Linear Programming Initialization Method of Evolution Strategies for Beef Cattle Feed Optimization

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***Abstract*—The biggest expense in cattle fattening is feed costs. Minimize expenses without ruling out the nutrients needed by the cattle is necessary. This study uses Evolution Strategies (ES) to optimize the beef cattle feed. However, the performance of the conventional ES takes a long time to obtain the optimal solution. This may be caused by an error in initial population which is a significant assignment in evolutionary algorithms since it can influence the convergence speed and the final solution quality. Random initialization is the most commonly utilized strategy to initialize the population. This paper proposes a novel initialization approach which utilizes Linear Programming (LP) to produce initial population. The experiments show that the ES (μ/r+λ) with LP surpassed the LP and ES (μ/r+λ). The fitness value obtained from ES (μ/r+λ) with LP was 13.12156 and the price was 763.8331 with zero penalties. The proposed method produce the highest fitness value with the lowest price and the lowest penalty, thus prove the usefulness of LP as the initial population of ES.**

***Index Terms*—Cattle Feed Optimization; Evolution Strategies; Linear Programming; System of Linear Inequalities.**

I. INTRODUCTION

For many years government struggles with the instability of beef price in the market because of supply shortages. Domestic beef production cannot fulfill the market demand so that to overcome this problem, government import beef from another country. This policy harms the local breeder because that imported beef is cheaper than domestic beef. It makes domestic beef is hard to compete with the imported beef. Another solution to overcome this problem is to increase domestic beef production by doing cattle feedlot. The benefits of doing local cattle fattening business are shorter time breeding, satisfy the large market's needs, increase extra benefit from the offer of cattle waste and first is to expand the wage of neighborhood breeder [1-2].

Although it has many advantages, cattle fattening business are not an easy task. It deals with various problems such as limited feed resources, disease, limited marketing area coverage and insufficient capital. However, the biggest issue is the beef market selling price is lower than the cost of livestock breeding [3].

The biggest spending by the breeder when fattening the cattle is cattle feed. For the best result, every cattle has to consume dry matter as much as 1-3% of their weight. The breeder should formulate precisely the proportion of the dry matter so they can reduce feed costs without neglecting the nutritional needs by the cattle [4-6].

There are so many things to consider when formulating the cattle feed. An error in feed formulation will lead to increasing feed costs and non-optimal cattle nutrition. So far the breeder does the formulation manually using trial and error method. This method is easy as it can be done using paper or a PC program, for example, Microsoft Excel. However, this method is slow and the usually the result is not optimal. There are another approach to calculation the optimal feed cattle composition, such as Pearson Square, Linear Programming, and Genetic Algorithm. Pearson Square is the simplest one, but it only works for two feed ingredients and, in some cases, it overrides the needs of other nutrients, such as minerals and vitamins. It is not suitable to formulate feed formulation which has multiple ingredients [7].

Another method is Linear Programming. Many studies utilize this method to find the optimum feed formulation, but the problems regarding volatile feed prices, unequal nutrition, inappropriate solution, and the labile level of feed nutrients still cannot be solved by this method [7].

Genetic Algorithm (GA) is a well-known method with satisfactory research results. GA is a heuristic random search technique proposed by John H. Holland. GA can be seen as evolutionary procedure wherein a population of solutions develops over a succession of generations. The fundamental idea of GA originates from the mechanics of natural selection [8]. GA can be utilized to finding the optimal solution of feed formulation [9]. Evolution Strategies (ES) is another evolutionary algorithm besides GA. It is well known as a method for determining complex improvement issues in different sorts of industries.

Although ES and GA belonging to the class of Evolutionary Algorithms (EAs), yet it has difference reproduction operators. ES are more reliant on mutation while GA uses the crossover as the main reproduction operator and mutation as supporting operator. ES backed up by the self-adaptation presence to control changes to the standard mutation parameters [10]. This paper is utilizing Linear Programming as an initialization population in ES for cattle fattening feed optimization. To ensure that the output only produces a positive value, we utilize random injection mutation as adapted from the previous paper [11].

Our goal is to help the breeder to find the proper combination of nutrients for cattle with minimum costs. If the domestic cattle feedlot success, it can fulfill the market demand and stabilize the beef market prices.

