



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**

# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 7, July 2024

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 8.423

 9940 572 462

 6381 907 438

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# Optimization of Layer Chicken Feed Formula with Nutritional Criteria and Cost Efficiency Using Linear Programming Method

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**ABSTRACT:** In the management of layer chickens, three equally important factors play critical roles: breeding, feeding, and management. Feed, either a single type of feedstuff or a mixture of various ingredients, must meet the nutritional needs for maintenance and production without compromising the chickens' health. Therefore, it is essential to formulate chicken feed that meets their nutritional requirements to maintain their health and enhance egg quality.

This study designs a web-based program to formulate chicken feed according to the nutritional needs at each stage of the layer chicken's life. Using the Linear Programming method, the program selects the best feed composition from all possible combinations of ingredients that meet specific nutritional criteria. Besides calculating the nutritional content of the feed composition, the program also identifies the least costly combination of ingredients. Users can input feed ingredients based on available stock and can limit the usage quantity of each ingredient.

Test results show that the program successfully identifies the most cost-effective feed composition using predetermined ingredients. Although the cost is lower, the nutritional content still meets the required criteria. Additionally, the program was tested against X farm's current feed formulation to compare whether their feed formulation meets all necessary criteria and represents the most cost-effective feed composition. Testing also included a scenario where the prices of corn and wheat were swapped to verify if the program could still find the optimal and cost-efficient feed combination.

**KEYWORDS:** Chicken Feed, Feed Formulation, Layer Chicken, Linear Programming, Machine Learning, Optimization Theory

## I. INTRODUCTION

In livestock maintenance, three equally important factors play critical roles: breeding, feeding, and management. Therefore, feed for laying hens plays a crucial role in their maintenance as the selection of feed greatly affects their performance, egg production, and egg quality. The growth stages of laying hens involve several phases, each requiring feed with specific compositions. Chicken feed is divided into four essential phases: starter, grower, pre-layer, and layer. In the early growth stage, such as Day-Old Chicks (DOC), starter feed is the most suitable to support early growth and the development of the digestive system. From 40 days to 10 weeks of age, chickens enter the starter phase where high-protein and nutrient-rich feed is required to support body growth and the further maturation of the digestive system. During the grower stage, lasting from 10 to 14 weeks, the feed focus shifts to muscle and bone development as the growth rate slows down. From 14 to 16 weeks, chickens enter the pre-layer phase where feed becomes important to prepare the reproductive system. Finally, the main egg production stage, from 16 weeks until the end of the laying period, requires layer feed specially formulated with appropriate protein and nutrient levels to support optimal egg production.

So far, poultry feed mills have only provided ready-made feed mixtures with different formulas for each growth phase. However, to save on operational costs, farmers usually start producing their own feed (self-mixing feed). This step helps control production costs and ensures the availability of feed that meets the specific needs of laying hens. When producing their own feed, farmers can adapt formulations according to the growth stages, ensuring optimal nutrient content for each stage. Despite the potential cost savings, self-mixing feed requires careful management and a deep understanding of feed composition and the nutritional needs of chickens to maintain their health and productivity. Monitoring the physical quality of the feed, evaluating daily feed intake, and paying attention to chicken health are essential steps. By understanding the nutritional needs at each growth stage, farmers can design optimal feed formulas,

replacing ready-made mixtures with self-produced feed. This decision allows farmers to control operational costs while ensuring the availability of feed that meets the needs of laying hens throughout their growth phases.

## II. RELATED WORK

The optimization of feed formulations for poultry using linear programming and other mathematical methods has been extensively studied in recent years. Various approaches have been employed to address the complexities involved in formulating nutritionally adequate and cost-effective diets for layer chickens.

### A. Layer Chicken

Laying hens are chickens raised specifically for egg production. Indonesian native chickens generally originate from jungle fowl and wild ducks, which were captured and kept for their eggs. Laying hens are the result of genetic engineering and have been domesticated for both egg and meat production[1]. Genetic improvements are continuously made to achieve more optimal laying hen performance, enabling them to produce a large number of high-quality eggs. Good laying hens can begin to produce eggs optimally at the age of 24-26 weeks. However, to produce optimal chickens and eggs, the hens must be well-maintained with adequate nutrition from hatching until the end of their laying period.

