Implementation of Particle Swarm Optimization (PSO) Method in Determining the Composition of Animal Feed in Broiler Chickens with Minimum Cost

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Abstract

Broiler is one type of vertebrate poultry and the most popular meat for consumption among the people of Indonesia. The growth of broilers is significantly influenced by the quality of the feed they receive. The composition of the feed must certainly meet the nutrients needed by broilers at a minimum price. Optimizing the feed composition is done using the Particle Swarm Optimization (PSO) method. The Particle Swarm Optimization (PSO) method is an optimization technique that follows the behavior of a group of living things for their survival such as a group of birds and a group of fish in search of food. In feed optimization using the PSO method, it is determined by looking at several particles and which particle has the largest fitness value. This study aims to see the results of feed composition optimization with the PSO method. From the calculation using the PSO method with the price from the breeder gives a price difference of Rp. 186 where the PSO parameters used are r_1 and r_2 are 0.2 and 0.4 and the values for c_1 and c_2 are Rp. 2,1 and 0.9.

Keywords: animal feed, broiler, Particle Swarm Optimization method, optimization

Introduction

Food is a basic need that must be met every day, because it functions as a source of energy and can affect growth rates if obtained and processed properly. Good food is food that can maintain health for the body by paying attention to the composition of the food ingredients contained therein [1]. Not only humans must pay attention to the composition of food ingredients but applies to animals, especially those who have livestock businesses (farms) because farms must maintain the health of these livestock.

According to UU No. 41 [2] on farming and animal health, animal husbandry is all matters relating to physical resources, seeds, breeds, breeding ruminants, feed, tools and machinery, animal cultivation, harvesting, post-harvesting, processing, marketing, business, financing, and facilities and infrastructure. In animal husbandry there is a term known as farm animals, farm animals are animals that are deliberately farmed or raised to meet food needs, help human labour, and as industrial raw materials, for example, such as broiler chickens that are used for meat. The growth of broilers is very fast due to the ability to change the meat produced from the food consumed (feed given) [3].

The broiler farming business was originally a side business of the layer farming business. Over time, many chicken farming businesses have now been established. By producing broiler chickens, businesses that can be established from producing broiler chickens include broiler farming operations and chicken meat processing operations [4]. In Indonesia, the development of the commercial chicken population was recorded starting in the mid-1970s and the development reached its peak in the early 1980s [5].

In feeding the farms want to spend a minimum cost in order to run the livestock business longer. Beef chicken farming is the most efficient and fastest business sector in meeting the consumption of meat needs and does not require a large area of land, and affordable prices [3]. In general, the feed that will be given to broilers comes from manufactured feed and the price of feed is not too cheap. Therefore, this research is intended to provide an alternative to broiler feed, but the mixture of ingredients to be used in making the feed uses ingredients that are easy to find so as not to make it difficult for broiler farms to make feed [6].

From these reasons, an optimization method is needed in determining the composition of good broiler feed. Optimization is a stage in finding optimal results or ideal results (the value achieved is an effective value). Another definition of optimization is an attempt to optimise existing problems or compile and make these problems solved optimally to achieve the goals to be achieved. The purpose of optimization itself is to find the best results or results that bring a lot of profit and little capital and to make business activities run longer [7]. This research will use the Particle Swarm Optimization (PSO) method. The Particle Swarm Optimization (PSO) method is an optimization technique by following the social behaviour that occurs in the lives of a flock of birds and a school of fish for survival [8].

The application of the PSO method used from several researchers such as those conducted by Juhardi and Andilala [9] on motorbike sales optimization can be known the nominal discount and down payment that will be used to increase the next motorbike sales and can assume the large number of sales for the next year. Furthermore, lecture scheduling conducted by Nugraha, Dodu, and Paloloang [10] that the PSO method can be applied to lecture scheduling. Then research conducted by Rachmat, Ratnawati, and Arwan [11] in optimising food composition for endurance athletes provides the results of the difference of each nutrient and calorie weight between nutritional needs and nutritional recommendations not exceeding the tolerance limit of ± 10%. Research on feed formula optimization in milkfish cultivation by applying PSO conducted by Darmawan, Cholissodin and Dewi [12] provides the best fish feed results with the characteristics of 10-week-old fish weighing 0.25 kg obtained feed cost expenditure of Rp. 15,017, 625 and fitness value 4.635699E-5. Then the research conducted by Istikomah, Cholissodin and Marji [13] with the PSO method provides results in saving the expenditure of parents of toddlers on fulfilling the nutritional needs of toddlers by 28.56%, making it easier for posyandu and parents of toddlers to provide daily toddler food according to their nutritional needs, and suggesting variations in food composition automatically.

