Cost Minimization of Feeds in RGS Hog Farm in the Philippines: An Operation Research Approach

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Abstract

The coronavirus disease poses a health threat not only to humans but also causes disruptions in the animal feed industry which had a huge impact on the hog industry. The uptrend rise in feed costs is one of the serious issues present in the said industry. To provide recommendations on how to deal with the threat of the rising cost of hog meat in the country, a case study was applied to test the proposed feed combination by utilizing linear programming to obtain an optimal solution in minimizing feed costs. The researchers considered RGS Hog Farm, a company established in 2018 and is located in San Pablo City, Laguna, Philippines. Using the linear programming method, the results yielded the minimum value of the objective function Z=29 occurring at the extreme point (0.5,0.5). Thus, the optimal solution can minimize the cost of feed consumption for as low as 29 dollars with a diet program inclusive of a combination of 25 kilograms each of ABC Feeds and XYZ Feeds. The amount of the combination can lead to significant savings of 11% daily and is enough to be fed for hogs in the grower stage all while satisfying their nutritional needs.

Keywords
Linear Programming, Cost Minimization, Hog Feeds, COVID-19, Operations Research

1. Introduction
In line with the projections of the United Nations data, the Philippines currently houses 111,042,894 citizens in which each person gobbles up roughly 15 kilograms of hogs (Statistica Research Department 2021). Undeniably, the country ranked in the top 10 as the world's largest hog consumer (Global Pork Market Forecast of the Research and Market 2020). In the same report, the country is the top 8 world's producers and the top 7 largest hog importers. As for the official count delivered by National Mapping and Resource Information Authority (NAMRIA) (2017), the country has a total of 7,641 islands wherein it breeds an estimated 9.55 million heads of hogs, the 71.1% were farmed in backyards, and the 28.9% in the commercial areas (Philippine Statistics Authority 2021).

The health threat posed by the COVID-19 pandemic restricts the activities of various industries in the country, including the animal feed industry. This caused disruptions in their usual operations which led to price increase. This results in an increase on the price of hog meats up to a farmgate price of 3.074 United States Dollars (USD) per kilogram. The said uptrend in feed costs is one of the serious issues present in the said industry. Given the aforementioned fact, the availability of studies relating to the firsthand impact of the COVID-19 pandemic on the hog meat industry, particularly, a study relating to cost-benefit for pigsty owners in consideration of hog's required nutrients is still limited. However, the knowledge on this matter is important to provide crucial insights for designing and implementing an effective feeding schedule strategy to achieve hog's optimal performance at minimal feed cost. Propitiously, there exists a sufficient recognition on the development of hog recommended nutrient requirements to boost its quality but based on the report of the National Hog Farmer (2019), it must be considered that the capability to add diet blending on hogs requires initial investment and understanding as means in exploiting its long-term benefits. As a result, considerable research interest has been generated in the area of hog's (1) energy, (2) amino acid, (3) protein, (4) minerals, and (5) vitamins requirement. Herewith, the researchers considered the RGS Hog Farm, a company established in 2018 and is located in San Pablo City, Laguna, Philippines. The company rear livestock with over two hundred hogs inclusive of ones that are around 127 – 147 days which are given grower feed. In line with the

statement of one of the hog raisers from RGS Hog Farm, the COVID-19 pandemic highlights difficulties in their business including the high cost of feed. Hence, in order to provide recommendations on how to deal with the threat of the rising cost of hog meat and to assist the hog farmers in coping with the current health threat in the country, a case study was applied to test the proposed approach of utilizing linear programming that meets the required nutrients of hogs at a minimal feed cost to achieve the hog's optimal quality and performance by satisfying its nutritional requirements.

1.1 Objectives

In the current system of the company, grower hogs consume a measureless amount of grower feed in order to maintain healthy stock as well as to maximize growth and reproduction. In this regard, the researchers aim to reduce the cost of feeding the hogs all while maintaining and ensuring that they are receiving the required nutrients in a day to guarantee that the quality meets the standard of the company. With this, the researchers are looking forward to the company achieving greater profit at the end of the day.

