Optimization of elderly nutrition needs using PSO algorithm: A case study at POSBINDU PTM Sejahtera

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Abstract. POSBINDU PTM Sejahtera is a health post that aims to increase awareness of the elderly in preventing non-communicable diseases. According to Departemen Kesehatan, this disease can be caused by food consumption. The food consumed must include vegetables and fruit to enhance the concept of active aging. However, these recommendations are not comparable with the POSBINDU PTM screening data. Screening data mentioned that only 3.5% of 73 elderly people consume vegetables and fruit three times a day. Factors that inhibit the elderly in consuming healthy food are the officers only giving food abstinence advice and expensive food staples. The problem of this optimization model can be solved by the artificial intelligence algorithm, Particle Swarm Optimization (PSO). The results of this study, PSO can provide varied food recommendations at a minimal price (optimization model). The calorie and carbohydrate content gets a value of $<10\%$ of the nutritional needs of the elderly, while the protein and fat content produce a greater difference of $>10\%$. The average price of foodstuffs produced by the PSO algorithm is Rp.50,965.

1. Introduction
POSBINDU PTM Sejahtera is a health post that is managed by the surrounding community to increase community participation in early detection and prevention of the risk of non-communicable diseases (PTM). Prevention of non-communicable diseases can be done by taking into account the nutritional needs of the composition of food consumed. Consumption of vegetables and fruits 3 times a day can prevent non-communicable diseases because it has rich nutrients in them such as fat, protein, and carbohydrates. However, this is not in line with POSBINDU PTM Sejahtera screening data which says 73 elderly patients consume fewer vegetables or fruit 3 times a day. Lack of information about food composition recommendations from POSBINDU PTM Sejahtera staff is one of the factors that patients experience saturation in consuming food.

Besides the saturation factor, the expensive food factor becomes an obstacle for the elderly in their consumption. Meanwhile, the food consumed must have a variety of food ingredients from a combination of vegetables and fruit. This is one of the efforts of the concept of active aging in improving the quality of healthy life with age. In increasing the nutritional needs of the elderly by taking into account their economic conditions, an optimization model that has a component of decision variables, goals and obstacles is needed to achieve optimal results. The solution to overcome the problems of this optimization model can use the theory of evolution (evolutionary computation) which assumes that the results of each evolution will produce optimal values [1].
Swarm intelligence is the result of the theory of evolution, some of the algorithms include Ant Colony, Bee Colony and Particle Swarm Optimization (PSO) [2]. In its application, PSO starts with a population consisting of several particles and is generated randomly. Randomly generated particles then search for optimum solutions through individual repetition/improvement in several iterations [3]. Each particle position is associated with a fitness value that is calculated based on optimization problems, this fitness value will be evaluated until it finds the best value and is stored by each particle that iterates [4]. There are considerable factors to achieve fitness value such as nutritional needs, a variety of food, and minimum food prices. This condition will always repeat until the stop condition is reached. PSO has a low computational time in the search for convergence points and is flexible in maintaining a balance between global and local search (individual particles) to the scope of the search [5]. PSO has parameters for learning (learning factor) individual particles (C1) and swarm (C2) in selecting optimal results.

In accordance with the problems above, it is hoped that the PSO method can optimize the nutritional needs of the elderly from food composition at a minimum cost.

2. Methods

Figure 1 shows the proposed method, consisting of analysis of nutritional needs, population initialization, update velocity, update position and calculate fitness, update pbest and gbest, stopping criteria and recommendation result.

2.1. Analysis of nutritional needs

There are two supporting data in the stages of analyzing the nutritional needs of the elderly, namely food material and elderly data. Food material data was obtained from various sources such as the health department and internet sources. Meanwhile, Posbindu PTM Sejahtera data was obtained from interviews with Posbindu staff. This data is called screening data which records the nutritional needs of the elderly, for example height, weight, activity, age, and gender. To calculate the nutritional needs of the elderly with their activity factors, this study uses the Harris Benedict formula which is often used in calculating individual nutrition [6].

