OPEN ACCESS
LEDGER, VOL. 3, NO. 1, FEB 2024

ISSN: 2963 – 8798 (ONLINE)

LEDGER: Journal Informatic and Information Technology

Optimizing Chicken Feed Using Evolution Strategies (ES) Algorithm

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Abstract

In the current livestock industry, developing effective and efficient methods to optimize chicken nutrition is a major challenge in the world of farming, given the increasing market demands where consumers always seek the best quality. In this research, we are applying the Evolution Strategies (ES) algorithm to optimize the chicken feed composition to enhance growth and production efficiency. Our experiments involve testing various combinations of parameters, including population size, recombination probability, and mutation rate. This approach can assist farmers in maximizing production and improving animal welfare.

Keywords: Chicken Feed, Evolution Strategies Algorithms, Optimization

Abstrak

Dalam industri peternakan saat ini, mengembangkan metode yang efektif dan efisien untuk mengoptimalkan nutrisi ayam, merupakan tantangan utama dalam dunia peternakan mengingat kebutuhan pasar yang semakin meningkat, para konsumen selalu menginginakan kualitas yang terbaik. Pada penelitian ini, kami menggunakan penerapan algoritma *Evolution Strategies* (ES) untuk mengoptimalkan komposisi pakan ayam guna meningkatkan pertumbuhan dan efisiensi produksi. Eksperimen kami melibatkan pengujian berbagai kombinasi parameter, termasuk ukuran populasi, probabilitas rekombinasi, dan tingkat mutasi. Pendekatan ini dapat membantu peternak memaksimalkan produksi dan meningkatkan kesejahteraan ternak.

Kata Kunci: Algoritma *Evolution strategies*, Pakan Ayam, Optimasi

I. INTRODUCTION

The rapid growth of the chicken farming industry and increasing demand for quality chicken products require farmers to look for more efficient and effective methods of preparing chicken feed. Optimal feed composition is very important in achieving good growth performance, optimal health, and high production efficiency.

In recent years, algorithm-based optimization techniques have become a research focus. One interesting approach is the use of the Evolution Strategies (ES) algorithm. Therefore, through this research, the author wants to increase the productivity of chicken livestock by using optimization techniques based on the Strategic Evolution (ES) algorithm to optimize the composition of chicken feed based on appropriate nutritional needs, so that the quality of the production produced is maximum.

Evolution Strategies (ES) is an optimization method inspired by the theory of natural evolution, where solutions are found through an iterative process involving reproduction, recombination and mutation. (ES) combines evolutionary principles with solution search strategies to achieve the best results in a complex search space [1].

Evolution strategies (ES) is an optimization method developed in 1960 by Rechenberg and Schwefel in Berlin, then further developed around the 1970s. This algorithm uses real numbers which are used as

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attributes or solution representations [2]. Apart from that, the Evolution Strategies (ES) algorithm is considered to have a faster execution process than other algorithms, such as the Genetic Algorithm [3].

The Evolution Strategies (ES) algorithm consists of several steps that repeat in generational iterations. At each generation, individuals in the population are evaluated based on established objective functions or performance criteria. The best individuals are then selected to enter the recombination and mutation phase. In the recombination phase, selected individual parameters are combined sexually to produce new offspring. Meanwhile, in the mutation phase, small variations are introduced in the hereditary parameters through random operations. After that, a new generation is formed and the iteration continues until the stopping criterion is met, such as reaching an adequate solution or passing the maximum iteration limit [4].

The advantage of Evolution Strategies (ES) is its ability to address complex and stochastic search spaces by simultaneously exploring multiple potential solutions. (ES) is able to adjust solution parameters through recombination and mutation inspired by the natural processes of evolution. This approach allows (ES) to find optimal solutions in situations where the objective function is complex, non-linear and may have many local peaks. Apart from that, (ES) also has advantages in its scalability and parallelization capabilities, which allow the application to large-scale problems [5].

By using the Strategic Evolution Algorithm (ES), of course, the composition of each ingredient contained in each type of chicken feed produced will get the maximum final value, so that the livestock production process required for each type of chicken will be carried out well and optimally.

II. LITERATURE REVIEW

A. *Nutritional Requirements for each type of Chicken*

It's important to pay attention to nutritional needs based on the classification of chicken types because each type of chicken has different nutritional needs. Factors such as age, gender, production level, and physical activity level of chickens can influence their needs for certain nutrients, such as protein, energy, vitamins, and minerals. Properly meeting these specific nutritional requirements will ensure optimal growth, egg production, or meat production, as well as good health and welfare of the chicken[6]. To ensure that the nutritional needs of each type of chicken can be met, we use several standards which can be seen in Table I and Table II for Broiler chickens and in Table III for Laying hens [7][8][9].