2. Literature Review

The COVID-19 pandemic brought significant changes in livestock and other related industries (Hashem et al. 2020). However, the availability of studies on the impact of the COVID-19 pandemic on the hog meat industry in the Philippines is still lacking. Only a few articles attempt to explore how the pandemic, along with the safety measures taken in order to prevent the further spread of it, influence the production of pork as this seems to dominate the meat industry in the country. Livestock Research Division, DOST-PCAARRD S&T Media Service (2016) stated that the hog industry is the leading industry among the livestock and poultry production in the county and is earning 190 billion in Philippine peso.

The Statistica Research Department (2021) reported that in the year 2020, 14.9 kilograms of hog per capita were consumed per person. In the same study, it is forecasted to hit approximately 15 kilograms per person per annum in the year 2021. These statistics make the Philippines the world's tenth-largest hog consumer (Research and Market 2020).

The response to growing pork demand is inadequate. The Swine Situation Report published by the Philippine Statistics Authority (2021) reported that during the presence of coronavirus in the country, as of April 2021, the country breeds an estimated 9.55 million heads of hogs which is lower by -22.6% from the 12.34 million head of the previous year in which 71.1% were farmed in backyards and 28.9% in the commercial areas. From January to March 2021, the total hog production of 21.79 thousand metric tons, liveweight is -25.8% lower from the previous year's 568.67 thousand metric tons, liveweight. The Research and Market (2020) further affirmed it in their Global Pork Market Forecast wherein the Philippines, in order to satisfy the demand becomes the seventh-largest hog importer.

Mead et al. (2020) and D'Souza and Dunshea (2021) revealed that the prices of goods and services have been altered at the onset of the pandemic as mobility restrictions have been implemented. This includes an upswing in prices of hog feeds which is one of the major concerns in the industry (Animal and Dairy Sciences n.d). Moreover, Zhuo et al. (2020) attained a similar outcome that highlights the influence of feed supply on the willingness of the hog farmers to recover hog production. It was found that with a higher feed supply, the hog farmer's willingness to recover the said production is also high. In the same manner, during the pandemic, labor shortage occurred (McEwan et al. 2020, Ijaz et al. 2021).

Hog farmers have the responsibility to provide the specified amount of nutrients in accordance with the hog's physiological needs. Soto et al. (2017) and Tokach et al. (2021) discussed that minimizing dietary protein may lower the growth rate. Likewise, overfeeding can cause a variety of health implications (Farm Animal Report n.d.).

The Research and Market (2020) suggested that there is a price uncertainty of hog meat as the overall production of it was affected by the COVID-19 pandemic. This includes animal feeds. The escalated price of feeds is reflected in hog pricing. To support this, the domestic price of hog per kilogram skyrocketed to approximately 8 United States Dollars (USD) (Rappler 2021). It also has a farmgate price of 3.074 United States Dollars (USD) per kilogram, liveweight (Philippine Statistics Authority 2021).

Hog farmers are facing a drastic rise in feed and production costs specifically, at the onset of the COVID-19 pandemic. The response to 14.9 kilograms of hog per capita that is consumed per person in 2020 is inadequate as there is only an estimated total hog production of 21.79 thousand metric tons, liveweight, a -25.8% lower from the previous year. Furthermore, due to the pandemic, adjacent with the safety measures taken such as physical distancing rules and mobility restrictions, goods and services surge in prices including animal feeds. The elevated prices of hog feed result in changes of the hog as well, amounting to 400 Philippines pesos (Rappler 2021).

