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The Optimization Problem of Product Mix and Linear Programing Applications, a Revise Simplex Approach; a Study of Amo Byng Nigeria Limited

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Abstract

Strategies for developing industries are characterized by the efficient use of resources at every production stage. Efficient utilization of resources is made sustainable by effective management decision making techniques employed in the industry. A quantitative decision-making tool called linear programming can be used for the optimization problem of product mix. Understanding the concept behind the optimization problem of product mix is essential to the success of the industry for meeting customer needs, determining its image, focusing on its core business, and inventory management. The firm's profit mainly depends on the proper allocation and usage of available production time, material and labor resources. This paper considers Amo Byng product and profit per unit for each product have been collected from the company. The data gathered was used to estimate the parameters of the linear programming model. The model was solved using Reverse simplex method. The findings of the study shows that, the profit of the company can be improved by 9.1% (from 26,520,300 naira per month to 29.192 million per month). by applying linear programming models if customer orders have to be satisfied. The profit of the company can be improved by 9.1% if the linear programming formulation does not need to consider customer order

Keywords: Optimization, Problem, Product, Linear Programing, Applications.

Introduction

It is obvious that most company around the world, including Nigeria, has a problem of optimization in product inputs. Nigeria's economy is fully depending on its manufacturing industries. In Nigeria, the manufacturing sector brings about 10% of each year's GDP. Millions of Nigerians are involved in this industry and they help to improve the country's economy. (Kumar 2010) stated that a company's endurance in a competitive market closely depends on its ability to produce the highest quality product at the lowest possible cost. Ezema and Amakom (2012) emphasized that organization in the world are challenge by shortage of production input and low capacity utilization the can consequently lead to low production outputs. Amo Byng Nigeria Limited was established in 1987 to produce high quality Feed Concentrates, and Finished feeds. Products are supplied to farmers all over the country and in West Africa. The main objective is to operate a state-of-the-art Feed mill that will consistently provide the best quality products available in Nigeria. Nowadays, intensive management of chicken feeding industries can save cost and realize maximum benefit. How to produce high quality feed and how to make animals digest the feed efficiently are what chicken farmers concerns all the time. Complete chicken feed pellet plant has been developed by Strong win with an objective of providing chicken with a hygienic, nutritionally balanced and easily digestible diet. Compared with feed mash or traditional fodder, chicken feed pellets are clearer, healthier and more convenient to transport. Feed pellets can provide condensed nutrition for livestock. Due to these advantages, feed pellet milling is getting more and more popular in recent years. Strong win Feed Manufacturing Machinery can make durable chicken feed pellets with a lustrous surface for the populace. This project will consider using the various feed productions in this company for product mix optimization using the linear programming applications. Linear programming is an operational research technique used to allocate optimally production resources for a firm's best practices. It is the most widely used tool -
(Reeb and Leavengood, 1998) to determine optimal resource utilization. Different product requires different amount of production resource having different cost and

revenues at different stages of production. Thus, the linear programming problem (LPP) technique will be used to determine the product mix that will maximize the total profit at a specified time. It is the best method for determining an optimal solution among alternatives to meet a specified objective function limited by various constraints and restrictions (Shaheen and Ahmad, 2015). The major objective of this study is to investigate the effect of using linear programming problem LPP on the product performance in the company and provide recommendations which will help to improve the product quality and competitive position of the company.

Research Questions

The purpose of this research is to investigate the effect of linear programming problem LPP on the company's product quality and competitive position. Therefore, the following research questions were developed to be answered as a result of the study. How would the LPP help within the company?
Does the LPP have an effect in the product quality?
Does the LPP affect the competitive position of the company?
How will the LPP help the company in the supply chain?

Data Analysis:

The information collected from the case company in addition to the sales and other operating data was analyzed to provide estimates for LPP model parameters. To set up the model, the first level decision variables on the volume of products to be produced were set.
x_1 = the amount spent on raw materials
x_2 = the amount spent on labor
x_3 = the time taking in production
Z = total profit during the month
Now, the linear programming model, maximizing the total profit is:

Table 1; Resources needed per unit of product for the month
The table below shows the data collected for the month

Products	Raw materials/Gram	Labor/naira	Finishing/hours/1000
Broiler starter	2m	**2.7m**	**3**
Broiler finisher			
Grower mash	**4.5m**	**6m**	**2**

Chick mash Layer mash Grower concentrates Chick concentrates Layer concentrate Broiler concentrate	**3m**	**4m**	**5.5**