II. MATERIAL

The nutrients used in this study are dry matter, protein, TDN, Calcium, and Phosphorus. Those nutrients for a certain weight and certain daily body weight gain obtained from National Research Council (see Table 1). The list of feed ingredients, nutrition, and price data obtained from East Java Province's Department of Animal Husbandry (see Table 2).

Table 1
Beef Cattle Nutrition Requirement

Body Weight (lb)	Average Daily Gain (lb)	Dry Matter Intake (kg/d)	Crude Protein (kg)	TDN (kg)	Ca (kg)	P (kg)
300	0.5	3.583	0.331	1.950	0.011	0.006

Table 2
Price and Nutrition Data

Ingredients	Price/ kg	Nutrients (%)				
		Dry Matter	Crude Protein	TDN	Ca	P
Rice Straw	100	90	6	51	0.21	0.08
Refined Corn Bran	2000	96.9	7.54	63.4	0.51	0.15
Corn Straw	150	86	6.6	50	1.4	0.3
Imported Fish Flour	4000	91	65	81.2	4	2.6
Molasses	1600	89	3	72	0.9	0.1
Peanut Cake	3500	92	42	78	0.21	0.25
Bulrush	150	89.9	9.1	46	0.7	0.38
Banana Leaf	150	94.6	5.79	73.5	2.54	1.56
Tofu Dregs	600	90	18.7	76	0.32	0.45
Cassava Dregs	650	90	3.7	63.2	0.31	0.15

III. EVOLUTION STRATEGIES

Evolution strategies were particularly appropriate (and created) for nonlinear optimization assignments [12]. In the beginning, there existed two different types of the multi-membered ES, to be specific the (μ,λ) and the (μ+λ) ESs. The symbol μ indicates the number of parents showing up at once in an imaginary individual's population. The symbol λ illustrates the quantity of all offspring made by these parents inside one synchronized generation. The difference between both methodologies comprises in the way the parents of another generation were chosen [13].

In the (μ+λ) ES the λ offspring and their μ parents were united before as indicated by a given criterion, the best individuals were chosen from this arrangement of size μ+λ. In the ES (μ,λ) with $\lambda > \mu \geq 1$, the μ new parents were selected from the λ offspring only regardless of whether they outperform their parents or not [13].

Like with every single established method, the performance of the evolution strategies largely relies on the modification of the internal parameters, unmistakably the mutation strength(s) [14]. The ES cycle described as follows [10]:

```
Procedure EvolutionStrategies
begin
 t = 0
 initialization P(t): generate μ individual
 while (not a stop condition) do
    recombination: produce C(t) as much as λ from P(t)
    mutation C(t)
    selection P(t+1) from P(t) and C(t)
    t = t + 1
 end while
end
```

IV. SYSTEM OF LINEAR INEQUALITIES

A declaration including the symbols >, <, ≥, ≤ is called an inequality [15]. The following is the example of a system of linear inequalities in variables x_1, x_2,…x_n.

$$a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \leq b_1$$

$$a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n > b_2$$

The value(s) of the variable(s) which creates the inequality a true representation is called its solutions. The arrangement of all solutions of inequality is known as the inequality's solution set which is a requested match that is a solution of every inequality in the system. The system of linear inequalities graph is all solutions of the system's graph [15], [16]. To answer an inequality, we can [15]:

1. Add (or subtract) a similar amount to (from) both sides without changing the indication of inequality.
2. Multiply (or separation) both sides by a similar positive amount without changing the inequality sign. Nonetheless, if both sides of the inequality were multiplied (or divided) by a same negative amount the inequality sign is turned around, i.e., ">" changes to "<" and the other way around.

V. LINEAR PROGRAMMING

Numerous viable applications can be explained by utilizing Linear Programming. The way of these issues is that certain constraints exist or are set the variables, and some function of these variables must be maximized or minimized. The constraints are frequently composed of a system of linear inequalities. The below steps can be utilized to deal with linear programming applications [17].

1. Specify variables.
2. Compose the constraints as a system of inequalities.
3. Graph the system and discover the coordinates of the vertices of the polygon shaped.
4. Compose an expression whose value is to maximized or minimized.
5. Substitute values from the coordinates of the vertices into the expression.
6. Select the best or minimum outcome.