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3. Methods

Operational research is the practice of implementing methods of science to the complex problems arising in the direction of managing different systems such as men, machines, materials, money, company, and government (Anderson et al. 2012). With regards to the study, operational research will be utilized to seek the optimal solution that will minimize the cost all while ensuring that the requirement set is still followed. The operational research approach helps in determining the policy and action scientifically for the management by generating a scientific model out of the measurements of different factors that will predict and compare the outcomes of alternative (1) decision, (2) strategies, or (3) control (Duckworth et al. 1962).

$$\text{MIN:} \quad c_1X_1 + c_2X_2 + \ldots + c_nX_n \tag{3.1}$$

$$\text{Subject to:} \quad a_{11}X_1 + a_{12}X_2 + \ldots + a_{1n}X_n \geq b_1 \tag{3.2}$$

$$\vdots$$

$$a_{k1}X_1 + a_{k2}X_2 + \ldots + a_{kn}X_n \geq b_k \tag{3.3}$$

The study is made to develop a strategy for the company's advantages by minimizing the cost without compromising the quality of the hogs using the linear programming method (Anderson et al. 2012). Linear programming is usually utilized to obtain the most optimal solution by formulating the real-life problem with constraints into a mathematical model to help managers make decisions. To solve the problem, optimization problems involve three elements namely, (1) decisions, (2) constraints, and an (3) objective. The decision variables are represented in the mathematical model by the symbol $X_1, X_2, \ldots, X_n$. These variables will represent the quantities of the product the business can choose to provide their hogs. The objective function (3.1) and constraints (3.2) of the problem will represent the weighted sum of the decision variables. The objective function will identify the decision variables that the researchers want to minimize, the symbols $c_1, c_2, \ldots, c_n$ in the equation are called objective function coefficients and might represent the marginal nutritional value in this study associated with the decision variables. The constraints are referred to as the "subject to" and have two sides, the symbols a_{ij} (3.2 to 3.3) found in the left-hand-side (LHS) represents the numeric coefficient in the *i*th constraint for variable X_j. The b_k (3.2 to 3.3) found in the right-hand-side (RHS) of the constraints represents the required intake of the hogs and is expressed by greater than. Overall, in the mathematical model, the equation identifies the objective function (3.1) that will be minimized and the constraints that must be satisfied (3.2 to 3.3) to find the optimized values of the decision variables that minimize the objective function without violating any constraints.

4. Data Collection

The method for collecting data used was a face-to-face semi-structured interview aided by direct observation. By these means, the researchers were able to subsist a number of key questions from the company itself to cover all the information needed to facilitate the objectives of the study with a little more leeway for the researchers and without altering the environment. This engenders an in-depth investigation to address the problem of the company. In Figure 1, the researchers were able to have the information on grower feeds, the ABC Feeds (left picture) costing 32.2 dollars per sack which the company uses, and is presented together with the proposed brand, namely XYZ Feeds (right picture) by the researchers with a cost of 25.8 dollars per sack to be mixed with the present grower feeds in order to nourish the hogs in the growing stage. For the reason that this suggested brand is affordable and still has the nutritional

values needed for growing pigs. Hence, the present grower feeds (i.e. ABC Feeds) will be mix with the suggested brand (i.e. XYZ feeds) in order to nourish the hogs in their growing phase.

Figure 1. ABC Feeds and XYZ Feeds

5. Results and Discussion

5.1 Data for Nutrient Content of Each Feed Brand

The nutrients crucial for nourishing the hogs in the grower stage and present in a sack of a 50-kilogram grower feed are crude protein, crude fiber, crude fat, calcium, phosphorus, and moisture. This required nutrition given the brand of hog feed in the RGS Hog Farm and its corresponding cost are illustrated in the table below (see Table 1).

Table 1. Data for the Nutrient Content of Feeds

Brand	Crude Protein	Crude Fat	Crude Fiber	Calcium	Phosphorus	Moisture	Cost
ABC Feeds	16%	3%	7%	0.8%	0.55%	12%	$ 32.2
XYZ Feeds	16%	5.5%	3%	0.95%	0.75%	12%	$ 25.8

The following results were yielded from the data collection within the company, however, it is expected that no more than nor less than 10 percent error of the diet will be consumed by the hogs, as overfeeding and underfeeding may result in health complications of the hogs.