2.2. Population initialization

The population initialization is the first step in the PSO algorithm, by entering the initial speed, position and fitness values. At first the particles are generated randomly at a speed of 0. After that, the fitness value is calculated according to this optimization problem with the following formula:

\[
fitness = \frac{1}{NutritionalPenalty} \times const_1 + \frac{1}{TotalPrice} \times const_2 + variation
\]  

(1)
Nutrition penalty is obtained from the difference between the nutritional requirements with the nutritional content obtained by the particles. The value of variation is obtained from whether or not the food is obtained in 1 day, where if in one day there is the same food on the same type of food it will be 0 and if it is not the same then it is 1 [7].

The fitness value obtained by the particle in the initial iteration will be the reference particle in the next iteration in finding the best position. The best value of each iteration is called pbest and the best value of all iterations is called gbest.

2.3. Update velocity
Next iteration, the particle will update the velocity that was previously worth 0. Previous particles that get better value than other particles with a velocity of 0, will be a reference to other particles in updating the velocity. Here is the formula for updating velocity [8]:

\[ V_{j}^{k+1} = W V_{j}^{k} + C_{1} \text{rand}_{1} \times (P\text{best}_{j} - X_{j}^{k}) + C_{2} \text{rand}_{2} \times (G\text{best}_{j} - X_{j}^{k}) \]  

(2)

2.4. Update position and calculate fitness
After the velocity has been updated, the particle's position moves. Here is the formula for updating position [9]:

\[ X_{j}^{k+1} = X_{j}^{k} + V_{j}^{k+1} \]  

(3)

After the particles get a new position, the best fitness value is again calculated using the same formula in equation 1. After getting the best fitness value in each iteration, then updated again pbest and gbest. Step B-D will always repeat until it reaches a stop condition that is maximum iteration. The value is said to be optimal if the difference between nutritional penalties produced is small, varied food and minimal expenditure. The output is to produce recommendations for the composition of food for the elderly for 7 days with three meals at breakfast, lunch and dinner.

3. Results and discussion
The experiment was carried out 10 times with different elderly nutritional needs. PSO parameters were tested such as the number of particles, iteration, c1-c2, wmax and wmin. The tested particles were 25 particles with 10 times iteration, C1-C2 was 1.5 [10] and wmax = 0.6 and wmin = 0.4. Here is one example from Baharudin, 50 years old, height 154 cm, and weight 68 kg.

| No. | Name    | Gender | Height | Weight | Age | Activity         |
|-----|---------|--------|--------|--------|-----|------------------|
| 1   | Baharudin | Male   | 158    | 64     | 50  | Very Rarely Exercise |

The data obtained in table 1 will be calculated the total energy expenditure (TEE) using the harris benedict formula. The TEE obtained will be reduced by 10% calorie restriction for the elderly. Then the results of the total energy will be calculated nutritional needs such as carbohydrates, protein and fat. The total calories obtained, 65% is the need for carbohydrates, 15% of the protein needs, and 20% of the fat needs. The percentage results are converted into units of grams, where carbohydrates are divided by 4, proteins are divided by 4, and fat is divided by 9.

| No. | Name    | BEE   | TEE     | Calorie Restriction | Carbohydrate | Protein | Fat   |
|-----|---------|-------|---------|---------------------|--------------|---------|-------|
| 1   | Baharudin | 1399.7 | 1679.64 | 1511.67             | 245.64       | 56.68   | 33.59 |
In the next step, PSO generates random particles with an initial velocity $= 0$. PSO parameters used include particles $= 2$, iteration $= 2$, $C1 - C2 = 1.5$, $w_{min} = 0.4$, $w_{max} = 0.6$.