TABLE I
NUTRIENT REQUIREMENTS FOR BROILER CHICKENS (STARTER)

No	**Broiler Chickens (*Starter*)**		
	Parameter	**Measure**	**Constraint**
1	Water	%	Max. 14.0
2	Raw Protein	%	Min. 19.0
3	Raw Fat	%	Max. 7.4
4	Raw Fiber	%	Max. 6.0
5	Ash/Minerals	%	Max. 8.0
6	Calsium (Ca)	%	0.90 – 1.20
7	Total Phospor	%	0.60 – 1.00
8	Phospor	%	Min. 0.40
9	Metabolism Energy	Kkal/kg	Min. 2900

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TABLE II
NUTRIENT REQUIREMENTS FOR BROILER CHICKENS (FINISHER)

No	**Broiler Chickens (*Starter*)**		
	Parameter	**Measure**	**Constraint**
1	Water	%	Max. 14.0
2	Raw Protein	%	Min. 18.0
3	Raw Fat	%	Max. 8.0
4	Raw Fiber	%	Max. 6.0
5	Ash/Minerals	%	Max. 8.0
6	Calsium (Ca)	%	0.90 – 1.20
7	Total Phospor	%	0.60 – 1.00
8	Phospor	%	Min. 0.40
9	Metabolism Energy	Kkal/kg	Min. 2900

TABLE III
NUTRIENT REQUIREMENTS FOR LAYING HENS

Nutrition Requirements	**Laying Hens**		
	Starter	**Layer**	**Finisher**
Water(%)	<14	<14	<14
Metabolism Energy(Kcal/kg)	2980	2750	2750
Raw Protein(%)	20.5	18	17
Raw Fat(%)	<6.5	<7	<7
Raw Fiber(%)	2.5 – 7	3.5 – 3.7	2.5 – 7
Ash/Minerals(%)	5 – 8	10 - 14	10 – 14
Calcium/Ca(%)	1.05 – 1.1	3.25 - 4	3.6 – 4
Phosphor(%)	0.48	0.40	0.33 – 0.37

B. *Types of chicken feed ingredients*

The type of chicken feed ingredient has a significant influence on chicken production. The nutritional composition, quality of feed ingredients, and feed digestibility will affect the growth, reproduction, and health of chickens. Selecting the right feed ingredients with appropriate nutritional content, such as protein, energy, vitamins and minerals, can increase egg production or meat production, increase chicken growth and development, and increase feed efficiency. On the other hand, the use of feed ingredients that are of low quality or do not meet nutritional needs can cause decreased production, health problems and nutritional imbalances [10].

Therefore, to make chicken feed, we will combine five ingredients which can be seen in Table IV along with the nutritional content contained in them [11].

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TABLE IV
TYPES OF CHICKEN FEED INGREDIENTS

Ingredients	Protein	Fat	Fiber	Calcium	Phosphor	Metabolism Energy
Corn	8.6	3.9	2	0.09	0.3	3370
Sorghum	10	2.8	2	0.4	2.13	3250
Rice	8	1.7	9	0.09	0.08	2660
Coconut Oil	14.1	8.12	23.32	0.29	0.79	1450
Tofu Dregs	18.7	5.32	14.53	0.32	0.45	0

C. *The basic structure of Evolution Strategies*

Basically, the procedure in (ES) uses the notation μ (miu) to express the size of parents (population) and λ (lambda) which is how many offspring (new individuals) are produced during the production process in the initial generation. Some researchers recommend a value of λ of 7μ.

Because (ES) relies more on mutation operators, the recombination process itself is not always used. The four types of processes used in (ES) in general are as follows:

- (μ,λ)
- (μ + λ)
- (μ/r, λ)
- (μ/r + λ)

The ES(μ,λ) and ES(μ + λ) methods do not involve recombination in the reproduction process. In ES(μ,λ) selection with elitism selection only involves individuals in the offspring and parent individuals are not included. Meanwhile, the ES (μ + λ) method involves offspring and parent individuals. The ES(μ/r, λ) method is similar to the ES(μ,λ) method but with a little additional recombination process, while the ES(μ/r+λ) method is similar to the ES(μ+ λ) method also with a little additionally involves recombination processes[3].

III. EVOLUTION STRATEGIES

A. *Chromosome Representation*

The chromosome representation process in the Evolution Strategies (ES) algorithm has a real code form. The solution to a problem is mapped to a string of chromosomes. In the decision variable, chromosomal genes are expressed in (x1, x2, x3, x4, and x5) and in this algorithm there is σ (sigma) as an additional parameter that is adaptive or can change until the generation process is complete. The σ (sigma) value represents the level of mutation on the chromosome. If P is one chromosome, then P = (x1,x2,x3,x4,x5, σ1, σ2, σ3, σ4, σ5) with a string length of 5[3].