VI. METHODOLOGY

A. Chromosome Representation

The chromosome consists of the feed ingredients used in the formulation. Each gene was obtained from the weight of fresh ingredients. Table 3 shows the example of chromosome representation.

Table 3
Chromosome Representation

Rice Straw (x_1)	Molasses (x_2)	Corn Straw (x_3)
0.12436	0.23123	0.75633

B. Initialization Population

As it has been known, random number generation is the most commonly utilized strategy for all EAs to initialize the population. The idea of Linear Programming initialization population can help us to acquire proper initial population. We propose the following Linear Programming population initialization algorithm which can be utilized rather than full random initialization. Here are the steps of our proposed algorithm.

1. Generate the first individual using LP.
2. Generate the rest of individual using random value.
3. Use the initial population from step 1 and 2 for ES.

The function used in LP can be seen from Equation (1-6) as follows. These equations were obtained from beef cattle nutrition requirement (see Table 1) and nutrients for each ingredient (see Table 2).

$$\text{Min: } 100x_1 + 2000x_2 + 150x_3 + 4000x_4 + 1600x_5 + 3500x_6 + 150x_7 + 150x_8 + 600x_9 + 650x_{10} \quad (1)$$

$$0.9x_1 + 0.969x_2 + 0.86x_3 + 0.91x_4 + 0.89x_5 + 0.92x_6 + 0.899x_7 + 0.946x_8 + 0.9x_9 + 0.9x_{10} \geq 3.583 \quad (2)$$

$$0.06x_1 + 0.0754x_2 + 0.066x_3 + 0.65x_4 + 0.03x_5 + 0.42x_6 + 0.091x_7 + 0.0579x_8 + 0.187x_9 + 0.037x_{10} \geq 0.331 \quad (3)$$

$$0.51x_1 + 0.634x_2 + 0.5x_3 + 0.812x_4 + 0.72x_5 + 0.78x_6 + 0.46x_7 + 0.735x_8 + 0.76x_9 + 0.632x_{10} \geq 1.950 \quad (4)$$

$$0.0021x_1 + 0.0051x_2 + 0.014x_3 + 0.04x_4 + 0.009x_5 + 0.0021x_6 + 0.007x_7 + 0.0254x_8 + 0.0032x_9 + 0.0031x_{10} \geq 0.011 \quad (5)$$

$$0.0008x_1 + 0.0015x_2 + 0.003x_3 + 0.026x_4 + 0.001x_5 + 0.0025x_6 + 0.0038x_7 + 0.0156x_8 + 0.0045x_9 + 0.0015x_{10} \geq 0.006 \quad (6)$$

C. Fitness Function

The fitness function for this study shown in Equation (7) which the total price obtained using Equation (8).

$$Fitness = \frac{10000}{total\ price + (total\ penalty * 10000)} \quad (7)$$

$$Total\ price = 100x_1 + 2000x_2 + 150x_3 + 4000x_4 + 1600x_5 + 3500x_6 + 150x_7 + 150x_8 + 600x_9 + 650x_{10} \quad (8)$$

If the individual nutrient value is less than the nutrition requirements, then the penalty awarded. The penalty was obtained from the difference between the nutrition requirements with the result obtained from the method (see Equations (9-13)).

$$penalty_{dry\ matter} = \begin{cases} 0, if \begin{pmatrix} 0.9x_1 + 0.969x_2 + 0.86x_3 \\ +0.91x_4 + 0.89x_5 + 0.92x_6 \\ +0.899x_7 + 0.946x_8 + 0.9x_9 \\ +0.9x_{10} \end{pmatrix} \geq 3.583 \\ 3.583 - \begin{pmatrix} 0.9x_1 + 0.969x_2 + 0.86x_3 + 0.91x_4 \\ +0.89x_5 + 0.92x_6 + 0.899x_7 \\ +0.946x_8 + 0.9x_9 + 0.9x_{10} \end{pmatrix}, others \end{cases} \quad (9)$$