**Table 3.** Dimension values.

| Particle | Dimension |
|----------|-----------|
| X1       | X2        |
| MP 6     | 0         |
| PN 4     | 20        |
| S 8      | 10        |
| PH 4     | 10        |
| PL 5     | 22        |
|          | 20        |
|          | 18        |
|          | 10        |

The dimension values in the table above represent food ingredients in the food type database. For example: MP (6) in particle X1 is a Makanan Pokok table with the 6th index. The food chosen also holds the nutritional content and price of the food, as follows:

**Table 4.** Food material and prices.

| Index | Type of Food | Food Name  | Energy (kkal) | Carbohydrate (gr) | Protein (gr) | Fat (gr) | Price (Rp.) |
|-------|--------------|------------|---------------|-------------------|--------------|----------|-------------|
|       |              | Breakfast  |               |                   |              |          |             |
| 1     | MP (6)       | Biscuits   | 30            | 140.4             | 18.7         | 31.5     | 5000        |
| 2     | PN (4)       | Red Beans  | 167.5         | 30.1              | 11.5         | 0.6      | 700         |
| 3     | S (8)        | Cucumber   | 25.8          | 5.6               | 1.4          | 0.2      | 4000        |
| 4     | PH (4)       | Squid      | 117.6         | 4                 | 20          | 1.8      | 3000        |
| 5     | PL (5)       | Ginger     | 98.9          | 23                | 3.1          | 0.5      | 1000        |
|       |              | Lunch      |               |                   |              |          |             |
| 6     | MP (3)       | Nasi Uduk  | 212.5         | 42.3              | 3.8          | 2.7      | 5000        |
| 7     | PN (6)       | Winged Beans | 174.5      | 12.7             | 15.4         | 8.4      | 2200        |
| 8     | S (0)        | Spinach    | 74.1          | 14.6              | 7.4          | 0.4      | 1500        |
| 9     | PH (2)       | Duck       | 269.6         | 0                 | 15.2         | 22.7     | 8000        |
| 10    | PL (9)       | Lime       | 37            | 14                | 17           | 0.5      | 2000        |
|       |              | Dinner     |               |                   |              |          |             |
| 11    | MP (1)       | Corn       | 120           | 5.5               | 2.5          | 0.4      | 6000        |
| 12    | PN (2)       | Tahu       | 38            | 0.9               | 4.1          | 2.5      | 1000        |
| 13    | S (4)        | Cassava Leaf | 74.1        | 14.6             | 7.4          | 0.4      | 4500        |
| 14    | PH (4)       | Squid      | 117.6         | 4                 | 20           | 1.8      | 3000        |
| 15    | PL (7)       | Pomelo     | 43.4          | 14                | 17           | 0.5      | 5000        |
|       |              | Total      | 1600.6        | 325.7             | 164.7        | 74.9     | 51900       |

Then the nutritional penalty is calculated from the food obtained by the particles:

$$PG = |1511.67 - 1600.6| + |245.6 - 325.7| + |56.6 - 164.7| + |41.9 - 74.9|$$

$$PG = 78.63 + 80.1 + 105.1 + 33.1 = 309.93$$

After that the calculated value of variation obtained by particles:
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Table 5. Variation values.

| No. | Mealtime | Type of Food | Food Name    | Variation |
|-----|----------|--------------|--------------|-----------|
| 1   |          | MP (6)       | Biscuits     | 1         |
| 2   |          | PN (4)       | Red Beans    | 1         |
| 3   | Breakfast| S (8)        | Cucumber     | 1         |
| 4   |          | PH (4)       | Squid        | 0         |
| 5   |          | PL (5)       | Ginger       | 1         |
| 6   |          | MP (3)       | Nasi Uduk    | 1         |
| 7   |          | PN (6)       | Winged Beans | 1         |
| 8   | Lunch    | S (0)        | Spinach      | 1         |
| 9   |          | PH (2)       | Duck         | 1         |
| 10  |          | PL (9)       | Lime         | 1         |
| 11  |          | MP (1)       | Corn         | 1         |
| 12  |          | PN (2)       | Tahu         | 1         |
| 13  | Dinner   | S (4)        | Cassava Leaf | 1         |
| 14  |          | PH (4)       | Squid        | 0         |
| 15  |          | PL (7)       | Pomelo       | 1         |

Variation Total: 13

After the nutritional penalty, the total price and variation values are obtained, then calculate the fitness as follows:

\[ f_{\text{fitness}} = \frac{1}{309.93} \times 100000 + \frac{1}{51900} \times 1000000 + 13 = 354.92 \]

The results obtained from particle X1 in the 0th iteration get a fitness value: 369.92, and to count the X2 particles the same process is carried out. Particle X2 gets fitness value: 145.36, where the value is smaller than X1, so X1 is Pbest and Gbest. X2 which gets a small value in the previous iteration, the velocity and position will be updated with reference to the 0th iteration gbest on particle X1.