B. *Initialization*

Initialization in the Evolution Strategies Algorithm is the initial process of creating a population of random solutions that will be used as a starting point in the optimization search. A diverse population of initials helps encourage exploration of a broader search space, which can increase the chances of finding better solutions. The correct initialization process can have a big influence on the performance and convergence of the algorithm [4].

In the initialization stage, the population of individuals is generated randomly. The values x1,x2,x3,x4, x5 and the values σ1, σ2, σ3, σ4, σ5 are generated as fractional numbers (Real) in the variable range [0,1]. It should be remembered that the initialization process is not present in the (μ/r, λ) and (μ/r + λ) cycles because both cycles require a recombination process involving two populations.

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For example, if μ= 5 is determined, a population will be produced like the following example:

Parent	x1	x2	x3	x4	x5
P1	0.5984	1.0000	0.0283	0.1089	0.0616
P2	0.7229	1.0000	0.0851	0.0820	0.3386
P3	1.0000	0.0377	0.1101	0.2005	0.0154
P4	1.0000	1.0000	0.0161	0.1399	0.4390
P5	0.8985	0.7044	0.0495	0.0427	0.6696
Parent	sigma1	sigma2	sigma3	sigma4	sigma5
P1	0.3305	1.0392	0.7399	0.2066	0.7109
P2	0.6628	0.9428	0.5868	0.6754	0.6644
P3	0.4666	0.9057	0.6292	0.5732	0.6151
P4	1.0148	0.7694	0.8868	0.5476	0.2223
P5	0.8618	0.1043	0.6510	0.9152	0.0761

Fig. 1. Initialize the population with variable μ= 5

C. *Reproduction*

In the reproduction process here for the (μ,λ) and (μ + λ) cycles, because recombination is not used, only mutation plays a role in producing Offspring. Meanwhile, the reproduction process in the (μ/r, λ) and (μ/r + λ) cycles contains recombination and mutation processes [3].

D. *Recombination*

The recombination process is used to produce λ offspring from a number of μ individuals in the population. Offspring individuals are produced through cross-breeding between several parents. The parent population itself is selected randomly. A simple recombination method can be calculated by averaging the values of the parent elements.
Examples of recombination processes in the (μ/r, λ) cycle and (μ/r + λ) cycle are as follows:
- For example, offspring are obtained from 2 parents. If P1 and P3 are selected then you will get offspring C = (0.1752,0.0205,0.2949,0.4687,0.1809,0.1586,0.0463, 0.0691,0.0679,0.1275)
- For example, offspring are obtained from 3 parents. If P2, P3, and P5 are selected then you will get offspring C=(0.1752,0.0205,0.2949,0.4687,0.1809,1.0000,0.6262,0.7678,0.8792,0.7790,0.2418,0.0336,0.2556,1.0000,0.1345)In the reproduction process here for the (μ,λ) and (μ + λ) cycles, because recombination is not used, only mutation plays a role in producing Offspring. Meanwhile, the reproduction process in the (μ/r, λ) and (μ/r + λ) cycles contains recombination and mutation processes [3].

E. *Mutation*

Mutation is one of the main operations in evolutionary algorithms used to create new genetic variations in populations. Through mutation, the values of individual genes or solutions can be changed randomly or by certain rules, allowing the exploration of a wider search space and exploring potential solutions that have not been explored before [4].

This mutation process involves four cycles to produce offspring. For example, P = (x1, x2',x3',x4',x5', σ1', σ2', σ3', σ4', σ5') with the following formula [3] :

$$x' = x + \sigma\, N(0,1)$$

Where N(0,1) is a random number through a normal distribution with an average of 0 and a standard deviation of 1. Through a computer program, this value is obtained from two random numbers r1 and r2 in the interval [0,1]

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The formula used is: [4]

$$N(0,1) = \sqrt{-2.\ln r_1}\sin 2\pi r_2$$

For example, the value of r1 = = 0.4749 and the value of r2 = 0.3296 will result in N(0,1)= 1.0709.

The (sigma) value is increased using the formula σ' = σ x 1.1 if there are at least 20% of mutations that produce offspring that are better than their parents. Meanwhile, if not, the σ (sigma) value will be reduced using the formula σ' = σ x 0.9[3].

F. *Selection*

In the Evolution Strategies Algorithm, selection is an important step used to select the best individuals from the current population who will become parents in the next generation. Selection is carried out based on the performance or fitness value of each individual. Individuals who have a higher fitness value have a greater chance of being selected as parents.

