random integers is 56. Fig. 1 presented the results of the test based on the number of particles.

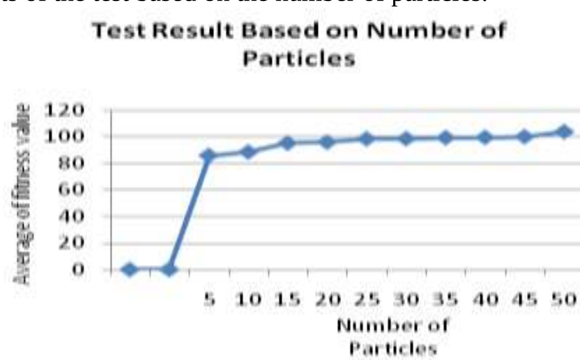

Fig. 1. Test Result Based on Number of Particles Graph

The conclusion of this test based on the number of particles is that the greater the number of particles then the better the fitness value. The number of particles affected the search for solutions in this program so that the more particles the more solutions are obtained and also the more varied the solutions. Fitness values tend to increase with great number of particles. But it is not possible that the fitness values using multiple particles will always have better value due to the initialization process which the particles being randomly initialized. The number of iterations also affected the optimization result. From the results of this test, the value of the number of particles can be taken as many as 40 because the average fitness value of 40 particles is not much different from 45 particles. And the time when running the program with the number of particles as many as 40 does not take too long unlike as many as 50 particles so the use of 40 particles are quite good.

B. Test Based on Number of Iterations

A test based on the number of iterations done in order to know the relationship of a number of iterations with the fitness' value where the number of iterations that are used in this test starts from 10 up to 100 with multiples of 10. The tests of each particle performed 10 times with the specified parameter i.e. number of particles are 40 particles, ωmax value of 0.9, ωmin value of 0.4, c1 and c2 values of 2, the number of days are 11 days and upper limit of random integers are 56. Fig. 2 presented the results of the test based on the number of iterations.

The conclusion of this test based on the number of iterations is that the greater the number of iterations then the better the fitness value. The number of iterations affected the search for solutions in this program to find a comprehensive solution. The more iterations were done then the search for a solution becomes more optimal because the particle position does not change much with the best solution value. The best fitness value obtained in the 100th iteration can be the optimal value as expected in this research because it has the best fitness value. The greater fitness value the better and the food ingredients more vary.

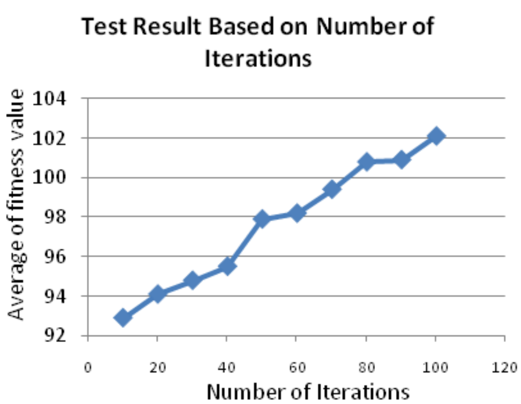

Fig. 2. Test Result Based on Number of Iterations Graph

Optimization result of this test also affected by initialization process which the particles initialized randomly, so that at the beginning of initialization process the position of the particle already good, then the searching process becomes less optimal and could reach the same value for next iteration. In this test, 80 iterations were taken because the fitness value in the 80th iteration fitness value is not too much different from the 90th iteration and 100th iterations where the average fitness value starting from the 80th iteration already good. The 80th iteration did not take a long time to run the program not as long as the 90th and 100th iteration.

C. Convergence Tests

Convergence tests are done know which value of the number of iterations had reached the maximum fitness value. In this test, using parameters that have been considered optimal based on the tests that have been done before. The parameters are the number of particles of 40 particles, the value of ωmax of 0.75, the value of ωmin of 0.25, the value of c1 and c2 of 2, the number of days as much as 11 days, the number of iterations of 1000 iterations and the upper limit value of random integers are 96. The result of this test presented in Fig. 3 below.