5.2 Mathematical Formulation

The required nutrients for hogs are provided in Table 2 in accordance with the Nutritional Requirements of Grower Pigs (Akinbobola 2018) and using the previously mentioned approach in the methods section, two variables were considered: the amount of nutrients available in a sack of ABC Feeds grower feed in percent, and the amount of nutrients available in a sack of XYZ Feeds grower feed in percent as well. The activities and their levels in the model are: activity j: to include the amount of kg of feed type j in the diet problem, associated level xj , for j =1, 2. Hence, the decision variables where the net content for every sack of ABC feed is 50 kgs, and the net content for every sack of XYZ feed is 50 kgs as well in this study is as follows:

Let x_1 = amount of sack to be feed daily for ABC brand
Let x_2 = amount of sack to be feed daily for XYZ brand

Table 2 shows the amount of nutrients available in a sack of ABC Feeds grower feed in percent, and the amount of nutrients available in a sack of XYZ Feeds grower feed in percent as well.

Table 2. Nutritional requirement for hogs

Nutrients	Nutrition Content (per sack)		Daily Requirement
	ABC Feeds	XYZ Feeds	
Crude Protein	16%	16%	16%
Crude Fat	3%	5.5%	3%
Crude Fiber	7%	3%	5%
Calcium	0.80%	0.95%	0.5%
Phosphorus	0.55%	0.75%	0.45%
Moisture	12%	12%	12%

With the objective of the study to minimize the cost of feed consumption without compromising the quality and health of the hogs in RGS Hog Farm, the researchers formulated the following linear function. The objective function (Minimize Z) is the cost of ABC Feeds per sack which is $32.20 and XYZ Feeds per sack which is $25.80.

Each of the various required nutrients leads to a constraint. For example, the amount (in percentage) of crude protein contained in x (ABC Feeds) is 16% and the amount (in percentage) of crude protein contained in y (XYZ Feeds) is also 16% which must be equal to or greater than 16% for crude protein requirement. This leads to the formulation below:

MIN:	$Z = \$\,32.20x + \$\,25.80y$		
Subject to:	$0.16x + 0.16y \geq 0.16$	(0,1) (1,0)	(Crude Protein Requirement)
	$0.03x + 0.055y \geq 0.03$	(0,0.55) (1,0)	(Crude Fat Requirement)
	$0.07x + 0.03y \geq 0.05$	(0,1.67) (0.71,0)	(Crude Fiber Requirement)
	$0.008x + 0.0095y \geq 0.005$	(0,0.53) (0.625,0)	(Calcium Requirement)
	$0.0055x + 0.0075y \geq 0.0045$	(0,0.6) (0.82,0)	(Phosphorus Requirement)
	$0.12x + 0.12y \geq 0.12$	(0,1) (1,0)	(Moisture Requirement)
	$x, y \geq 0$		

Using the graphical method and given the limitations on the availability of nutrients present in the feeds and their coordinates, respectively, the minimum point of the intersection between the objective function line and the feasible region is shown through the graph (see Figure 2).