In the selection process using elitism selection, there are fundamental differences in each cycle. In the cycles (μ, λ) and (μ/r, λ) only the offspring individuals are involved and the parent individuals in the population are not involved. Meanwhile, the cycles (μ + λ) and (μ/r + λ) involve both offspring individuals and parent individuals in the population [3].

IV. TESTING AND ANALYZING RESULTS

A. *Algorithm design*

The following is the design of a chicken feed optimization algorithm using the evolution strategies (ES) algorithm.

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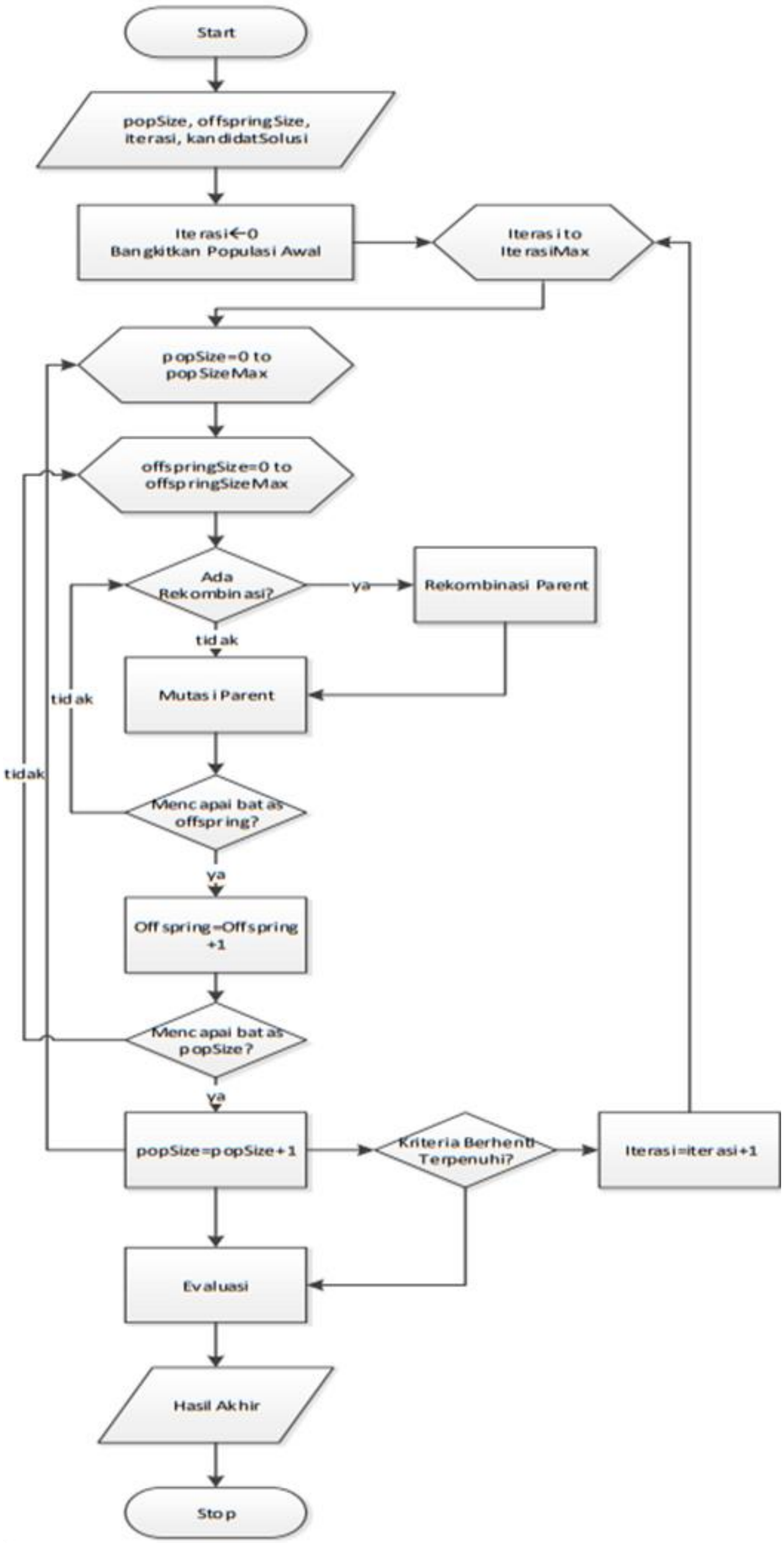

Fig. 2. Initialize the population with variable μ= 5

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B. *Testing broiler chicken types*

Testing on starter and finisher broiler chickens was carried out by calculating the convergence value in the population tested on 10 individuals and then taking the highest point value. Meanwhile, testing on offspring and generations was also tested on 10 offspring individuals and also on 10 generations by taking the highest fitness value. Then in the final process, we take the sample with the best fitness value and analyze the best method used to produce the best fitness value.