Therefore, with the optimization system of feed composition in broiler chickens using the Particle Swarm Optimization (PSO) method is expected to be able to overcome problems with optimal solutions.

Methods

In this section, the Particle Swarm Optimization (PSO) method is employed to determine the composition of animal feed in broiler chickens with minimum cost. According to Wardhany, Cholissodin, and Santoso [14] the use of the Particle Swarm Optimization (PSO) method is described in the flowchart below.

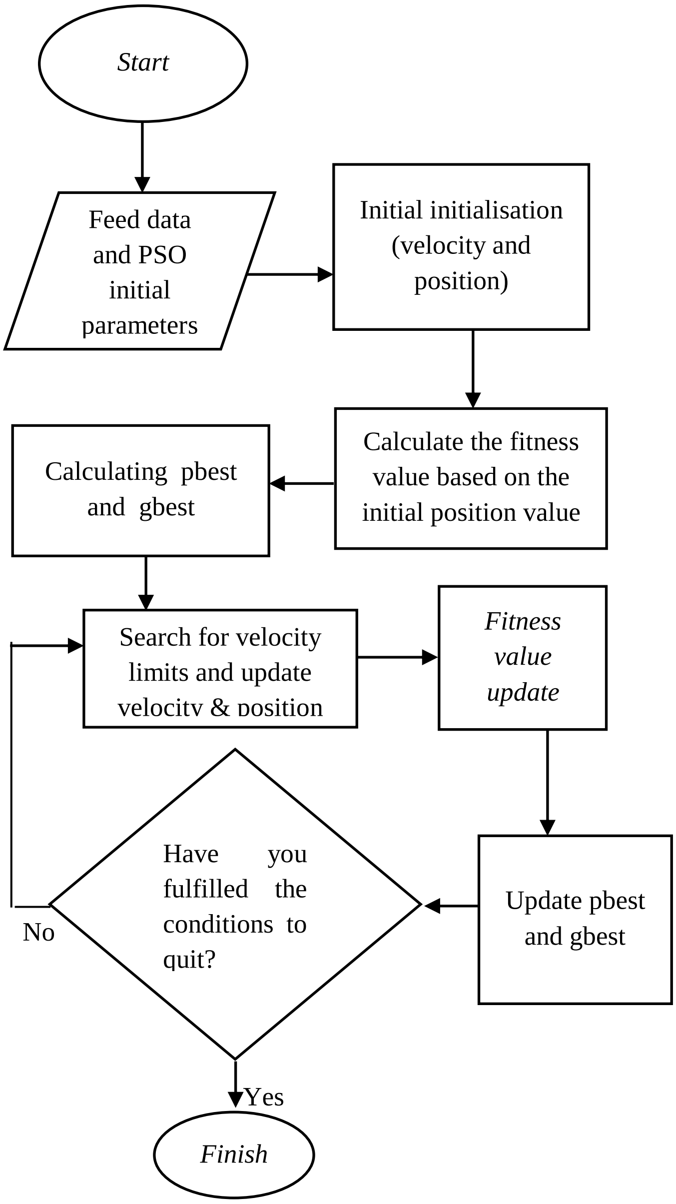

Figure 1. Flow Chart of Particle Swarm Optimization (PSO) method

The PSO method begins by finding the initial velocity and position initialisation, secondly calculating the fitness value, thirdly calculating pbest and gbest, fourthly finding the velocity limit and updating the velocity & position, fifthly updating the fitness value, sixthly updating pbest and gbest, seventhly repeating (iteration) from the fourth to sixth step comparing the fitness value from the initial iteration to the final iteration if it has found the largest fitness value then the iteration stops.

The following is the equation within the PSO method.

The first calculation in the PSO method is to find the initial velocity, as shown in Equation 1.

$$V_{i,j}(t) = 0. \tag{1}$$

For the initial velocity value, all particles are 0 because the particle position is at rest, so there is no velocity (according to equation 1).