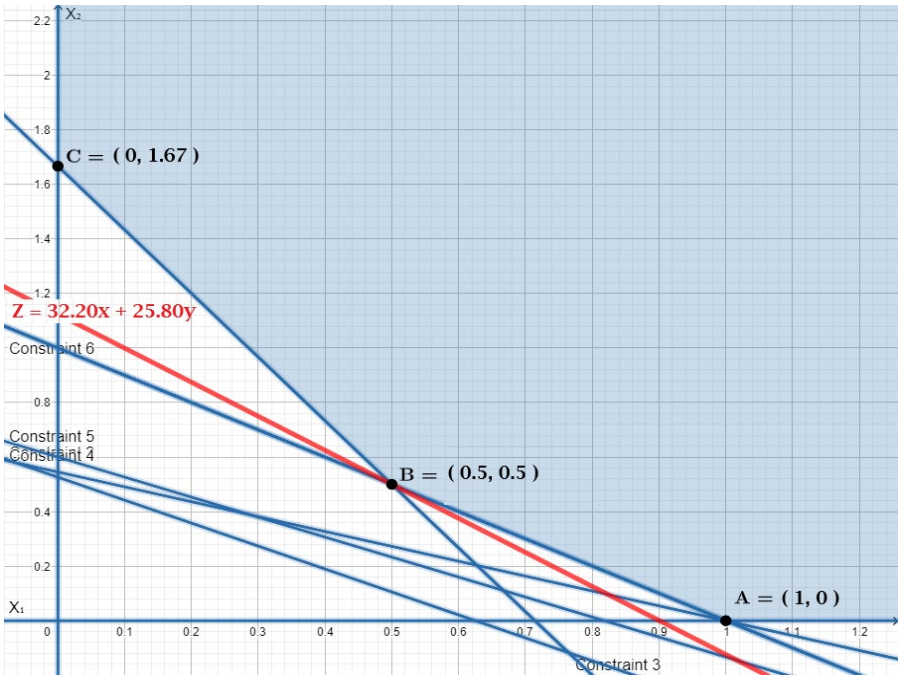

Figure 2. Graphical representation of constraints

The value of the objective function at each of these extreme points is shown in Table 3.

Table 3. The objective function value of each extreme point coordinates

Extreme Point Coordinates (x,y)	Objective function value Z=32.20x + 25.80y
A (0,1.67)	32.20(0) + 25.80(1.67) = 43
B (0.5,0.5)	**32.20(0.5) + 25.80(0.5) = 29**
C (1,0)	32.20(1) + 25.80(0) = 32.2

The minimum value of the objective function Z = 29 occurs at the extreme point (0.5,0.5). Hence, the optimal solution in the linear programming problem is x = 0.5, y = 0.5 and min Z = 29, determining the percentage of ABC Feeds and XYZ Feeds needed to feed eleven hogs daily. Moreover, the researcher utilized the MS Excel Solver to solve this diet problem. As expected, the graphical method and the software method (MS Excel Solver) resulted with the same solutions wherein the optimal solution is both x=0.5 and y =0.5 with min Z = 29 as shown in Figure 3.

5.3 Proposed Improvements

A proposed efficient diet program is provided for RGS Hog Farm using a combination of hog feeds available to feed the hogs at minimum cost while also ensuring that each hog receives an adequate amount of nutrients.

		ABC Feeds	XYZ Feeds			
Cost per sack (50 kgs)	Minimize	$32.20	$25.80			
		Nutrition Content (per sack)		Total Nutrients		Daily Requirement
Crude Protein		16.00%	16.00%	16.00%	>=	16.00%
Crude Fat		3.00%	5.50%	4.25%	>=	3.00%
Crude Fiber		7.00%	3.00%	5.00%	>=	5.00%
Calcium		0.80%	0.95%	0.88%	>=	0.50%
Phosphorus		0.55%	0.75%	0.65%	>=	0.45%
Moisture		12.00%	12.00%	12.00%	>=	12.00%

	ABC Feeds	XYZ Feeds	Total Cost
Proposed Diet	0.5	0.5	**$29.00**
	25 kgs	**25 kgs**	

Figure 3. Summary of optimum diet for grower hogs

Applying the operations research approach, the optimum diet program was identified for RGS Hog Farm. The result shows that given all the data gathered, in order to minimize the cost of feed consumption, the company must feed a combination of 0.5 sack or 25 kilograms (kgs) of grower feeds from ABC Feeds and 0.5 sack or 25 kilograms (kgs) of grower feeds from XYZ Feeds.