The following is a table of test results for starter broiler chicken types:

TABLE V
TESTING BROILER STARTER

Method	**Population**	**Offspring**	**Generation**	**Fitness**
(μ,λ)	70	20	300	0.0013324
(μ+λ)	50	100	1000	0.6102061
(μ/r,λ)	50	60	100	0.0005141
(μ/r+λ)	60	70	700	0.3104237

In table V, it can be seen in the row colored light blue that in the test of starter broiler chickens, the population value was at its highest point at 50, with the 100th new individual (offspring) and the 1000th generation. This calculation is taken from the results of the highest fitness value or the best value results. So for starter broiler chickens, the best method to use is the (μ+λ) method.

The following are the test results for finisher broiler chickens:

TABLE VI
TESTING BROILER FINISHER

Method	**Population**	**Offspring**	**Generation**	**Fitness**
(μ,λ)	50	40	1000	0.0005477
(μ+λ)	70	70	600	0.8497798
(μ/r,λ)	60	20	700	0.0004969
(μ/r+λ)	80	50	1000	0.6172205

In table VI, the row colored light blue shows that the results of testing broiler finisher chickens, the best population value is at 70 with the 70th new individual (offspring) and the 600th generation. This calculation is taken from the results of the best fitness value. So for finisher broiler chickens, the best method is the (μ+λ) method.

C. *Testing Laying Hens*

Testing on laying chickens is the same as on broiler chickens, namely by calculating the convergence value in the population. Testing on offspring and generations by taking the highest fitness value. Then in the final process, analyze the best method used to produce the best fitness value.

The following are the test results for starter types of laying hens:

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TABLE VII
TESTING STARTER LAYING HENS

Method	Population	Offspring	Generation	Fitness
(μ,λ)	70	70	900	0.0004705
(μ+λ)	60	40	500	0.0965037
(μ/r,λ)	90	60	500	0.0005721
(μ/r+λ)	80	50	200	0.3752623

In table VII the test results for the starter laying hen type have the best population value which reaches the highest point at 80 with the 50th new individual (offspring) and the 200th generation. This calculation is taken using the best fitness value. So the best method used for starter types of laying hens is the (μ/r+λ) method

The following are the test results for layers of laying hens:

TABLE VIII
TESTING LAYER LAYING HENS

Method	Population	Offspring	Generation	Fitness
(μ,λ)	40	70	700	0.0004891
(μ+λ)	80	90	100	0.0995437
(μ/r,λ)	70	60	800	0.0005443
(μ/r+λ)	50	50	800	0.3578102

In Table VIII the test results for the layer-laying hen type have the best population value which reaches the highest point at 50 with the 50th new individual (offspring) and the 800th generation. This calculation is taken using the best fitness value. So the best method used for layer-laying hens is the (μ/r+λ) method.

The following are the test results for finisher laying hens:

TABLE IX
TESTING FINISHER LAYING HENS

Method	Population	Offspring	Generation	Fitness
(μ,λ)	70	80	200	0.0005078
(μ+λ)	70	30	500	0.6400631
(μ/r,λ)	50	90	800	0.0005131
(μ/r+λ)	70	30	400	0.4909371

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In table IX the test results for the finisher laying hen type have the best population value which reaches the highest point at 70 with the 30th new individual (offspring) and the 500th generation. This calculation is taken using the best fitness value. So the best method used for layer-laying hens is the (μ+λ) method.

D. *Comparison of the best parameters for each type of chicken*

A comparison of the best parameters for each type of chicken is needed to find out what method is most suitable to use to find the best performance/fitness value for each type of chicken, in order to be able to analyze which individual has the right to be the parent of the next generation. After previous tests, the results of the analysis of the best methods used for each type of chicken have been obtained.

TABLE X
COMPARISON OF EACH TYPE OF CHICKEN

Type of Chicken	**Best Method**
Broiler Starter	(μ+λ)
Broiler Finisher	(μ+λ)
Laying Starter	(μ/r+λ)
Laying Layer	(μ/r+λ)
Laying Finisher	(μ+λ)

E. *Proving the best method is taken from the penalty value of the needs of each type of chicken that has the best fitness value*

1) *Starter Broiler* : In testing starter broiler-type chickens, the best and most effective method is the (μ+λ) method. Therefore, we calculate the penalty value for each chicken feed content. The following is the penalty value for each chicken feed content obtained by multiplying the initial values x1, x2, x3, x4, and x5