The growth phases of laying hens include Day-Old Chick, Starter, Grower, Pre-Layer, Layer, and Finisher. Day-Old Chick, commonly referred to as DOC, is the first stage in the growth of chickens, occurring when the chicks have just hatched and are less than 24 hours old. At this stage, chicks are highly susceptible to illness and death and require a warm and clean environment. Farmers typically use incubators or heaters to maintain optimal temperatures and ensure the chicks stay healthy[2]. Chicks also need specialized feed for this early growth stage, containing high protein levels to support rapid body growth and weight gain. The starter phase follows the DOC stage and lasts until the chicks are about three weeks old. During this phase, the chicks grow larger and become more active, necessitating a larger coop. Proper nutrition is crucial at this stage, focusing on adequate protein and vitamins to support bone and muscle growth. The grower phase occurs when the chickens are about 4 to 10-12 weeks old, depending on the type of chicken and the farm's focus (meat or eggs). In this phase, chickens begin to grow rapidly, and their nutritional needs change slightly, with a decrease in protein content compared to the starter phase.

The pre-layer phase is the transition period before laying hens begin to lay eggs, usually when they are 12 to 18-20 weeks old. During this phase, hens prepare for egg-laying, and their nutritional needs change again. Feed given to pre-layer hens should be high in calcium and other minerals to support eggshell formation. Farmers need to ensure that hens have enough space for nesting. The layer phase is when hens start laying eggs, usually from 18-20 weeks old and continuing up to around 72 weeks or more. During this phase, hens need special coops with adequate nesting spaces. Nutrition is vital to maintaining good health and high egg production. Feed must be rich in calcium and protein to support consistent egg production. Farmers need to pay close attention to lighting, temperature, and sanitation to ensure high-quality eggs and optimal egg production. The finisher phase, also known as the culling period, is the final stage of the layer chicken's life cycle when egg production significantly declines or the hens are no longer efficient at producing eggs. Culled hens are usually harvested for meat or other products. In some cases, culled hens can be sold to markets for older chickens for specific processing. Farmers need to ensure that hens reaching this stage are treated well and harvested properly according to procedures.

### B. Chicken Feed

Feedstuffs refer to all substances that can be eaten and partially or fully digested, allowing them to be absorbed for the livestock's survival. Feedstuffs must meet the livestock's maintenance and productivity needs without compromising their health and should be beneficial to the animals. In feed companies, the mixture of formulated ingredients is called finished feed. A ration is the feed provided to livestock over a 24-hour period, regardless of its quantity or quality. A balanced ration is one that meets both the quantity and nutritional content appropriate for its intended maintenance.

The feed ingredients used in the formulation of chicken feed for laying hens at various growth phases, such as Starter, Grower, Developer, Pre-layer, and Layer, play a crucial role in supporting the health and productivity of the chickens[3]. Feed mills also produce chicken feed tailored for each growth phase, such as Starter, Grower, Developer, Pre-Layer, Layer, and Finisher. Generally, there are three forms of feed that can be produced from feed ingredients: mash, pellets, and crumble. The form of the feed is influenced by the ingredients used in the feed formulation.



In the process of formulating chicken feed, there are over 100 ingredients that can be mixed. Common ingredients in chicken feed include[4]:

- Corn: Rich in carbohydrates, providing energy for growth and activities of chickens.
- Rice: High in energy content but lower in protein compared to corn.
- Wheat: Similar in energy content to corn, but higher in protein.
- Corn Gluten Feed: A byproduct of the corn milling process with high crude protein content, beneficial for chickens.
- Soybeans: The highest plant-based protein content among feeds, containing high levels of amino acids such as lysine and tryptophan.
- Soybean Meal: Made from extracted soybean oil, it is an essential source of plant-based protein for chicken growth and development.
- Pollard: A byproduct from wheat milling, containing fiber, vitamins, and minerals that aid in chicken digestion.
- Meat and Bone Meal (MBM): A byproduct of beef or pork production, high in animal protein but tends to be more expensive.
- Vitamins and Minerals (Premix): Essential for body metabolism, growth, and chicken health, required in small amounts.
- Feed Additives: Such as Biofos and Aking, which maintain the quality of chicken feed and address specific issues like controlling fly populations.
- Antibiotics: Substances produced by living organisms that can inhibit or destroy pathogens. Farmers need to pay attention to withdrawal times to avoid potential issues.