X2 particles, which get a value smaller than X1, are updated as follows:

\[
V^1_{MP} = 0.55 \times 0 + 1.5 \times 0.9706 \times (0 - 0) + 1.5 \times 0.374 \times (6 - 0) = 3.36
\]
\[
V^1_{PN} = 0.55 \times 0 + 1.5 \times 0.9706 \times (20 - 20) + 1.5 \times 0.374 \times (4 - 6) = -1.12
\]
\[
V^1_S = 0.55 \times 0 + 1.5 \times 0.9706 \times (1 - 1) + 1.5 \times 0.374 \times (8 - 1) = 3.92
\]
\[
V^1_{PH} = 0.55 \times 0 + 1.5 \times 0.9706 \times (10 - 10) + 1.5 \times 0.374 \times (4 - 10) = -3.36
\]
\[
V^1_{PL} = 0.55 \times 0 + 1.5 \times 0.9706 \times (10 - 10) + 1.5 \times 0.374 \times (5 - 10) = -2.80
\]
\[
V^1_M = 0.55 \times 0 + 1.5 \times 0.9706 \times (10 - 10) + 1.5 \times 0.374 \times (3 - 10) = -3.92
\]
\[
V^1_N = 0.55 \times 0 + 1.5 \times 0.9706 \times (22 - 22) + 1.5 \times 0.374 \times (6 - 22) = -8.97
\]
\[
V^1_S = 0.55 \times 0 + 1.5 \times 0.9706 \times (20 - 20) + 1.5 \times 0.374 \times (0 - 20) = -11.2
\]
\[
V^1_{PH} = 0.55 \times 0 + 1.5 \times 0.9706 \times (18 - 18) + 1.5 \times 0.374 \times (2 - 18) = -8.97
\]
\[
V^1_{PL} = 0.55 \times 0 + 1.5 \times 0.9706 \times (10 - 10) + 1.5 \times 0.374 \times (9 - 10) = -0.56
\]
\[
V^1_M = 0.55 \times 0 + 1.5 \times 0.9706 \times (0 - 0) + 1.5 \times 0.374 \times (1 - 0) = 0.56
\]
\[
V^1_N = 0.55 \times 0 + 1.5 \times 0.9706 \times (5 - 5) + 1.5 \times 0.374 \times (2 - 5) = -1.68
\]
\[
V^1_S = 0.55 \times 0 + 1.5 \times 0.9706 \times (1 - 1) + 1.5 \times 0.374 \times (4 - 1) = 1.68
\]
\[
V^1_{PH} = 0.55 \times 0 + 1.5 \times 0.9706 \times (18 - 18) + 1.5 \times 0.374 \times (4 - 18) = -7.85
\]
\[
V^1_{PL} = 0.55 \times 0 + 1.5 \times 0.9706 \times (14 - 14) + 1.5 \times 0.374 \times (7 - 14) = -3.92
\]

New velocity obtained by each dimension, then updated its position to get a new fitness value, as follows:
The new velocity obtained, then rounded up and again refers to the existing food index in the food database. After that the fitness value is recalculated and compared with particle X1. The value being compared will be updated to pbest and gbest, as follows:

Table 6. Update pbest and gbest.