In validating the effectiveness of the optimal solution, the study uses the formula (3.1) in the linear programming model as it also provides the total minimize cost of the proposed diet for the RGS Hog Farm. To compute the new costs, the amount for the two 50 kilograms (kg) grower feeds is provided as follows. The amount for the two feeds is from the actual feed price where the farm is willing to purchase, however, the name of the feeds is covered up and changed by a fictional name. Because the result of the optimum feed combination of 25 kgs of ABC Feeds and 25 kgs of XYZ Feeds supplies a total nutrients value of 16% of crude protein, 4.25% of crude fat, 5% of crude fiber, 0.88% of calcium, 0.65% of phosphorus, and 12% of moisture. These amounts of nutrients are equal to or above the required daily nutrients for the hogs, thus, the nutritional requirements in feeding the hogs were met and satisfied. From feeding the hogs with the proposed combination of ABC Feeds and XYZ Feeds, the company will have a minimized cost resulting in 29 United States Dollars (USD) cost of grower feeds without compromising the required nutrients needed for the hogs in a day. The existing costs that the farm is paying to feed the hogs for a day reach 32.20 United States Dollars (USD) and the computed optimum proposed diet has a total cost of 29 United States Dollars (USD). The results indicate that there is a difference in the cost of feeding the hogs for a day by 3.20 United States Dollars (USD), which also means saving 11% of the cost for the hogs feed per day.

6. Conclusion

Taking everything into account by applying the operations research approach, the optimum diet program was identified for RGS Hog Farm. The result shows that given all the data gathered, in order to minimize the cost of feed consumption, the company must feed a combination of 25 kilograms (kgs) of grower feeds from ABC Feeds and 25 kilograms (kgs) of grower feeds from XYZ Feeds. In validating the effectiveness of the optimal solution, the nutritional requirements in feeding the hogs were met and satisfied, considering that the result in the optimum mix of feeds which are 25 kgs of ABC Feeds and 25 kgs of XYZ Feeds supplies a total nutrients value of 16% of crude protein, 4.25% of crude fat, 5% of crude fiber, 0.88% of calcium, 0.65% of phosphorus, and 12% of moisture. These amounts of nutrients are equal to or above the required daily nutrients for the hogs. Taking everything into account, it was possible to provide an optimum solution to the diet problem in the specified case study company. The proposed diet plan for the hogs in the RGS Farm using the linear programming optimization approach minimizes the costs but not compromising the nutrition requirements of hog farms. It resulted in a significant saving of 11% for the cost of the farm for their hogs feed per day. This study was done to present a developed strategy that can help the farm increase efficiency in operating their farm while ensuring that the hogs received the required nutrients in a day which leads to

assure the quality of hogs in the farm. In the study, it is identified that escalating feed prices poses a problem in the industry. As the growing commercial hogs have a regular and systematic feeding schedule, to ensure the quality and size of the hogs. Thus, as the feeding prices increase the profit margin can also be affected. Specifically, since there is a distinguished substantial hog farming in the Philippines, being the 10th largest consumer, top 8th in terms of producers, and among the 7th largest importer of pork. For that reason, the researchers concluded that there is significant importance in looking for the feeding cost as well as the nutritional value provided by the feed as it affects the efficiency and productivity of the RGS Hog Farm.

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Biographies

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Arriane A. Palisoc is an Associate Professor, and Program Chair of Industrial Engineering Department of Technological Institute of the Philippines Quezon City. She earned her Bachelor of Science in Industrial Engineering from Technological Institute of the Philippines and a Master's Degree holder in Industrial Engineering and Management from Polytechnic University of the Philippines, Manila. Presently, she is taking up her Doctor of Engineering in Engineering Management at Polytechnic University of the Philippines. She was awarded the status of ASEAN Engineer by the ASEAN Federation of Engineering Organisations (AFEO) Governing Board and has been recognized as Professional Industrial Engineer (PIE) by the Industrial Engineering Certification Board (IECB) of Philippine Institute of Industrial Engineers (PIIE).