The ingredients mentioned above are just a few examples of those that can be used in the chicken feed production process. In feed management, the selection and quality testing of raw materials to formulate feed that meets the protein requirements at each growth stage is the focus. This can optimize egg productivity and improve the quality and health of laying hens[5]. The choice of feed ingredients also affects chicken manure. Generally, broiler chicken manure contains more ammonia than that of laying hens because broilers require more chemicals compared to laying hens.

### C. Linear Programming

Linear Programming (LP) is a mathematical optimization technique used to find the optimal (maximum or minimum) value of a linear function within the context of linear constraints[6]. In mathematical terms, LP is a tool to optimize (minimize or maximize) a linear function of a set of decision variables while adhering to several problem constraints. In LP, problems are expressed through an objective function that needs to be optimized and a series of constraints expressed as linear equations or inequalities[7]. The main goal of LP is to find the values of decision variables that satisfy all constraints while simultaneously optimizing the value of the objective function[8].

Using LP to address complex problems, such as feed formulation with various raw materials and different nutritional contributions, proves to be a highly effective method for providing structured solutions to enhance the overall efficiency of chicken feed formulation.

## III.METHODOLOGY

This study utilizes Linear Programming (LP) as a mathematical optimization technique to find the optimal (maximum or minimum) value of a linear function within the context of linear constraints. LP is a tool to optimize (minimize or maximize) a linear function of a set of decision variables while adhering to several problem constraints. The primary objective of LP is to find the values of decision variables that satisfy all constraints while simultaneously optimizing the value of the objective function.

The application of LP in addressing complex problems, such as feed formulation with various raw materials and different nutritional contributions, proves to be a highly effective method for providing structured solutions to enhance the overall efficiency of chicken feed formulation.

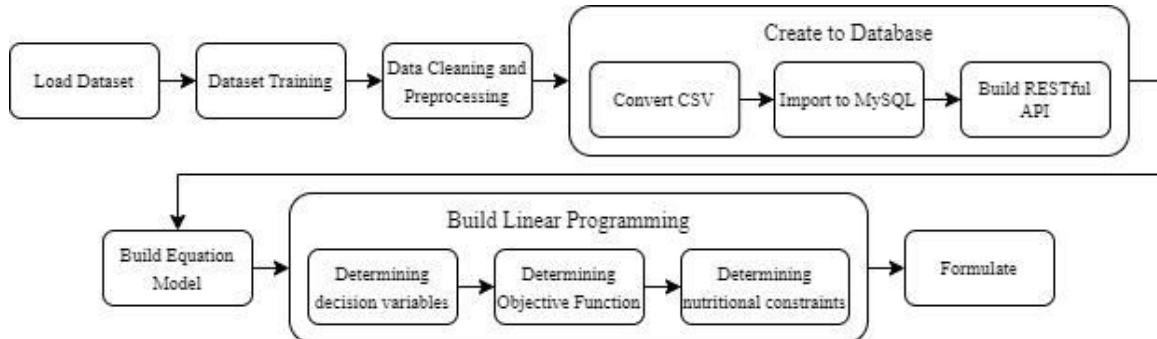


Fig. 1. Dataset and Linear Programming

Fig.1 represents the data that has been entered into the database will be called in Python to formulate equations based on the available nutritional content. Subsequently, these data will be processed using Linear Programming methods to find the optimal solution for chicken feed types and selected ingredients at the minimum cost.

#### IV. EXPERIMENTAL RESULTS

The testing will utilize a dataset stored in a MySQL database containing food ingredients with their prices and nutritional contents, as well as nutritional criteria for various types of chicken feed provided by the program, including both minimum and maximum parameters. When the program runs, the user will input the chicken feed type (phase) and the specific food ingredients they wish to use. The program will then output the composition of the food ingredients, the total cost of the feed, and the total nutrition produced. However, if no food ingredients meet the selected nutritional criteria, the program will output the text 'No solution found.'

Therefore, the results of this testing include:

- Determining the number of food ingredients that can be used to meet the selected nutritional criteria.
- Comparing the total cost of the feed produced by the chicken feed optimization program with other chicken feed formulations.

##### A. Testing Based on the Paper "Feed Formulation Using Phytase in Laying Hen Diets" by F.G. Silversides and M. Hruby

Three diet formulas were used for these chickens: a formula containing 0, 300, and 600 U/kg of phytase, with or without enzyme supplementation. Phytase is considered capable of releasing phosphorus (P), calcium (Ca), energy, and protein. This test used a chicken feed formulation containing 0 U/kg of phytase and no enzyme supplementation. The result can be seen on table 1.