TABLE XI
RESULTS OF INITIALIZATION ON BROILER STARTER

Method	**x1**	**x2**	**x3**	**x4**	**x5**
(μ,λ)	0.9164	0.8686	0.002	0.0583	0.0361
(μ+λ)	0.8188	1	0.0007	0.0979	0.0786
(μ/r,λ)	0.111	0.0248	0.1818	0.5424	0.0973
(μ/r+λ)	1	0.6031	0.0271	0.1689	0.1487

Because the best method chosen was the (μ+λ) method, we multiplied it by the content of each type of chicken feed which can be seen in Table IV of types of chicken feed ingredients and obtained the following results:

TABLE XII
RESULTS TOTAL NUTRITIONAL VALUE IN BROILER STARTER

bs (μ+λ)	**Corn**	**Sorghum**	**Rice**	**Coconut Oil**	**Tofu Dregs**	**Total**
Protein	6.88	10	0.0005	1.2	1.3	19.4

 ISSN: 2963 – 8798 (ONLINE)

bs (μ+λ)	Corn	Sorghum	Rice	Coconut Oil	Tofu Dregs	Total
Fat	3.12	2.8	0.00011	0.7308	0.3724	7.02
Fiber	1.6	2	0.0005	2.0988	1.01	6.7
Calcium	0.072	0.4	0.0005	0.02	0.02	0.52
Phosphor	0.24	2.13	0.0005	0.0711	0.03	2.4
Metabolism Energy	2696	3250	0.16	130.5	0	6076

After we calculate them one by one, namely corn multiplied by x1, sorghum multiplied by x2, etc.. So, we add up the results of each content in it, which will later be used to calculate the penalty value.

TABLE XIII
RESULTS OF PENALTY VALUE IN BROILER STARTER

bs (μ+λ)	Limit	Total	Difference	Penalty
Protein	>=19	19.4	0.4	0
Fat	<=7.4	7.02	0.2	0
Fiber	<=6	6.7	6-6.7 = -0.7	0.7
Calsium	>=0.9 - <=1.2	0.52	0.9-0.52=0.38	0.38
Phosphor	>=0.6 - <=1	2.4	1-2.4=-1.4	1.4
Metabolism Energy	>=2900	6076	3176	0

For starter broiler chickens, it can be seen in Table I. The nutritional requirements for starter broiler chickens for each required nutritional limit. For values that meet the limits, the penalty value is filled with 0 because they do not violate them, while for those that do not meet the nutritional limits, the difference is calculated to know how many limits have been violated.

2) *Finisher Broiler Chickens*: When testing starter broiler chickens, the best and most effective method is the (μ+λ) method. Therefore, we calculate the penalty value for each chicken feed content. The following is the penalty value for each chicken feed content obtained by multiplying the initial values x1, x2, x3, x4, and x5

TABLE XIV
RESULTS OF INITIALIZATION ON BROILER FINISHER

Method	x1	x2	x3	x4	x5
(μ,λ)	0.1576	0.0425	0.238	0.1467	0.0326
(μ+λ)	0.6888	1	0.0458	0.0886	0.0344
(μ/r,λ)	0.0927	0.0313	0.1876	0.8274	0.083
(μ/r+λ)	0.9816	1	0.0193	0.0189	0.0042

 ISSN: 2963 – 8798 (ONLINE)

Because the best method chosen is the (μ+λ) method, we multiply it by the content of each type of chicken feed which can be seen in Table 1 IV of types of chicken feed ingredients and get the following results:

TABLE XV
RESULTS TOTAL NUTRITIONAL VALUE IN BROILER FINISHER

bf (μ+λ)	Corn	Sorghum	Rice	Coconut Oil	Tofu Dregs	Total
Protein	5.16	10	0.32	1.12	0.561	17.16
Fat	2.34	2.8	0.068	0.649	0.159	6.01
Fiber	1.2	2	0.36	1.86	0.435	5.8
Calcium	0.054	0.4	0.003	0.023	0.009	0.49
Phosphor	0.18	2.13	0.003	0.063	0.013	2.3
Metabolism Energy	2022	3250	106.4	116	0	5494

After we calculate them one by one, namely corn multiplied by x1, sorghum multiplied by x2, etc.. So, we add up the results of each content in it, which will later be used to calculate the penalty value.

TABLE XVI
RESULTS OF PENALTY VALUE IN BROILER FINISHER

bf (μ+λ)	Limit	Total	Difference	Penalty
Protein	>=18	17.1	18-17.1=0.9	0.9
Fat	<=8	6	2	0
Fiber	<=6	5.8	0.2	0
Calsium	>=0.8 - <=1.2	0.4	0.8-0.4=0.4	0.4
Phosphor	>=0.6 - <=1	0.4	0.6-0.4=0.2	0.2
Metabolism Energy	>=2900	5494	2594	0

For finisher broiler chickens, it can be seen in Table II. The nutritional requirements for finisher broiler chickens for each required nutritional limit. For values that meet the limits, the penalty value is filled in with 0 because they do not violate them, while for those that do not meet the nutritional limits, the difference is calculated to know how many limits have been violated.

