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Optimization of Food Composition for Hypertensive Patient using Variable Neighborhood Search

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Abstract

Hypertension is a major symptom that cause other diseases appear such as non-communicable diseases, cancer, and diabetes if the nutrients on hypertensive patients not controlled from the actual nutrition need. One of healthy life effort for the patients is consuming healthy food that considers level of salt in the foods. The problem to determine the food composition that considers level of salt and minimum cost of the food is solved using Variable Neighborhood Search. This study compares 3 neighborhood structures: insertion, exchange, and 2-opt. The use of 2-opt neighborhood structure gives the highest fitness averages of other neighborhood structure. Selection and arrangement of neighborhood structure in every k neighborhood have effect on the solution is obtained. The result of this study contains composition of foods with nutrients which are close to the needs of hypertension patients with attentions the sodium and minimal cost within a day.

Keywords*: variable neighborhood search, optimization, food composition, hypertension*

1. Introduction

High blood pressure or hypertension is caused by high systole or diastole blood pressure increase in body, there is if systole blood pressure more than equal to 140 mmHg and diastole blood pressure more than equal to 90 mmHg [1]. Moreover, high blood pressure is metabolic factor that causing various non-communicable diseases appeared in Southeast Asia such as cardiovascular, cancer, respiratory disease, and diabetes [2].

In Indonesia, the main cause of death was communicable disease in 1995, but in 2007 the main cause of death was non-communicable disease. Hypertension includes type of non-communicable disease. Indonesia have the highest hypertensive patients in adults after Myanmar within the scope of Southeast Asia [2]. The example area in Indonesia whose many hypertensive patients were Malang and Klaten. Around 58,046 cases of hypertensive patients was happened in Malang [3]. The same thing was happened in Klaten, hypertension was the highest of patients between other non-communicable diseases, is about 42,375 people of essential hypertension and 17,204 people of other type's hypertension between other non-communicable diseases [4].

The consumption of much salt, alcohol, obesity, lack of sports that accumulates with age factor increase blood pressure [5]. Therefore, treatment of hypertensive patient can be done with more physical activities and consumption healthy foods that contain low of salt [6]. Moreover, the lack of knowledge about nutrition need in hypertensive patient is also a factor that causing high blood pressure.

Food composition for hypertensive patient can be done manually or by using software. The manual way in preparation of food composition is more difficult to do because the number of calories in food composition should be close to needs nutrition of the patient. While the preparation food composition with the software can be done easier with optimization that searching the food composition which is more close to the needs nutrition of hypertensive patient.

The previous researchs on optimization were done. One of them was done by [7]. Their research is optimization food composition on hypertensive patient using linear programming. However, the use of complex mathematic model with many constraints as problem in this paper

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may require high computational time [8-9]. The problem can be solved by using meta-heuristic method.

The use of meta-heuristic method on cost optimization was done by using genetic algorithm. The previous researchs were [10] and [11]. The [10] research about cost optimization in feed mixture for poultry and cattle. The proposed approch is compared with linear programming to measures the performance and show that GA give lower cost than linear programming. While the [11] approach give feasible solution of animal diet formulation in all runs. The use of genetic algorithm on the several research of food composition optimization had been implement and give optimal result. But the other side, genetic algorithm have several parameters so it needs more time for decides optimal parameter value that will give optimal result such as population number, generation number and combination of crossover rate and mutation rate.

Other meta-heuristic method with lower parameter number is Variable neighborhood Search (VNS). VNS includes simple method because it have two parameters, there are neighborhood numbers and termination condition [12]. VNS have several steps, there are shaking, local search, and improvement. VNS had succesfully solved various problems such as scheduling problem [13], [14], optimization of high-performance concrete structures [15], and Flexible Manufacturing System problem [12].

Based on the importance of optimization of food composition for hypertensive patients and simple VNS that can solve some problems, then in this study the authors pro

2. Variable Neighborhood Search

A simple and effective meta-heuristic method can be obtained through change processing systematically in local search. In 1997, Hansen and Mladenovic proposed Variable Neighborhood Search based on meta-heuristic method. VNS exploring neighborhood from the incumbent solution. Most of the solution in optimal value will be saved and be used to getting promising neighborhood solution [16]. The steps of VNS firstly initialization neighborhood and solution and then shaking, local search and move or not [17]. VNS iterates local search technique when local search exploring search space from new starting point which is decided with neighborhood structure in every iteration. The neighborhood structure for giving solution candidate with changing initial solution or updated solution [12]. The solution that have been changed will be used as solution candidate if only there has been an improvement better solution [18]. The steps are used on VNS most of them using iterates until getting promising termination condition. The big Kmax value will give better solution furthermore it needs high time computation [12].