$$penalty_{crude\ protein} = \begin{cases} 0, if \begin{pmatrix} 0.06x_1 + 0.0754x_2 + 0.066x_3 \\ +0.65x_4 + 0.03x_5 + 0.42x_6 \\ +0.091x_7 + 0.0579x_8 + 0.187x_9 \\ +0.037x_{10} \end{pmatrix} \geq 0.331 \\ 0.331 - \begin{pmatrix} 0.06x_1 + 0.0754x_2 + 0.066x_3 \\ +0.65x_4 + 0.03x_5 + 0.42x_6 \\ +0.091x_7 + 0.0579x_8 + 0.187x_9 \\ +0.037x_{10} \end{pmatrix}, others \end{cases} \quad (10)$$

$$penalty_{TDN} = \begin{cases} 0, if \begin{pmatrix} 0.51x_1 + 0.634x_2 + 0.5x_3 \\ +0.812x_4 + 0.72x_5 + 0.78x_6 \\ +0.46x_7 + 0.735x_8 + 0.76x_9 \\ +0.632x_{10} \end{pmatrix} \geq 1.950 \\ 1.950 - \begin{pmatrix} 0.51x_1 + 0.634x_2 + 0.5x_3 \\ +0.812x_4 + 0.72x_5 + 0.78x_6 \\ +0.46x_7 + 0.735x_8 + 0.76x_9 \\ +0.632x_{10} \end{pmatrix}, others \end{cases} \quad (11)$$

$$penalty_{calcium} = \begin{cases} 0, if \begin{pmatrix} 0.0021x_1 + 0.0051x_2 + 0.014x_3 \\ +0.04x_4 + 0.009x_5 + 0.0021x_6 \\ +0.007x_7 + 0.0254x_8 + 0.0032x_9 \\ +0.0031x_{10} \end{pmatrix} \geq 0.011 \\ 0.011 - \begin{pmatrix} 0.0021x_1 + 0.0051x_2 + 0.014x_3 \\ +0.04x_4 + 0.009x_5 + 0.0021x_6 \\ +0.007x_7 + 0.0254x_8 + 0.0032x_9 \\ +0.0031x_{10} \end{pmatrix}, others \end{cases} \quad (12)$$

$$penalty_{phosporus} = \begin{cases} 0, if \begin{pmatrix} 0.0008x_1 + 0.0015x_2 + 0.003x_3 \\ +0.026x_4 + 0.001x_5 + 0.0025x_6 \\ +0.0038x_7 + 0.0156x_8 + 0.0045x_9 \\ +0.0015x_{10} \end{pmatrix} \geq 0.006 \\ 0.006 - \begin{pmatrix} 0.0008x_1 + 0.0015x_2 + 0.003x_3 \\ +0.026x_4 + 0.001x_5 + 0.0025x_6 \\ +0.0038x_7 + 0.0156x_8 + 0.0045x_9 \\ +0.0015x_{10} \end{pmatrix}, others \end{cases} \quad (13)$$

D. Reproduction

This study uses ES (μ/r+λ) which utilize the recombination and mutation. The recombination was used to produce offspring as many as λ of a number of individuals in the population μ. In this study, every single individual offspring produced from two parents which selected randomly from the population. The offspring generated by calculating the average value of the parent element. After the offspring obtained, it mutated using the following equations Eq. (14-15) [18].

$$x' = x + N(0,1) \quad (14)$$

$$N(0,1) = \sqrt{-2.\ln r_1} \sin 2\pi r_2 \quad (15)$$

$N(0,1)$ is a random number that follows a normal distribution with an average of 0 and a standard deviation of 1. The value of r_1, r_2 were generated randomly between 0 and 1.

E. Selection

Based on [18] and [19], elitist selection has produced fit populations and can be used to keep up the population diversity and escape from local optimum to examine the search space. Therefore, in this study, we use the elitist selection which selects the next population from parents and offspring.

VII. Experimental Result

The ES parameters were determined as follows:

- μ = 500
- λ = 50
- Chromosome length = 10
- Number of generations = 10,000
- ES type = ES (μ/r+λ)

The testing using cattle with a weight of 300 lb with a daily weight gain of 0.5 lb/day (see Table 1) by using ten feed ingredients (see Table 2). ES was run ten times.

A. Best Feed Combination from LP

The linear function and problem constraints used was presented in Equations (1-6). The Table 4 below shows the best feed combination for each ingredient obtained by LP.