Table 2; Average monthly resources held and consumed in quality/value terms in Naira

Resources			
Resources Type	Measurement Unit	Held Value	Consumption Value
Raw materials	Kg	1,350,000	1,023,400
Labor	Naira	1,300,000	987,560
Finishing	Hours	1,650,000	192,000

Table 3; demand and profit earned for the month

	Broiler starter Broiler finisher	Grower mash Chick mash Layer mash	Grower concentrate Chick concentrate Layer concentrate Broiler concentrate
Demand	822,905	381,453	620,453
Profit per Unit	4.3	6.6	9.5

Based on the data collected, we will calculate per thousand unit in each of the variables to avoid bulky work in the calculation.

Max $Z = 4.3x_1 + 6.6x_2 + 9.5x_3$

Subject to;

$2x_1 + 4.5x_2 + 3x_3 \leq 1350$

$2.7x_1 + 6x_2 + 4x_3 \leq 1300$

$3x_1 + 2x_2 + 5.5x_3 \leq 1650$

Solution

Step 1; the problem is converted to canonical form by adding slack, surplus, and artificial variables as appropriate.

After introducing slack variables, we have;

$Z = 4.3x_1 + 6.6x_2 + 9.5x_3$

$2x_1 + 4.5x_2 + 3x_3 + S_1 = 1350$

$2.7x_1 + 6x_2 + 4x_3 + S_2 = 1300$

$3x_1 + 2x_2 + 5.5x_3 + S_3 = 1650$

With $x_1, x_2, x_3, S_1, S_2, S_3 \geq 0$

Representing the new system of constraint equation in the matrix form below

$$\begin{pmatrix} 1 & -4.3 & -6.6 & -9.5 & 0 & 0 & 0 \\ 0 & 2 & 4.5 & 3 & 1 & 0 & 0 \\ 0 & 2.7 & 6 & 4 & 0 & 1 & 0 \\ 0 & 3 & 2 & 5.5 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} Z \\ x_1 \\ x_2 \\ x_3 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = \begin{pmatrix} 0 \\ 1350 \\ 1300 \\ 1650 \end{pmatrix}$$

Or

$$\begin{bmatrix} 1 & -C \\ 0 & A \end{bmatrix} \begin{bmatrix} Z \\ X \end{bmatrix} = \begin{bmatrix} 0 \\ b \end{bmatrix} \quad ; X \geq 0$$

Where $e = \beta_0, \alpha_4 = \beta_1, \alpha_5 = \beta_2, \alpha_6 = \beta_3$

Step 2; the basis matrix β_1 of order $(3 + 1) = 4$ can be expressed as

$$B_1 = (\beta_0, \beta_1, \beta_2, \beta_3) = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Then, $\beta_1 = \begin{bmatrix} 1 & C \\ 0 & B \end{bmatrix} = 1$; $B = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$ = ($\beta_0, \beta_1, \beta_2, \beta_3$) ; = C_B = (0 0 0)

		Basic Inverse β_1				Y_i	Min Ratio			
		β_0	β_1	β_2	β_3	$C_k - Z_k$				
B	X β	Z	S_1	S_2	S_3		-	X_1	X_2	X_3
Z	0	1	0	0	0		-	-3.3	-6.6	-9.5
S_1	135	0	1	0	0		-	2	4.5	3
S_2	130	0	0	1	0		-	2.7	6	4
S_3	165	0	0	0	1		-	3	2	5.5

Iteration 1; repeat steps 3 to 5 to get new solution.

Step 3; to select the vector corresponding to a non-basic variable to enter into the basis, we compute.

$C_k - Z_k$ = Max [(Cj – Zj) > 0; $j = 1, 2$]

Max [- (first row of β_1) (column aj not in basis)]

Max [- [-4.3, -6.6, -9.5]]

Max [[4.3 6.6, 9.5]]

9.5 (corresponds to $C_3 - Z_3$)

Thus, the vector X_3 is b selected to enter into the basis for K = 3

Step 4; to select the minimum ratio to the basic variables to leave the basis, we compute Yk for K = 3, as follows

And $X_B = \begin{bmatrix} 130 \\ 165 \end{bmatrix}$

Now, we will calculate the minimum ratio to select the basic variable to leave the basis

$\frac{XBr}{Yrk}$ = Min $\frac{XBi}{Yik}$, Yik > 0

Min $\frac{135}{3}$, $\frac{130}{4}$, $\frac{165}{5.5}$

Min $\begin{bmatrix} 45, & 32.5, & 30 \end{bmatrix}$

30 (corresponds to $\frac{XB3}{Y33}$)