3. Research Method

Optimization of food composition on this study implements Variable Neighborhood Search algorithm. The steps are used on food composition problem solving is shown by flowchart Figure 1.

The data are used on this study includes secondary data, there are:

a. 103 food data with its nutrition are obtained from Nutri Survey Software.
b. The hypertensive patient data with age more than 18 years old.

The first step on solving problem is calculating energy and nutrition on hypertensive patient, and then searching process of food composition solution using VNS. Food composition are represented by integer number which will be coded as food index in food data. The representation of food composition is shown on Table 1.

Table 1. Representation of Solution

Type of menu	Breakfast	Lunch	Dinner
PK	3	1	2
S	1	3	10
N	2	12	11
H	16	6	3
B	16	18	26

The steps of VNS algorithm are shown by Figure 2.

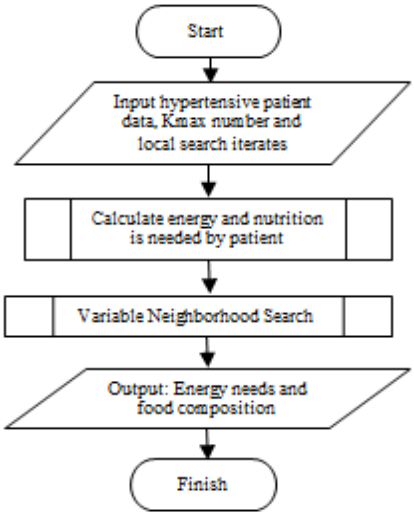

Figure 1. System flowchart

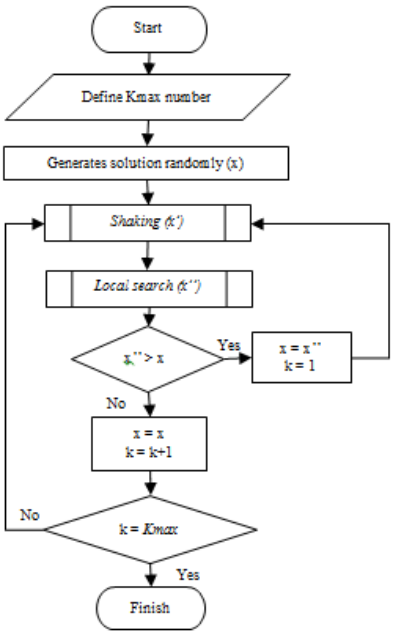

Figure 2. VNS flowchart

Based on Figure 2, the steps of VNS algorithm on solving problem in this study, there are:

a. Generates solution randomly (x) and define k=1.
b. Repeat the following steps until k=Kmax:
    1) Shaking stage

The solution on shaking is obtained with changing neighborhood structure. The neighborhood structures are used in this study are insertion, 2-opt and exchange. Each type of neighborhood structure has different change mechanisms. Operation of insertion is delete index position randomly then re-insert to another position [19]. The insertion mechanism is shown in Figure 3.

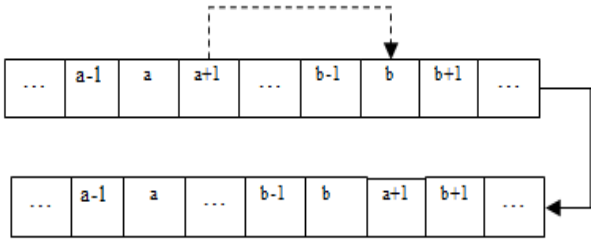

Figure 3. Insertion

The mecanism of the 2-opt is select two positions and then to be reversed mutually [19]. The 2-opt mechanism is shown in Figure 4.

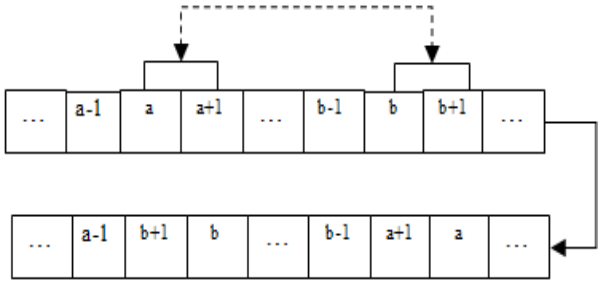

Figure 4. 2-Opt

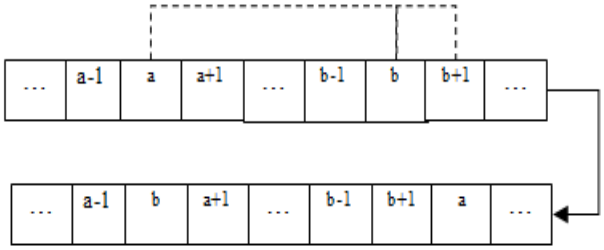

Figure 5. Exchange (example k=3)

2) Local search stage

This stage uses solution from shaking stage as initial solution. The changing of x value is in the range around of x value with changing 1 value. On the local search happens comparison between fitness solution on the previous iteration and the fitness solution in each iterates to look for better solution. The example of local search mechanism is shown by Table 2 and Table 3.