| No. | Dimension | Value | Particle | Dimension | Value | Particle |
|-----|-----------|-------|----------|-----------|-------|----------|
| 1   | MP        | 6     | X2^1_{MP} | 0 + 3.36 = 3.36 |
| 2   | PN        | 4     | X2^1_{PN} | 20 + (-1.12) = 18.8 |
| 3   | S         | 8     | X2^1_{S}  | 1 + 3.92 = 4.92  |
| 4   | PH        | 4     | X2^1_{PH} | 10 + (-3.36) = 6.64 |
| 5   | PL        | 5     | X2^1_{PL} | 10 + (-2.80) = 7.2  |
| 6   | MP        | 3     | X2^1_{MP} | 10 + (-3.92) = 6.08 |
| 7   | PN        | 6     | X2^2_{PN} | 22 + (-8.97) = 13.03 |
| 8   | S         | 0     | X2^3_{S}  | 20 + (-11.2) = 8.8  |
| 9   | PH        | 2     | X2^1_{PH} | 18 + (-8.97) = 9.03 |
| 10  | PL        | 9     | X2^1_{PL} | 10 + (-0.56) = 9.44 |
| 11  | MP        | 1     | X2^1_{MP} | 0 + 0.56 = 0.56  |
| 12  | PN        | 2     | X2^1_{PN} | 22 + (-8.97) = 13.03 |
| 13  | S         | 4     | X2^1_{S}  | 1 + 1.68 = 2.68  |
| 14  | PH        | 4     | X2^1_{PH} | 18 + (-7.85) = 10.15 |
| 15  | PL        | 7     | X2^1_{PL} | 14 + (-3.92) = 10.08 |

Repetition in the search for a more optimal value between particles X1 and X2 will always be repeated until it reaches the maximum iteration. Here are the results of the 2nd iteration (maximum iteration) of particles X1 and X2:
Table 7. Maximum iteration.

| Particle | Iteration | Dimension Value | Fitness |
|----------|-----------|-----------------|---------|
|          |           |                |         |
| X1       | 0         | MP 6, PN 4, S 8, PH 4, PL 5 | 354.92  |
|          |           | Mealtime         |         |
|          |           | Breakfast, Lunch, Dinner |         |
| X2       | 0         | MP 0, PN 20, S 1, PH 10, PL 10 | 149.04  |
| X1       | 1         | MP 6, PN 4, S 8, PH 4, PL 5 | 354.92  |
|          |           | Mealtime         |         |
|          |           | Breakfast, Lunch, Dinner |         |
| X2       | 1         | MP 3.36, PN 18.8, S 4.92, PH 6.64, PL 7.2 | 145.1   |
| X1       | 2         | MP 6, PN 4, S 8, PH 4, PL 5 | 354.92  |
|          |           | Mealtime         |         |
|          |           | Breakfast, Lunch, Dinner |         |
| X2       | 2         | MP 6.69, PN 9.88, S 8.8, PH 3.31, PL 4.43 | 374.29  |

The results of the maximum iteration obtained in Table 7, are tested in order to get the optimal value. This study examines several parameters, including the number of particles, iteration, C1 & C2. Testing the number of particles carried out as many as 10, 20 and 25 particles as shown in Figure 2 below.
Figure 2. Particles test.

Based on Figure 2 above, the best value is produced by a population of 20 with an average of 7 meals a day that is 1848.78. The best particle or population will be the next reference in testing the iteration in Figure 3 below.

Figure 3. Iteration test.

Based on Figure 3 above, the best value is generated by an iteration of 20x. The best value is generated by an iteration of 20x with an average fitness for 7 days of eating, 1981.50. The population and iteration that achieve the best value will be the next reference in testing the combination of C1 and C2. Next is a test combination of C1 and C2 which can be seen in Figure 4 below.

Figure 4. C1 & C2 Combination test.
Based on Figure 4 above, the best combination value is produced by $C_1 = 1.5$ and $C_2 = 1.5$ with an average fitness for 7 days of eating which is 2043.207. It can be concluded that this study uses 20 particles, 20 times iteration, with a combination of $c_1$ and $c_2 = 1.5$ on the PSO parameter. From the test results, obtained examples of the results of food recommendations on day 1 of the elderly Baharudin in table 8 below.