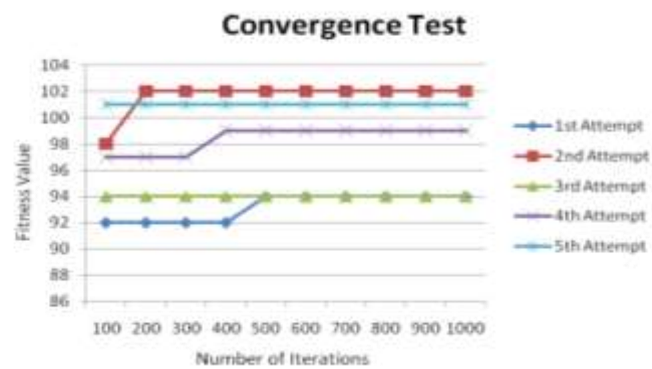

Fig. 3. Convergence Test Result

Based on the test results, obtained that the number of iterations value that produces the convergence value began at 500th iterations. The differences of fitness values caused by the random initialized at the beginning of the algorithm. This test took a long time to run the program, which average times of these attempts are approximately 1560 seconds or 26 minutes per attempt. The graph of the average time of this test can be seen in Fig. 4 below.

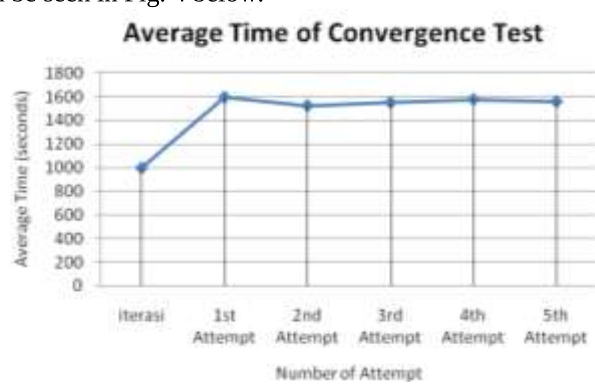

Fig. 4. Average Time of Convergence Test Graph

D. Global Analysis

Based on the results of the tests that had been done before, obtained parameters that have been considered optimal. The parameters that have been considered optimal will be tested to the outpatient cardiovascular disease data. The parameters used are the number of particles of 40 particles, the value of ωmax of 0.75, the value of ωmin of 0.25, the value of c1 and

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c2 of 2, the number of days as much as 11 days, the number of iterations of 80 iterations and the upper limit value of random integers are 96. Parameters that have been considered optimal will be used for global analysis testing which is comparing the results of the program using these parameters and patient's data. The data of a patient is obtained from interviews with an outpatient with heart disease. The global analysis of these tests is useful to see if the needs of the program can meet the needs of the patient. The data used the amount of food consumed from food sources such as carbohydrates sources, source of animal protein, source of vegetable protein, the amount of vegetables, the amount of fruits, oil/fat, milk and expenses in a day. An example of the solution of this research can be seen in Table II below.

TABLE II:
PART OF FOOD INGREDIENTS SOLUTION N-DAY

Day	Time	Name of Food Ingredients	Weight (kg)	Price per gr
1 ..	Morning (Breakfast)	Macaroni	65	1,378
		Beef	425	6,023
		Peanuts	9	216
		Pumpkin	80	1,160
		Kedondong	120	1,560
		Safflower Oil	6	330
	Snack	Yogurt Non-Fat	24	3,360
	Afternoon (Lunch)	..	..	..
	Snack	..	..	..
	Night (Dinner)	..	..	..
	Snack	..	..	..
..	..	..	..	..
N	..	..	..	..

The result showed that the patient consumed 3 carbohydrate source 3 times a day, source of animal protein 3 times, source of vegetable protein twice, the amount of vegetables 3 times, the amount of fruits 3 times, the oil/fat consumed 2 times, and consume milk once a day. The cost of this meal is around IDR 50,000. Data of the patient's actual nutritional needs with the results of the recommendation data from the program can be seen in Table III.