Thus, the vector S_3 is selected to leave the basis for r = 3

The table below shows the new entries with column Y_3 and the minimum ratio

		Basic Inverse β_1^{-1}				Y_3	Min Ratio			
		β_0	β_1	β_2	β_3	$C_k - Z_k$				
B	X β	Z	S_1	S_2	S_3		$\frac{X_B}{y_2}$	X_1	X_2	X_3
Z	0	1	0	0	0	-9.5	-	-4.3	-6.6	-9.5
S_1	135	0	1	0	0	3	45	2	4.5	3
S_2	130	0	0	1	0	4	32.5	2.7	6	4
S_3	165	0	0	0	1	5.5	30	3	2	5.5

The table solution is now updated by replacing variable S_2 with the variable X_1 into the basis.

For this we apply the following row operations in the same way as in the simplex method.

	X β	**β₁**	**β₂**	**β₃**	y_3
R_1	0	0	0	0	-9.5
R_2	135	1	0	0	3
R_3	130	0	1	0	4
R_4	165	0	0	1	5.5

R_4(new) = R_4(old) × 0.1818

R_1(new) = R_1(old) + 9.5 R_4(new)

R_2(new) = R_2(old) - 3 R_4(new)

R_3(new) = R_3(old) - 4 R_4(new)

The improved solution is

		Basic Inverse β_1^{-1}				Y_3	Min Ratio			
		β_0	β_1	β_2	β_3	$C_k - Z_k$				
B	X β	Z					$\frac{X_B}{y_2}$	X_1	X_2	S_3
Z	285	1	0	0	1.7273		-	-4.3	-6.6	0

S_1	45	0	1	0	-0.5455	-	2	4	0
S_2	10	0	0	1	-0.7273	-	2.7	6	0
S_3	30	0	0	0	0.1818	-	3	2	1

Iteration 2, repeat step 3 to 5 to get new solution, to select the vector corresponding to a non-basic variables to enter into the basis, we compute $C_k - Z_k = \text{Max}\ [\ (Cj - Zj) > 0;\ j = 1, 2]$

$$\text{Max} \left[\quad - (\text{first row of } \beta_1)\ (\text{ column aj not in basis}) \right]$$

$$\text{Max} \left(-4.3 \quad -6.6 \quad 0 \quad - [1 \quad 0 \quad 0 \quad 1.73\,] \begin{pmatrix} 2 & 4 & 0 \\ 2.7 & 6 & 0 \\ 3 & 2 & 1 \end{pmatrix} \right)$$

$$\text{Max} \left[- [0.88, \quad -3.15, \quad 1.73] \right]$$

$$\text{Max} \left[[-\,0.88, \quad 3.15, \quad -1.73] \right] = 3.1455 \text{ (corresponds to } C_2 - Z_2)$$

Thus, the vector X_2 is selected to enter into the basis for K = 2

Step 4; to select a basic variable to leave the basis, we compute Y_k for k = 2 as follows

$$Y_2 = \beta_1^{-1}\alpha_2 = \begin{pmatrix} 1 & 0 & 0 & 1.73 \\ 0 & 1 & 0 & -0.55 \\ 0 & 0 & 1 & -0.73 \\ 0 & 0 & 0 & 0.18 \end{pmatrix} \begin{pmatrix} -6.6 \\ 4 \\ 6 \\ 2 \end{pmatrix} = \begin{pmatrix} -3.15 \\ 3409.09 \\ 4545.45 \\ 0.36 \end{pmatrix}$$

Now, we will calculate the minimum ratio to select the basic variable to leave the basis

$$\frac{x_{Br}}{y_{rk}} = \text{Min} \quad \frac{x_{Bi}}{y_{ik}}, \; y_{ik} > 0$$

$$\text{Min} \left[\frac{45}{2.9091}, \frac{10}{4.5455}, \frac{30}{0.3636} \right]$$

$$\text{Min} \left[15.4688, 2.2, \quad 82.5 \right]$$

2.2 (corresponds to $\frac{x_{B2}}{y_{22}}$)

Thus, the vector S_2 is selected to leave the basis for r = 2

The table with new entries in column Y_2 and the minimum ratio

		Basic Inverse β_1^{-1}				**Y_3**	**Min Ratio**			
		β_0	β_1	β_2	β_3	**C_k - Z_k**				
B	X β	Z	S_1	S_2	x_3		$\frac{X_B}{y_2}$	x_1	x_2	x_3
Z	285	1	0	0	1.7273	-3.1455		- 4.3	- 6.6	0
S_1	45	0	1	0	- 0.5454	2.9091	15.4688	2	4	0
S_2	10	0	0	1	- 0.7273	4.5455	2.2	2.7	6	0
X_3	30	0	0	0	0.1818	0.3636	82.5	30	2	1

The table solution is now updated by replacing variable S_2 with the variable X_1 into the basis. For this we apply the following row operations in the same way as in the simplex method.