### Table 8. Food recommendation.

| Mealtime | Type of Food | Food Name       | Energy (kkal) | Carbohydrate (gr) | Protein (gr) | Fat (gr) | Price (Rp.) |
|----------|--------------|-----------------|---------------|-------------------|--------------|----------|-------------|
| Breakfast| Makanan Pokok| White Sweet Potato | 201.8         | 47.3              | 4.3          | 0.2      | 1500        |
|          | Protein Nabati| Red Beans       | 167.5         | 30.1              | 11.5         | 0.6      | 700         |
|          | Sayuran       | Selada          | 25.8          | 2.2               | 2            | 0.4      | 3000        |
|          | Protein Hewani| Lettuce         | 67.1          | 0                 | 11.8         | 1.8      | 2000        |
|          | Pelengkap     | Catfish         | 123           | 31.9              | 0.3          | 0.6      | 1500        |
| Lunch    | Makanan Pokok| Salak           | 120           | 5.5               | 2.5          | 0.4      | 6000        |
|          | Protein Nabati| Corn            | 207           | 5.9               | 9.4          | 18       | 500         |
|          | Sayuran       | Peanuts         | 69.8          | 15.8              | 3.8          | 0.6      | 10500       |
|          | Protein Hewani| Winged          | 104           | 0                 | 14.6         | 4.6      | 5000        |
|          | Pelengkap     | Gold fish       | 73.5          | 18.6              | 0.6          | 0.6      | 3000        |
| Dinner   | Makanan Pokok| Rambutan        | 212.5         | 42.3              | 3.8          | 2.7      | 5000        |
|          | Protein Nabati| Nasi Uduk       | 17.4          | 4                 | 0.9          | 0.2      | 500         |
|          | Sayuran       | Long beans      | 25.8          | 5.6               | 1.4          | 0.2      | 4000        |
|          | Protein Hewani| Cucumber        | 55.3          | 3.6               | 2.9          | 3.3      | 5000        |
|          | Pelengkap     | Goat milk       | 88.6          | 23                | 0.3          | 0.6      | 5000        |
|          |              | Total           | 1559.1        | 237.8             | 70.1         | 34.8     | 53200       |

Table 8 is a food recommendation for Baharudin at the age of 50 years, body weight 64 kg, height 158 cm and very rarely exercise. After getting the food composition for the elderly Baharudin, the results of the recommendation are compared with the nutritional needs of the elderly, as follows:

### Table 9. Validation.

| Name    | Nutritional Needs of the Elderly | System Result | Price (Rp.) |
|---------|---------------------------------|---------------|-------------|
|         | Calories (kkal) | C | P | F | Calories (kkal) | C | P | F |             |
| Baharudin| 1511.67          | 245.64 | 56.6 | 33.5 | 1559.1          | 237.8 | 70.1 | 34.8 | 53200       |

The results of the system recommendations in the validation table produce values that are not significantly different from the nutritional needs of the elderly. The results obtained by the system in finding the optimal food composition are influenced by PSO parameters such as number of particles, number of iterations, Rand1-Rand2, C1-C2, and weight of inertia that were previously initialized.

Based on a search made by 20 particles with 20 times iteration on the PSO algorithm, it can be said that the PSO algorithm produces an optimal value in meeting the nutritional needs of the elderly in the form of food recommendations. The results of the optimal value will produce food recommendations for 7 days which can be seen in the attachment.

### 4. Conclusion

Particle Swarm Optimization (PSO) algorithm can be implemented to optimize the nutritional needs of the elderly in Posbindu PTM Sejahtera. The best parameter values used by PSO in the search for optimal values such as number of particles = 10, number of iterations = 10x, C1-C2 = 1.5, Rand1 = 0.5.
0.9706, Rand2 = 0.374, wmin = 0.4, wmax = 0.7 and weight of inertia = 0.55. PSO parameters greatly affect the results of optimization of the nutritional needs of the elderly. With this parameter PSO can produce optimal values. The value is said to be optimal if the nutritional penalty produces a small difference. Posbindu PTM Sejahtera elderly data used are 77 elderly with each of their nutritional needs and activity factors. From the results of the search for PSO in finding food compositions that fit the nutritional needs of the elderly, the calorie and carbohydrate content only disagree on average < 10% of the nutritional needs of the elderly, while the average content of protein and fat produces a large difference with an average of > 10% of the nutritional needs of the elderly and low prices with an average of < Rp.65,000.

Further research is expected to do time series analysis by weight to produce a food composition in accordance with BB fluctuations, adding factors of aging or allergic disease in determining the composition of food consumption and the results of the PSO parameters used in this study, need to be increased again by testing the particles, iteration, C1-C2, the weight of inertia, and add a minimum-maximum function.

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