TABLE III:
NUTRITIONAL NEEDS OF PATIENTS AND NUTRITIONAL NEEDS OF THE PROGRAM

	Energy (kcal)	Carbohydrates (gr)	Proteins (gr)	Fats (gr)
Patient's Data	2230,8	371,4	46,8	61,96
Program's Output	2236,1	347.2	71,9	56,6
Result Difference	5,3	-24,3	25,1	-5,36

Based on Table III above, obtained that the energy difference between the patient's data with the result of the program is 5.3 or 0.24%. Carbohydrates difference of -24.3 or -7.0%. Proteins difference of 25.1 or 34.9%. Fats difference of -5.36 or -9.48%. Then meal costs difference by IDR 6.401 or about -14.68% of the patient's actual expenses of approximately IDR 50.000. The average difference between the nutritional needs of the patient and the recommendation from the program is 0.1833 or 4.67%. Results of the program can still meet the nutritional needs required. Table IV below showed the differences between patient's data, PSO and Improved PSO result.

TABLE IV:
NUTRITIONAL NEEDS OF PATIENTS AND NUTRITIONAL NEEDS OF THE PROGRAM USING PSO AND IMPROVED PSO

	Energy (kcal)	Carbohydrates (gr)	Proteins (gr)	Fats (gr)
Patient's Data	2230.8	371.4	46.8	61.69
PSO	2236.1	347.2	71.9	56.6
Improved PSO	2237.5	371.0	73.0	45.0

The result of the Improved PSO doesn't show much difference with the result of PSO. Some of the nutritional needs cover the needs of the patient's and some don't. PSO can reduce expenses up to IDR 6.401 while Improved PSO result up to IDR 30.282. Improved PSO showed that the compositions of the food ingredients are more affordable. But the nutritional needs don't mean more acceptable that PSO result. Table 5 below showed the differences between PSO result and Improved PSO result in percentage

TABLE V:
PERCENTAGE DIFFERENCES BETWEEN PSO AND IMPROVED PSO RESULT

	Energy (kcal)	Carbohydrates (gr)	Proteins (gr)	Fats (gr)
PSO	5.3 (0.24%)	-24.3 (-7.00%)	25.1 (34.91%)	-5.36 (-9.48%)
Improved PSO	6.7 (0.30%)	-0.475 (-0.13%)	26.2 (35.89%)	-16.69 (-37.09%)
Result Difference	0.06%	6.87%	0.98%	27.61%

The result both of the algorithm doesn't show any much difference of the nutritional needs except fats. The result from Improved PSO showed that fats don't cover the patient's need as much as 37.09% while result from PSO showed the lack of fats as much as 9.48%. This means that the Improved PSO doesn't always have an optimal solution for this problem. Both of the algorithms have advantages and disadvantages for this problem while Improved PSO result reduced IDR 30.282 from patient's expenses IDR 50.000, PSO result has more acceptable nutritional needs

V.CONCLUSION AND FUTURE WORKS

A. Conclusion

Conclusions from this research as follows:

a. Initialization process of the particle swarm optimization algorithm of this research used random integer numbers from 1 to 56.Then the random numbers will be calculated into the index value of food ingredients. The process of calculating the fitness value, it takes the value of the nutritional content difference with the name of the variable is a penalty, the price of each food ingredients and the amount of variation. After doing the test scenarios, it can be concluded that the suitable particle swarm optimization parameters for this research are 40 particles, the value of ωmax is 0.75, the value of ωmin is 0.25, c1 value of 2, c2 value of 2 and number of iterations of 80 iterations.

b. The result of this research where the parameter used is the number of particles is 40 particles, the value of ωmax is 0.75, the value of ωmin is 0.25, the value of c1 is 2, the value of c2 is 2 and the number of iterations is 80 iterations. Solutions generated based on penalty value, price, and variations of food ingredients. The smaller the value of penalty and the total price of food ingredients in a particle then the greater the variety of food in 11 days, then the better the solution and meet the standards of experts. The results of the recommendation of the program obtained from the division of eating with the frequency as many as 3 times a day.

B. Future Works

a. This research using constant parameter values of c1 and c2 values, therefore for further research can do the test based on the value of c1 and c2 in order to achieve a more optimal solution and produce better results.

b. This research generates only recommendation results for outpatient with heart disease. For further research to be able to generate recommendation results for heart disease with Cardiac Diet 1 to 3 or food ingredients composition for a family with one family member who has heart disease.

c. The recommendation of this program only in the form of food ingredients compositions, for further research can be made into the food menu so that the user can easily determine the food menu with the needs of the users.

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