	X β	**β_1**	**β_2**	**β_3**	**y_2**
R_1	285	0	0	1.7273	-3.1455
R_2	45	1	0	-0.5455	2.9091
R_3	10	0	1	-0.7273	4.5455
R_4	30	0	0	0.0002	0.3636

R_3(new) = R_3(old) × 0.22

R_1(new) = R_1(old) + 3.1455 R_3(new)
R_2(new) = R_2(old) – 2.9091 R_3(new)
R_4(new) = R_4(old) – 0.3636 R_3(new)
The improved solution is

		Basic Inverse β_1^{-1}				y_2	**Min Ratio**			
		β_0	β_1	β_2	β_3	**C_k - Z_k**				
B	X β	Z	S_1	X_2	X_3		$\frac{X_B}{y_z}$	X_1	S_2	S_3
Z	29.192	1	0	0.692	0.0012		-	- 4.3	- 6.6	0
S_1	38.6	0	1	-0.64	-0.08		-	2.0	4.5	0
X_2	2.2	0	0	0.22	-0.16		-	2.7	6.0	0
X_3	29.2	0	0	-0.08	0.24		-	3.0	2.0	1

Iteration 3, repeat step 3 to 5 to get new solution.
Step 3; to select the vector corresponding to a non-basic variable to enter into the basis, we compute
$C_k – Z_k$ = Max [$(Cj – Zj) > 0; \; j = 1, 2$]

Max - (first row of β_1^{-1}) (column aj not in basis)

Max (- [1.24, 0.6, 1.22])

Max [- 1.24, -0.69 -1.22]
Since all Zj – Cj ≥ 0
Hence, optimal solution is arrived with value of variable as;

$$x_1 = 0, x_2 = 0.22, \; x_3 = 2.92 \; and \; Z = 29.192$$

Data solutions

Objectives value;	29.192;
Infeasibilities;	0.0000
Total solver iterations	3.0;

Model class;	L P
Total variables;	3
Total constraints;	3
x_1	0
x_2	0.22
x_3	2.92

Variable	Value	Reduced cost
Z	29,192,000	0.000000
x_1	822,905	0.000000
x_2	381,453	0.000000
x_3	620,453	0.000000

Using sensitivity analysis to express the solution we have;

$$x_1 = \frac{Z}{c_1} - \frac{x_2}{c_1} - \frac{x_3}{c1}$$

$$x_1 = \frac{291.92}{4.3} - \frac{2.2}{4.3} - \frac{29.2}{4.3} = \frac{260.52}{4.3}$$

$$x_1 = 60.58$$

$$x_2 = \frac{Z_2}{C_2}$$

$$x_2 = \frac{291.92}{6.6} - \frac{0}{6.6} - \frac{29.2}{6.6}$$

$$\frac{260.52}{4.3}$$

$$x_2 = 39.81$$

$$x_3 = \frac{z}{c_1} - \frac{x_2}{c_1} - \frac{x_3}{c_1}$$

$$x_3 = \frac{291.92}{9.5} - \frac{0}{9.5} - \frac{2.2}{9.5}$$

$$\frac{260.52}{4.3}$$

$$x_3 = 30.497$$

From the analysis, there was a difference between the LPP solutions obtained to satisfy customer orders using the reverse simplex method and actual production in Table 3. In the former case, the product mix was the broiler starter and broiler finisher, grower and layer mash and grower and chick concentrate with volumes of 822,905.00, 381453.00 and 620,453.00 respectively, and with a total profit of 29.192m per month upon selling. In the latter case, the product mix was broiler starter and broiler finisher, grower and layer mash and grower and chick concentrate with optimal volumes of 822,905.00, 381453.00 and 620,453.00 respectively, and with a total profit of 26,520,300 naira per month. At optimality, resources consumed by the reverse simplex method result were compared with the customer orders during the month. In this case, the profit of the company could be improved by 9.1%. From Table 2, the monthly consumption values of customer orders for each available resource were gathered from the company's records. These consumption values and LPP consumption values are summarized in Table 4. The ratios of monthly consumption of the resources held were calculated to find the percentage usage by each chicken feed productions.