3) *Starter-Laying Hens*: When testing starter-laying chickens, the best and most effective method is the (μ/r+λ) method. Therefore, we calculate the penalty value for each chicken feed content. The following is the penalty value for each chicken feed content obtained by multiplying the initial values x1, x2, x3, x4, and x5

ISSN: 2963 – 8798 (ONLINE)

TABLE XVII
RESULTS OF INITIALIZATION IN STARTER LAYING HENS

Method	x1	x2	x3	x4	x5
(μ,λ)	0.017	0.0992	0.0977	0.9793	0.0963
(μ+λ)	0.6385	0.1702	0.1106	0.3131	0.0637
(μ/r,λ)	0.0477	0.0799	0.4274	1	0.0462
(μ/r+λ)	1	0.3998	0.049	0.1819	0.0485

Because the best method chosen was the (μ/r+λ) method, we multiplied it by the content of each type of chicken feed which can be seen in Table IV of types of chicken feed ingredients and obtained the following results:

TABLE XVIII
RESULTS TOTAL NUTRITIONAL VALUE IN STARTER LAYING HENS

ps (μ/r+λ)	Corn	Sorghum	Rice	Coconut Oil	Tofu Dregs	Total
Protein	8.6	3	0.32	2.538	0.748	15.2
Fat	3.9	0.84	0.068	1.461	0.212	6.4
Fiber	2	0.6	0.36	4.197	0.581	7.7
Calcium	0.09	0.12	0.0036	0.052	0.012	0.27
Phosphor	0.3	0.639	0.0032	0.142	0.018	1.1
Metabolism Energy	3370	975	106.4	261	0	4712

After we calculate them one by one, namely corn multiplied by x1, sorghum multiplied by x2, etc.. So, we add up the results of each content in it, which will later be used to calculate the penalty value.

TABLE XIX
RESULTS OF PENALTY VALUE IN STARTER LAYING HENS

ps (μ/r+λ)	Limit	Total	Difference	Penalty
Protein	=20	15.2	20-15.2=4.8	4.8
Fat	.>=2.5 - <=7	6.4	0.6	0
Fiber	<=6.5	7.7	6.5-7.7=-2.2	2.2
Calsium	>=1.05 - <=1.1	0.2	1.05-0.2=1.3	1.3
Phosphor	= 0.48	1.1	0.48-1.1=-0.62	0.62

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ps (μ/r+λ)	**Limit**	**Total**	**Difference**	**Penalty**
Metabolism Energy	>=2980	4712	1732	0

Starter-laying chickens, it can be seen in Table III. The nutritional requirements for starter laying chickens for each required nutritional limit. For values that meet the limits, the penalty value is filled with 0 because they do not violate them, while for those that do not meet the nutritional limits, the difference is calculated to know how many limits have been violated.

4) *Layer-laying hens*: In testing layer-laying chickens, the best and most effective method is the (μ/r+λ) method. Therefore, we calculate the penalty value for each chicken feed content. The following is the penalty value for each chicken feed content obtained by multiplying the initial values x1, x2, x3, x4, and x5

TABLE XX
RESULTS OF INITIALIZATION IN LAYER LAYING HENS

Method	**x1**	**x2**	**x3**	**x4**	**x5**
(μ,λ)	0.0913	0.0565	0.1605	0.0044	0.0569
(μ+λ)	0.6682	0.0997	0.0464	0.2733	0.0654
(μ/r,λ)	0.0526	0.0319	0.3105	0.9013	0.1318
(μ/r+λ)	0.6763	1	0.0034	0.1729	0.1944

Because the best method chosen was the (μ/r+λ) method, we multiplied it by the content of each type of chicken feed which can be seen in Table IV of types of chicken feed ingredients and obtained the following results:

TABLE XXI
RESULTS TOTAL NUTRITIONAL VALUE IN LAYER LAYING HENS

pl (μ/r+λ)	**Corn**	**Sor-ghum**	**Rice**	**Coconut Oil**	**Tofu Dregs**	**To-tal**
Protein	5.16	10	0.24	2.397	3.553	21.3
Fat	2.34	2.8	0.051	1.3804	1.010	7.5
Fiber	1.2	2	0.27	3.9644	2.760	10.1
Calcium	0.054	0.4	0.002	0.0493	0.060	0.5
Phosphor	0.18	2.13	0.002	0.1343	0.0855	2.5
Metabolism Energy	2022	3250	79.8	246.5	0	5598

After we calculate them one by one, namely corn multiplied by x1, sorghum multiplied by x2, etc.. So, we add up the results of each content in it, which will later be used to calculate the penalty value.