Table 2. Solution before Local Search

Type of menu	Breakfast	Lunch	Dinner
PK	3	20	13
S	1	3	10
N	2	12	11
H	16	6	3
B	16	18	22

Table 3. Solution after Local Search

Type of menu	Breakfast	Lunch	Dinner
PK	3	20	13
S	1	3	10
N	2	12	11
H	16	6	3
B	16	18	21

3) Move or Not stage

The mechanism of this stage is compares fitness value between fitness of initial solution with fitness of local search solution. If the fitness of initial solution is better than fitness of local search then initial solution will be used in next solution searching and change k=k+1. Otherwise, change k=1 and define local search solution as initial solution.

The quality of solution is represented from its fitness. The greater solution will result better solution. The fitness is used in this research as follows:

$$Fitness = \frac{10000}{(penalty\ total * criteria\ value) + cost}$$

Penalty total is addition of penalty value each constraint. There are calorie, carbohydrate, fat, protein, and sodium constraints.The criteria value for avoiding the results of a solution that only pay attention the low cost without attention the quality of nutrition is obtained. While the total cost l is the addition of all food prices on every solution.

To verify the quality of solutiond produced using VNS, we implement a random search method that produce baseline solutions.

4. Results and Analysis

The purpose of Kmax number and local search iteration number testing is to find the relationship of Kmax number and local search iteration number in every neighborhood structures. The neighborhood structures are used on this study, there are exchange, insertion and 2-opt.

4.1. Kmax Number

Scenario on the Kmax testing use one of the hypertensive patient data as input on the system and kmax number is 1 until 15. The result of kmax testing on the every neighborhood structures as shown on the Figure 6.

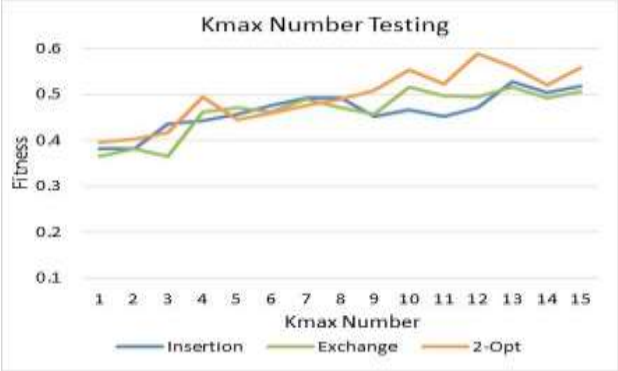

Figure 6. Kmax number testing

The graph of Figure 6 shows that the highest fitness average in the use of kmax number 13 on exchange and insertion neighborhood structure. While the use of 2-opt neighborhood structure give average of the highest fitness with kmax number 12.

The test result in Figure 6 shows that the average of fitness value tends to increase although at some point it has decreased the average of fitness value on several neighborhood structures. The decrease at a particular point in the graph of Figure 6 is caused because the initial solution used varies based on random numbers between the experiments with each other so that the solution results and the fitness values in each experiment vary. But in general the greater the Kmax value will produce better results because it allows VNS to search for a solution in the larger search space [12] Another factor that influences the results during the search is the opportunity of change the best solution of each neighborhood K at the Move or Not stage. That is ensures that the best solution is traced on each neighborhood k until the neighborhood k=Kmax and the previous best solution will be saved and will be use in next neighborhood if the lower fitness is obtained in that neighborhood.

The behaviour of exchange neighborhood structures changes more in the solution in the larger number of neighborhood areas because the solution changes depend on the large number of neighborhoor. While the behaviour of insertion neighborhood structures performs a permanent pattern of change by selecting one index from the solution then moving to the other index of the designated solution so that the number of neighborhood does not affect the pattern of change in insertion neighborhood structures. While the 2-Opt neighborhood structure changes with a fixed pattern of change in each neighborhood, choosing two parts of position and then exchanging each others [19]. The change of solution more dynamic are made with 2-Opt patterns than other neighborhood structures such as exchange and insertion because it more changed from the initial solution. However, the change of 2-Opt can give result better fitness value but the other side, it can give too fitness value that is no better than the initial solution.

4.2. Local Search Iteration

The result of local search iteration testing on the fitness value with exchange neighborhood structure shows that the fitness value has increased but decreased in the several

iterations. The graph shows that the highest fitness average in the use of iteration 2000 is 0.524301 with the average change of fitness value is small. While the highest average fitness on insertion neighborhood structure is the use of 1000 iterations with an average fitness is 0.529034. And the use of 2-opt neighborhood structure give average of the highest fitness is 0,567881 with local search iteration 2000.