Find the initial position using Equation 2.

$$\mathrm{X}_{i,j}\ (\mathrm{t}) = X_{min} + \mathrm{rand}[0,1] \times (X_{max} - X_{min}). \tag{2}$$

For example, initial position is calculated as:

$\mathrm{X}_{1,1}\ (0) = 0 + 0{,}7 * (50 - 0) = 35.$

After calculating the initial position, then calculate the fitness value shown in Equation 7. Before calculating the fitness value, first calculate the feed nutrition (Equations 3 and 4), find the penalty value (Equation 5), and calculate the feed cost (Equation 6).

$$N_j\ (\%) = \frac{\beta_{\mathrm{i,j}}\ (\%)}{T} \times 100\ \%. \tag{3}$$

Determination of the value of m (the value of the ingredients in the feed can be seen in the initial position table or in table 2).

$$A(X) = \frac{\gamma_{i,j}(\%)}{100} \times y_i(\%). \tag{4}$$

A(X) shows the initials of the calculation of nutrients to be sought (the level of nutrients to be calculated) there are 8 types of nutrients.

$$\mathrm{Penalty}\ (\%) = \begin{Bmatrix} 0 & \mathrm{if} & \mathrm{p} \geq \mathrm{m} \\ m - p & if & p < m \end{Bmatrix}. \tag{5}$$

Calculating feed cost

$$feed\ cost = \left(\frac{feed\ value_{i,j}}{100} \times \alpha\right) \times\ cost. \tag{6}$$

Feed value determination can be seen from Table 2 (initial position) and the cost value is obtained from table 1 but for the 1st iteration the material value can be seen in the position update section.

The calculation of this fitness value will determine the gbest result where the biggest fitness result is gbest. So to calculate the fitness value, it is determined by finding feed nutrition, total penalty, and total cost. According to Wardhany, Cholissodin, and Santoso [2017] where the value of q is a multiplier constant worth 20 so that the price difference and feed penalty are not too large while the multiplier constant (constant K) so that the fitness value is not too small is worth 1000.

$$Fitness = \left(\frac{1}{x_i + (y_i \times \mathrm{q}\,)}\right) \times\ K. \tag{7}$$

After obtaining the pbest and gbest values, the velocity limit is found by using equation 8 for the calculation of the upper velocity limit and equation 9 for the lower velocity limit.

$$V_{max} = \left(\frac{X_{max} - X_{\ min}}{2}\right) \times h, \tag{8}$$

$$V_{min} = -V_{max.} \tag{9}$$

After the calculation is done using equations 8 and 9, the next calculation is to find the velocity update with equation 10.

$$V_{i,j}^{t+1} = w.V_{i,j}^t + c_1 r_1\left(pbest_{i,j}^t - X_{i,j}^t\right) + c_2 r_2\left(gbest_{i,j}^t - X_{i,j}^t\right). \tag{10}$$

From Equation 10 (velocity update), the velocity improvement is obtained by taking into account the conditions in equations 11 and 12.

$$V_{i,j}(\mathrm{t}+1) > V_{max} \text{ then } V_{i,j}(\mathrm{t}+1) = V_{max}\ , \tag{11}$$

$$V_{i,j}(\mathrm{t}+1) < \ -V_{maks} \text{ then } V_{i,j}(\mathrm{t}+1) = \ (-V_{maks})\ or\ V_{min}. \tag{12}$$

Next, the position update is given in Equation 13

$$X_{i,j}^{t+1} = X_{i,j}^{t} + V_{i,j}^{t+1} \tag{13}$$

Description of each parameter and variable is provided below:

$\beta_{\mathrm{i,j}}$ (%) = ingredient value in feed

T = total feed ingredient value

$A(X)$ = nutrients to be sought (metabolic energy, phosphorus, calcium, crude protein, crude fibre, crude fat, ash content, and moisture content)

y_i = nutrient content of ingredient i

$\gamma_{i,j}$(%) = feed value of the i-th particle of the j-th dimension

m = nutrient requirement

p = total nutrients

α = feed requirement per day (gr)

q = multiplier constant of 20

K = multiplier constant of 1000

$Cost$ = cost of feed ingredients

$\omega = inertia\ value$

x_i = total cost of i-th feed (i=1,2,3,..)

y_i = i-th total penalty

$Vmin$ = velocity lower limit

$Vmax$ = velocity upper limit

h = random number between 0 and 1

$X_{i,j}^{t+1}$ = current particle position

$X_{i,j}^{t}$ =previous particle position

$V_{i,j}^{t+1}$ = current particle velocity

X_{min} = lower limit

X_{max} = upper limit

Results and Discussion

The place where the farm was conducted was in Kampung Baru, Lingga Tiga Village, Bilah Hulu District, Labuhanbatu Regency, North Sumatra Province. Data on broiler chickens used are 10 days old with a daily feed requirement of 58 grams, 8 raw materials for making feed, 8 types of nutrient content used (metabolic energy, crude fiber, crude protein, crude fat, moisture content, ash content, total phosphorus, and calcium), the price used is in units of grams.