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TABLE XXII
RESULTS OF PENALTY VALUE IN LAYER LAYING HENS

pl (μ/r+λ)	Limit	Total	Difference	Penalty
Protein	= 18	21.3	18-21.3=-3.3	3.3
Fat	>=3.5 - <=3.7	7.5	3.7-7.5=-3.8	3.8
Fiber	<=7	10.1	7-10.1=-3.1	3.1
Calsium	>=3.5 - <=4	0.5	3.5-0.5=3.0	3
Phosphor	=0.4	2.5	0.4-2.5=-2.1	2.1
Metabolism Energy	>=2750	5598	2848	0

Layer-laying chickens can be seen in Table III. The nutritional requirements for layer-laying chickens for each required nutritional limit. For values that meet the limits, the penalty value is filled with 0 because they do not violate them, while for those that do not meet the nutritional limits, the difference is calculated to know how many limits have been violated.

5) *Finisher-laying hens*: In testing finisher-laying hens, the best and most effective method is the (μ+λ) method. Therefore, we calculate the penalty value for each chicken feed content. The following is the penalty value for each chicken feed content obtained by multiplying the initial values x1, x2, x3, x4, and x5

TABLE XXIII
RESULTS OF INITIALIZATION IN FINISHER LAYING HENS

Method	x1	x2	x3	x4	x5
(μ,λ)	0.0552	0.0605	0.3876	1	0.0019
(μ+λ)	0.9843	0.6629	0.0076	0.128	0.023
(μ/r,λ)	0.1343	0.1097	0.016	0.2453	0.0503
(μ/r+λ)	0.6893	1	0.0391	0.0241	0.0742

Because the best method chosen was the (μ+λ) method, we multiplied it by the content of each type of chicken feed which can be seen in Table IV of types of chicken feed ingredients and obtained the following results:

TABLE XXIV
RESULTS TOTAL NUTRITIONAL VALUE IN FINISHER LAYING HENS

pf (μ+λ)	Corn	Sorghum	Rice	Coconut Oil	Tofu Dregs	Total
Protein	7.74	6	0.056	1.41	0.374	15.5
Fat	3.51	1.68	0.0119	0.812	0.1064	6.1
Fiber	1.8	1.2	0.063	2.332	0.2906	5.6

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pf (μ+λ)	Corn	Sorghum	Rice	Coconut Oil	Tofu Dregs	Total
Calcium	0.081	0.24	0.00063	0.029	0.0064	0.35
Phosphor	0.27	1.278	0.00056	0.079	0.009	1.6
Metabolism Energy	3033	1950	18.62	145	0	5146

After we calculate them one by one, namely corn multiplied by x1, sorghum multiplied by x2, etc.. So, we add up the results of each content in it, which will later be used to calculate the penalty value.

TABLE XXV
RESULTS OF PENALTY VALUE IN FINISHER LAYING HENS

pf (μ+λ)	Limit	Total	Difference	Penalty
Protein	=17	15.5	17-15.5=1.5	1.5
Fat	>=2.5 - <=3.7	6.1	3.7-6.1=-2.1	2.1
Fiber	<=6.5	5.6	0.9	0
Calsium	>=3.25 - <=4	0.3	3.25-0.3=-2.95	2.95
Phosphor	>=0.33 - <=0.37	1.6	0.37-1.6=-1.23	1.23
Metabolism Energy	>=2750	5146	2396	0

For finisher-laying chickens, it can be seen in Table III. The nutritional requirements for finisher laying chickens for each required nutritional limit. For values that meet the limits, the penalty value is filled with 0 because they do not violate them, while for those that do not meet the nutritional limits, the difference is calculated to know how many limits have been violated.

V. Conclusion

Through the use of algorithms (ES), chicken feed optimization can consider factors such as specific nutritional needs based on chicken type classification, quality of feed ingredients, and nutritional properties needed for optimal growth and production. By paying attention to proper nutritional needs, both in terms of composition and quality of feed ingredients, the ES algorithm can help increase growth, egg production, and meat production in chickens, as well as overall chicken health and welfare.

Acknowledgment

We would like to express our sincere thanks to all parties who have participated and provided support in completing this journal. Without their help and encouragement, writing this journal would not have been completed. The author also thanks his friends who contributed in helping the author complete this journal so that the author can complete it on time.

ISSN: 2963 – 8798 (ONLINE)

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