Table 4
Best Feed Combination from LP

Rice Straw	Refined Corn Bran	Corn Straw	Imported Fish Flour	Molasses
1.33918	0.0	0.0	0.0	0.0
Peanut Cake	**Bulrush**	**Banana Leaf**	**Tofu-Dregs**	**Cassava Dregs**
0.0	2.75439	0.0	0.0	0.0

Table 5
The Fulfillment of Beef Cattle Nutrition by LP

Nutrients	Dry Matter	Crude Protein	TDN	Calcium	Phosphorus
Min	3.583	0.231	1.95	0.011	0.006
Max	5.443	0.479	-	0.074	0.037
Result	3.68146	0.29765	1.75373	0.01986	0.01037

For the result obtained by LP (see Table 10), even though the total price was 547.07602, the amount of TDN did not meet the minimum TDN for beef cattle (see Table 5). It caused the penalty was 0.19627, which obtained from the difference between minimum TDN and the obtained result. The penalty contributes to the low fitness value (3.98447).

B. Best Feed Combination from ES (μ/r+λ) Without LP

Table 6 shows the best ingredient from ES (μ/r+λ) without LP. Based on Table 7, ES (μ/r+λ) was able to provide the nutrient requirement for beef cattle.

Table 6
Best Feed Combination from ES (μ/r+λ) Without LP

Rice Straw	Refined Corn Bran	Corn Straw	Imported Fish Flour	Molasses
2.03528	0.01609	0.9747	0.00579	0.04547
Peanut Cake	**Bulrush**	**Banana Leaf**	**Tofu-Dregs**	**Cassava Dregs**
0.00669	0.35305	0.7216	0.06526	0.04309

Table 7
The Fulfillment of Beef Cattle Nutrition by ES (μ/r+λ) Without LP

Nutrients	Dry Matter	Crude Protein	TDN	Calcium	Phosphorus
Min	3.583	0.231	1.95	0.011	0.006
Max	5.443	0.499	-	0.077	0.038
Result	3.83502	0.25445	2.11830	0.03612	0.01637

Based on Table 10, the penalty obtained from ES (μ/r+λ) without LP was 0, the total price was 729.602, and the fitness value was 13.70610.

C. Best Feed Combination from ES (μ/r+λ) With LP

Table 8 shows the best ingredient from ES (μ/r+λ) with LP. Based on Table 9, ES (μ/r+λ) was able to provide the nutrient requirement for beef cattle.

Table 8
Best Feed Combination from ES (μ/r+λ) With LP

Rice Straw	Refined Corn Bran	Corn Straw	Imported Fish Flour	Molasses
1.58458	0.01836	0.22226	0.00466	0.01106
Peanut Cake	**Bulrush**	**Banana Leaf**	**Tofu-Dregs**	**Cassava Dregs**
0.00709	0.4167	1.58996	0.17759	0.00591

Table 9
The Fulfillment of Beef Cattle Nutrition by ES (μ/r+λ) With LP

Nutrients	Dry Matter	Crude Protein	TDN	Calcium	Phosphorus
Min	3.583	0.231	1.95	0.011	0.006
Max	5.443	0.481	-	0.074	0.037
Result	3.69953	0.25658	2.25246	0.04739	0.02749

Based on Table 10, the penalty obtained from ES (μ/r+λ) with LP was 0, the total price was 701.0625, and the fitness value was 14.26406. The penalty from ES (μ/r+λ) without LP and ES (μ/r+λ) with LP were the same. However, the total price from ES (μ/r+λ) with LP produced a lower price by a margin of 28.5395. This led to a higher fitness value by a margin of 0.55796.

D. The Comparison of LP, ES (μ/r+λ) Without LP, and ES (μ/r+λ) With LP

From Table 10 and Table 11, the ES (μ/r+λ) with LP surpassed the ES (μ/r+λ) and LP. The best fitness value conducted from experiments was 14.26406 with total price 701.0625. The penalty obtained by ES (μ/r+λ) and ES (μ/r+λ) with LP were 0 (zero) which means that the nutrient conducted from experiments can meet the cattle's requirements. Even though the LP produce lower price, the penalty of LP was higher than the other methods.