Table 1. Raw Materials and Prices

Raw Material	Price
Yellow Corn	7
Fish Flour	8
Tofu Dregs	6
Gaplek Flour	12
Stone Flour	1
Rice Bran	4
Soya Bean Meal	8
Coconut meal	4

source: [Karjono, interview, 2023]

At this stage, 5 iterations are performed and there are 4 particles, 8 dimensions, and the range of lower limit is 0 and the determination of the upper limit is adjusted to the needs, here the author uses 50 for J1, 12 for J2, 10 for J3, 5 for J4, 5 for J5, 17 for J6 and J7, 5 for J8. J1 is yellow corn, J2 is fish meal, J3 is tofu dregs, J4 is cassava flour, J5 is stone flour, J6 is rice bran, J7 is soya bean meal, J8 is coconut meal.

1. Initial velocity and position

Determination of the initial velocity is all zero where the velocity does not move (at rest). As for the initial position, it will be shown in table 2. This stage is carried out for the first iteration (iteration (0)).

Table 2. Initial Position

	$x1\ (0)$	$x2\ (0)$	$x3\ (0)$	$x4\ (0)$
Yellow Corn	35	15	45	50
Fish Flour	4	6	8	10
Tofu Dregs	8	4	2	3
Gaplek Flour	1	4	5	6
Stone Flour	2	5	2	4
Rice Bran	2	12	14	3
Soya Bean Meal	10	3	8	2
Coconut meal	2	4	1	2

2. Finding Fitness Value

Before finding the fitness value, there are three stages that must be found first, first finding the feed nutrition (normalisation and the level of nutrients needed), second finding the penalty value, and third calculating the cost of feed. Table 3 is the fitness value used as a reference in determining the pbest and gbest values.

Table 3. Fitness Value 0th Iteration

	1st particle	2nd particle	3rd particle	4th particle
J1	35	15	45	50
J2	4	6	8	10
J3	8	4	2	3
J4	1	4	5	6
J5	2	5	2	4
J6	2	12	14	3
J7	10	3	8	3
J8	2	4	1	2
Fitness	2,340378849	2,272441386	2,083862568	1,911787753

The following is an example calculation for the first particle.

- Feed nutrition

$$N_1\,(\%) = \frac{35}{64} \times 100\,\% = 54{,}6875\%.$$

Then

$$\text{metabolic energy}_1 = \frac{54{,}6875}{100} \times 3360 = 3043{,}203125,$$

so that the total nutrients from metabolic energy were obtained at 3032,580645.

- Penalty value

P.ME $= 3032{,}580645 > 2900 \rightarrow 0kkal/kg$, specific metabolic energy converted to %

P.ME$= \frac{0\frac{kkal}{kg}}{2900\frac{kkal}{kg}} \times 100\% = 0\%$

so the total penalty of 8 nutrients for particle 1 is 8,7490625.

- Cost of feed

$$cost_1 = \left(\frac{35}{100} \times 58\right) \times 7 = 142{,}1$$

so the total feed cost of 8 nutrients for particle 1 is 252,3

- Fitness value

$$Fitness = \left(\frac{1}{252{,}3 + (8{,}7490625 \times 20)}\right) \times 1000 = 2{,}340378849$$

3. Personal Best and Global Best Initialisation

Pbest is shown from the initial position value and fitness, while the largest fitness is the gbest. Where the gbest value is obtained on the 1st particle with a value of 2,340378849.

4. Finding the Velocity Limit

Table 4 is the result of calculating the velocity limit using equations 8 and 9.

Table 4. Velocity Limit

Vmax		*Vmin*	
J1	2.5	J1	-2.5
J2	0.6	J2	-0.6
J3	0.25	J3	-0.25
J4	0.5	J4	-0.5
J5	0,25	J5	-0.25
J6	0.85	J6	-0.85
J7	0.85	J7	-0.85
J8	0.25	J8	-0.25

5. Update Velocity and Position

This stage starts the next iteration, namely the 1st iteration and the next iteration until the 4th iteration. Velocity improvements can be seen in Table 5 and position updates are presented and can be seen in Table 6 below.