The test results show that more local search iterations do not guarantee the better fitness value is obtained (in different experiment), but it more provide greater opportunities for finding the best solution which depends on changing the solution of the best solution in previous local search iteration with the change of fitness not too big. However, in one experiment local search iterations provide solutions increasingly with greater fitness value because the best solution in each iteration is always selected for the initial solution at the next iteration with longer computational time. Moreover, more local search iteration number of search gives more opportunity toward fitness selection from local search searching.

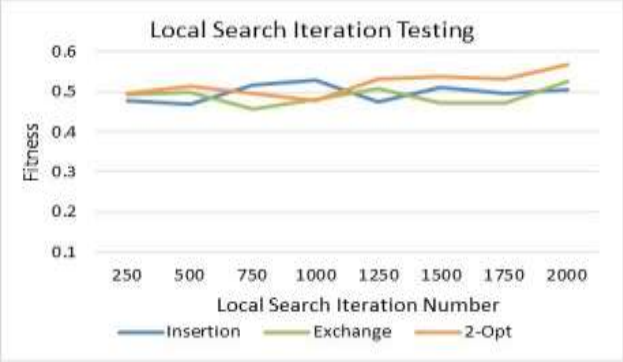

Figure 7. Local search iteration testing

4.3 System Result

Table 4 shows the results given by the system by using parameters that produce the best fitness value based on testing of kmax number and local search iteration that consists of kmax number=12 and local search iteration=2000 with using 2-Opt neighborhood structure. That parameters are used to test the results of the system toward 3 cases of hypertensive patients. The system result should meet nutritional need with maximum 10% tolerance difference from the nutritional needs of the patient.

Table 4. The Result Using VNS

Case	Difference (%)				Sodium (gram)
	Calorie	Carbohydrate	Fat	Protein	
1	0,0065934	5,9989257	4,4448224	1,5523052	0,3702
2	0,0956743	0,98240741	6,35114433	5,0709223	0,31969
3	0,271251	6,27235	7,272371	6,007748	0,1762

The result of food composition using VNS on Table 4 is also compared with Random Search using the same cases. The result using Random Search is shown by Table 5.

Table 5. The Result Using Random Search

Case	Difference (%)				Sodium (gram)
	Calorie	Carbohydrate	Fat	Protein	
1	26.40636662	25.1299791	33.64247	59.9714	0.1977
2	63.32371431	49.91290573	83.73673	156.88888	0.2954
3	8.364507672	21.81356	29.72028	38.13220	0.2859

The result of food composition using Random Search mostly exceed tolerance limit from the patient's nutritional needs. This verify that the result using VNS is better than the result using Random Search because can fulfill patient's nutritional needs with no more than 10% tolerance limit.

Overall from the Table 4 explain analysis of outcomes performed on 3 cases with different hypertensive patients data concluded that the recommendation of the system was successful in providing a combination of low-sodium foods that did not exceed the maximum limit of sodium consumption in patients. Nutritional compliance from system result to fulfill requirement of calorie, carbohydrate, fat and protein still within tolerance limit±10% which allowed in nutrition preparation with difference not too big with requirement of nutrition of patient. However, nutritional intake results of the system does not always produce recommendations that match the nutritional needs of patients. This is because the criterion value on each nutrient's penalty and the amount of the price variable affects the fitness value obtained. But generally, the results of the system provide the total nutrient that is still within the tolerance limit of±10% that allowed in the preparation of nutrition so it concluded the results of the system can meet the nutritional needs of patients with hypertension optimally.

5. Conclusion

In this study, food composition with considers level of salt and minimum cost for hypertensive patient are obtained so food composition from the system give tolerance limit±10% which allowed in nutrition preparation with fill requirement of nutrition of patient.

Based on the results of the Kmax and the local search iteration test indicate that the best fitness value is obtained by using 2-opt neighborhood structure with kmax number=12 and local search iteration=2000. However this does not always guarantee that the use of 2-opt always provide the best solution.There are several factors that influence the resulting solution such as the use of neighborhood structures and the arrangement of neighborhood structures in each k^{th} neighborhood. The use of neighborhood structures affects the solution changes that enable better solution but it is also possible to produce solution changes that are no better than solutions before the change.

VNS has been effectively applied in some studies includes in this study but VNS is less efficient in terms of exploration. To improve the performance of VNS this can be combined with other algorithms such as genetic algorithm [20]. Although genetic algorithms also have shortcomings such as local optimal solutions, lower convergence speed [21] but incorporating the two algorithms in several studies are able to produce solutions that outperforms because genetic algorithms have advantages in exploration in huge search space while VNS has an advantage on exploitation in local search areas [22].

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