Table 10
Best Fitness Value, Total Penalty, and Total Price

	Fitness Value	Total Penalty	Total Price
LP	3.98447	0.19627	547.07602
ES (μ/r+λ)	13.70610	0	729.602
ES (μ/r+λ) with LP	14.26406	0	701.0625

Table 11
Average Fitness Value, Total Penalty, and Total Price

	Fitness Value	Total Penalty	Total Price
LP	3.98446	0.19627	547.07602
ES (μ/r+λ)	12.8373	0	772.7941
ES (μ/r+λ) with LP	13.12156	0	763.8331

From Figures 1 and 2, the fitness value was always increased and the price decreases for each generation. It starting to converge when the number of generation was 8676 with the best fitness value was 13.70610, the average fitness value was 12.8373, and the worst fitness value was 12.08422.

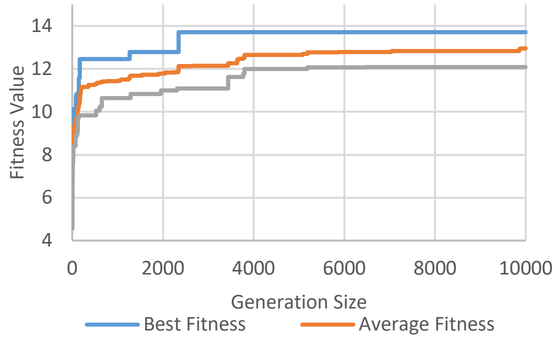

Figure 1: Fitness chart for ES (μ/r+λ) without Linear Programming

Figure 2: Total price chart for ES (μ/r+λ) without Linear Programming

From Figure 3 and 4, the fitness value was always increased and the price decreases for each generation. It starting to converge when the number of generation was 8453 with the best fitness value was 14.26406, the average fitness value was 13.12156, and the worst fitness value was 12.22528.

By comparing those charts and observe the starting-point of the average fitness value convergence, the ES (μ/r+λ) with LP was converge faster (start at 8453rd generation). The ES (μ/r+λ) without LP was a little longer (start at 8676th generation). However, the best fitness value of ES (μ/r+λ) without LP was not changed from 2343rd generation until 10000th generation.

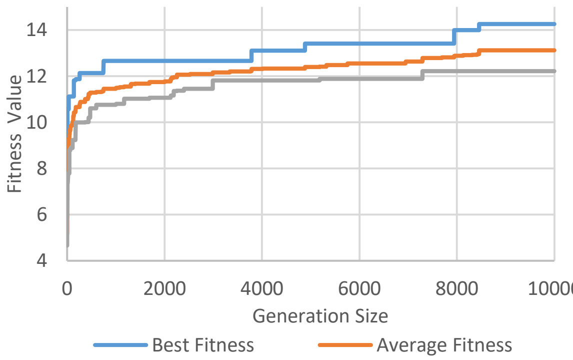

Figure 3: Fitness chart for ES (μ/r+λ) with Linear Programming

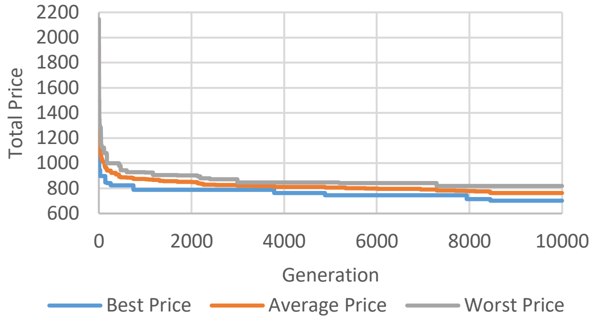

Figure 4: Total price chart for ES (μ/r+λ) with Linear Programming

VIII. CONCLUSION

ES (μ/r+λ) and ES (μ/r+λ) with LP that create preferred outcomes over linear programming in the solution of nonlinear feed mix problems which is one of the issues experienced in the beef cattle feed optimization were demonstrated in consistence with the problem and utilized. As indicated by results, ES (μ/r+λ) with LP deliver more rapid with zero penalties and the cost was lower than LP and ES (μ/r+λ). Thus, prove the usefulness of LP as the initial population of ES. Furthermore, from the experiments, it can be concluded that the proposed solution enabled us to obtain the best fitness. It has as of now been acknowledged that new era optimization strategies have a lot of prospects as it has direct practical utility in the field of cattle feed nutrition.