Table 5. Velocity Improvement

	$v1(1)$	$v2(1)$	$v3(1)$	$v4(1)$
J1	-2,5	-2,5	-2,5	-2,5
J2	-0,59746	-0,6	-0,6	-0,6
J3	-0,5	-0,5	-0,5	-0,5
J4	0,25	-0,25	0,122536	-0,23746
J5	0,122536	-0,25	0,122536	-0,25
J6	0,122536	-0,85	-0,85	-0,23746
J7	-0,85	-0,23746	-0,85	0,122536
J8	0,122536	-0,25	0,25	0,122536

Table 6. Position Update

	$x1(1)$	$x2(1)$	$x3(1)$	$x4(1)$
J1	32,5	12,5	42,5	47,5
J2	3,402536	5,4	7,4	9,4
J3	7,5	3,5	3,5	6,5
J4	1,25	3,75	2,122536	2,762536
J5	2,122536	4,75	2,122536	3,75
J6	2,122536	11,15	13,15	2,762536
J7	9,15	2,762536	7,15	2,122536
J8	2,122536	3,75	1,25	2,122536

6. Update Personal Best (Pbest) and Global Best (Gbest)

The following table contains the calculation results to find pbest and gbest updates.

Table 7. Personal Best (Pbest) and Global Best Iteration

	Pbest 1(1)	*Pbest* 2(1)	*Pbest* 3(1)	*Pbest* 4(1)
J1	32,5	12,5	42,5	47,5
J2	3,402536	5,4	7,4	9,4
J3	7,5	3,5	3,5	6,5
J4	1,25	3,75	2,122536	2,762536
J5	2,122536	4,75	2,122536	3,75
J6	2,122536	11,15	13,15	2,762536
J7	9,15	2,762536	7,15	2,122536
J8	2,122536	3,75	1,25	2,122536
Fitness	2,415621	2,386443	2,127504	1,923628

So that the pbest and gbest values are obtained in the 1st particle. Pbest is shown from the initial position value and fitness, while the best fitness is the gbest. Where the gbest value is obtained with a value of 2,415621. Then, the steps for the 2nd iteration and so on can be done by following the steps to find the velocity limit to update pbest and gbest. So that the optimization results obtained from the 0th to 4th iteration are obtained in the 4th iteration with a fitness value of 2,830688. Table 8 is the pbest and gbest values for the 4th iteration.

Table 8. Personal Best (Pbest) and Global Best 4th Iteration

	Pbest 1(4)	*Pbest* 2(4)	*Pbest* 3(4)	*Pbest* 4(4)
J1	24,25	8,379911	42,475	47
J2	2,927414	4,208311	7,394	9,28
J3	5,85	3,011911	3,495	6,4
J4	1,719961	3,220911	2,125036	2,712536
J5	1,408473	3,925	2,125036	3,7
J6	2,345502	8,345	13,1415	2,625694
J7	6,555741	2,508796	7,1415	2,240574
J8	2,278384	3,220911	1,2525	2,172536
Fitness	2,830688	2,546097	2,246643	2,109222

For the price incurred by a 10-day-old broiler farmer and the daily feed requirement of 58 grams using the PSO method is calculated as follows.

$$Tot.raw\ materials = 24{,}3 + 2{,}9 + 5{,}9 + 1{,}7 + 2{,}4 + 2{,}3 + 6{,}6 + 23 = 47{,}4$$

Then the optimal feed composition given by calculating the PSO method for 1 chicken with the weight of each ingredient is as follows.

Yellow Corn ; ingredient weight $= \frac{24{,}3}{47{,}4} \times 58 = 29{,}7$

Cost $= 7 \times 29{,}7 = 207{,}9$

Therefor, the cost incurred with 8 raw materials using the PSO calculation is Rp. 394 for 1 chicken with a feed weight of 58 grams

Conclusion

Based on the results of this study, it can be concluded that the implementation of the Particle Swarm Optimisation (PSO) method can be solved on the problem of optimising the composition of animal feed in broiler chickens by using the value of h starting from 0 to 1. The feed composition optimisation problem obtained a solution by looking at the largest fitness value from the 0th iteration to the 4th iteration. Finally, the difference in costs from calculations using PSO with costs incurred by farmers is Rp. 186.

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