Table 1. The food ingredients used in the chicken feed for Lohmann Classic Brown chickens

Ingredients	Ammount
BARLEY [SID]	36.75 kg
CAMELINA MEAL [CR]	21.30 kg
CANOLA MEAL [CR]	160.20 kg
COMMON SALT	4.95 kg
CORN [CR]	751.20 kg
DICAL. PHOS.	18.45 kg
DL-METHIONINE	1.50 kg
LIMESTONE	134.10 kg
SOYBEAN MEAL (44% CP) [CR]	248.25 kg
VITAMIN PREMIX	3.30 kg
WHEAT [SID]	120.00 kg

**B. Testing Based on the Paper "Effect of Feed Form, Formulation, and Restriction on the Performance of Laying Hens" by T. A. Scott, F. G. Silversides, D. Tietge, and M. L. Swift**

In the study "Effect of Feed Form, Formulation, and Restriction on the Performance of Laying Hens" by T. A. Scott, F. G. Silversides, D. Tietge, and M. L. Swift, an egg production experiment was conducted on 1,440 laying hens from the DeKalb® factory, housed in barns at 18 weeks of age, to test the effects of feed form (expanded pellets or mash) and formulation type (based on Crude Protein [CP] or amino acids [AA]). This experiment was conducted at five levels of feed restriction applied at 24 weeks or 32 weeks of age.

Table 2. The food ingredients used in the chicken feed for HP for laying hens.

Ingredients	Ammount
CANOLA MEAL [CR]	63.90 kg
CHOLINE CL -70%	3.75 kg
COMMON SALT	4.65 kg
CORN [CR]	75.00 kg
DICAL. PHOS.	4.95 kg
FAT, ANIMAL	22.50 kg
FISH MEAL, Menhaden [CR]	39.30 kg
L-LYSINE HCL	5.85 kg
L-THREONINE	2.70 kg
L-TRYPTOPHAN	0.75 kg
LIMESTONE	126.00 kg
MEAT & BONE MEAL. CP<45% [SID]	118.50 kg
VITAMIN PREMIX	3.15 kg
WHEAT [SID]	1029.00 kg

**V. CONCLUSION**

Based on the results of the tests conducted, both from academic papers and real-life cases at barn X, several conclusions can be drawn. In testing against the papers, the nutritional requirements of both chicken feed compositions from the papers—whether written by F.G. Silversides and M. Hruby or by A. Scott, F.G. Silversides, D. Tietge, and M.L. Swift—are equally fulfilled by the composition generated by the chicken feed optimization program. However, the nutritional content of the food ingredient composition produced by the optimization program is slightly closer to the given minimum parameters. Moreover, the total cost of the chicken feed produced by the optimization program is lower compared to the total cost of the chicken feed based on both papers. This is because in both papers, the authors focused more on specific chicken feed compositions according to their respective research, prioritizing nutrition over cost. This demonstrates that the chicken feed optimization program aims to find a cost-effective chicken feed composition.

In the testing conducted at barn X, the total cost of the feed produced by the food ingredient composition from barn X is higher than the feed composition produced by the chicken feed optimization program. Additionally, the nutritional content in the food ingredient composition from barn X does not fully meet the nutritional criteria for the tested chicken feed type. Furthermore, the nutritional content from barn X lacks three nutritional criteria: Na (sodium), choline, and dMET. A drawback of the chicken feed optimization program is the need for specific experience and skills in chicken husbandry. Additionally, deeper knowledge of chicken characteristics and the required food ingredients is necessary to operate the chicken feed optimization program effectively.

In addition to testing based on existing papers, the testing for this thesis is conducted in a real case, specifically by testing food materials in barn X. This testing involves inputting all available food materials in barn X, including those already in the warehouse (barn stock) and accessible materials. The first step is selecting the type of chicken feed for a specific phase, utilizing parameters provided by the program or using custom inputs. Once the parameters are chosen, the second step is selecting the food materials to be used in the calculation process. Besides selecting the status of the food materials, minimum and maximum limits can also be added to active food materials. Then, testing can be

conducted multiple times until a suitable composition of food materials that is cost-effective according to the barn's needs and conditions is found.

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