IX. REFERENCES

[1] R. Tawaf and H. A. W. Lengkey, "The impact of imported beef boxed to feedlot business development in Indonesia," vol. 53, pp. 401–409, 2007.
[2] J. L. Malole, R. J. M. Kadigi, and A. Z. Sangeda, "Costs and benefits of beef cattle fattening schemes some selected areas of north west Tanzania," *Iran. J. Appl. Anim. Sci.*, vol. 4, no. 4, pp. 699–706, 2014.
[3] T. Lijalem, A. Daniel, and T. Ermias, "Assessment of beef cattle fattening in selected districts of Hadya," *J. Biol. Agric. Healthc.*, vol. 6, no. 5, pp. 167–172, 2016.
[4] R. M. Garrard and J. B. Glaze, "Supplement allows ranchers to eliminate hay feeding and reduce winter feed costs," *J. Ext.*, vol. 46, no. 3, 2008.
[5] A. F. J. Cordova, J. D. Wallace, and R. D. Pieper, "Forage intake by grazing livestock : a review," *J. Range Manag.*, vol. 31, no. 6, pp. 430–438, 1978.
[6] P. U. Hadi, N. Ilham, A. Thahar, B. Winarso, D. Vincent, and D. Quirke, "Improving Indonesia's beef industry," Australian Centre for International Agricultural Research, Canberra, ACT, Australia, 2002.
[7] A. M. Olatunde and M. Afolayan, "Nigeria Oriented Poultry Feed Formulation Software Requirements," *J. Appl. Sci. Res.*, vol. 4, no. 11, pp. 815–821, 2006.
[8] S. Lianshuan and W. Huahui, "A Multi-Agent Self-Adaptive Multi-Objective Genetic Algorithm," *Int. J. Intell. Eng. Syst.*, vol. 8, no. 2, pp. 7–13, 2015.
[9] R. A. Rahman, C. Ang, and R. Ramli, "Investigating Feed Mix Problem Approaches : An Overview and Potential Solution," *World Acad. Sci. Eng. Technol.*, vol. 46, no. 10, pp. 424–432, 2010.
[10] W. F. Mahmudy, "Evolutionary algorithms (algoritma evolusi)," *Progr. Inf. Technol. Comput. Sci. Univ. Brawijaya, Malang*, pp. 73–82, 2013.
[11] T. N. Fatyanosa and W. F. Mahmudy, "(in press). Modified evolution strategies for beef cattle feed optimization," *Int. J. Intell. Eng. Syst.*, 2016.
[12] T. Bäck, C. Foussette, and P. Krause, *contemporary evolution strategies*. Berlin: Springer-Verlag Berlin Heidelberg, 2013.
[13] H. Schwefel, G. Rudolph, and T. Bäck, *Contemporary evolution strategies*. Berlin: Springer-Verlag Berlin Heidelberg, 1995.
[14] H.-G. Beyer and H.-P. Schwefel, *Evolution strategies – A comprehensive introduction*, vol. 1, no. 1. Berlin: Kluwer Academic Publisher, 2002.

[15] Disha Experts, "Linear inequalities," in *NCERT Solutions Class 11 Mathematics*, New Delhi: Disha Publication, 2013, pp. 98–99.

[16] R. Larson, L. Boswell, T. D. Kanold, and L. Stiff, "Systems of linear equations and inequalities," in *Algebra 2: Applications, Equations, Graphs*, Boston, Massachusetts: Houghton Mifflin Harcourt, 2004, p. 156.

[17] G. J. Cuevas, D. Marks, J. A. Carter, B. Holliday, and M. S. McClure, "Systems of linear equations and inequalities," in *Systems Of Linear Equations And Inequalities*, New York: McGraw-Hill Education, 2005, pp. 115–116.

[18] H. P. P. Schwefel, *Evolution and optimum seeking: the sixth generation*. New York: Wiley, 1995.

[19] C. Chudasama, S. M. Shah, and M. Panchal, "Comparison of parents selection methods of genetic algorithm for TSP," in *International Conference on Computer Communication and Networks CSI-COMNET*, 2011, pp. 85–87.

[20] W. F. Mahmudy, R. M. Marian, and L. H. S. Luong, "Real coded genetic algorithms for solving flexible job-shop scheduling problem - part I: modelling," *Adv. Mater. Res.*, vol. 701, pp. 359–363, 2013.