Table 4: Monthly consumption by LPP techniques and customer order production

			Monthly resources consumption		Percentage % of usage	
Type	Unit	Value	Customers order	LPP	Customers order	LPP
Raw material	Gram	1350000	1023400	975000	75.8	72
Labor	Naira	1300000	987560	1008000	75.9	77.5
Finishing	Hours	1650000	192000	1650000	11.6	100

The study shows that the LPP resource utilization in producing and finishing the chicken feed relatively improved by 72%75.5%, 100%. Thus, Figure 1 shows that production based on customer orders lead to efficient resource utilization since most of the resources are not idle.

Figure 1; chart showing customer order and LPP

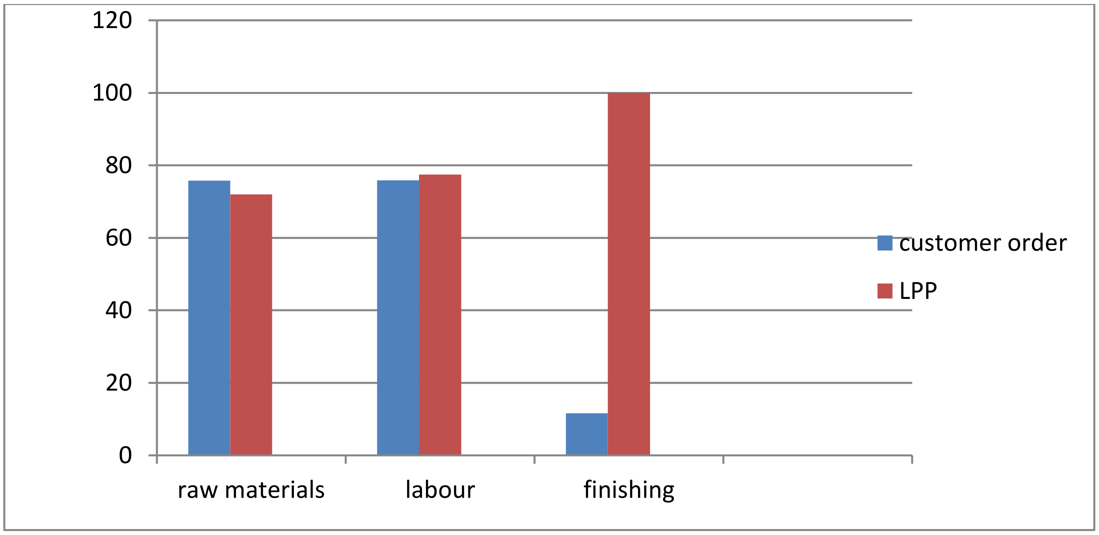


Figure 1: Comparison of customer order and LPP production resources utilization.

Here, an analysis has been made without considering customer orders to develop a LPP model using monthly consumption of resources. The monthly consumption of each resource values is given under the left-hand side column in Table1.5. 2, which was used as the constraints. The optimal solution values of the decision variables were obtained using the reverse simplex method. Table1.5. 5 shows the monthly product mix of the actual system obtained from the company and that suggested by the LPP model. These values have been multiplied by their respective unit profits to obtain the profit per month of each product. In this case where customer orders were not considered, the product mix suggested by the LPP model was broiler starter and broiler finisher, grower and layer mash and grower and chick concentrate at optimal volumes of 0, 2.2, and 2.92 respectively with a total profit of 26,520,300 naira per month. It can be shown then that with the LPP optimal solution, the profit of the company can be improved by 9.1% (29.192 million). Adopting operational research techniques in the production decision help the company to improve its objective.

Table 5: Comparison of customer order production and LPP values

		Monthly production volume		**Percentage % of usage**	
Product type	Profit per unit/naira	Customers order	LPP	Customers order	LPP
Raw materials	4.3	975000	0	4,192,500	0
Labor	6.6	1008000	2.2	6,652,800	14.52
Finishing time	9.5	1650000	29.2	15,675,000	277.4
Total profit/naira				26,520,300	29.192m

Table 6; Tabulating the customer order, LPP and the sensitivity analysis and expressing it with a pie chat

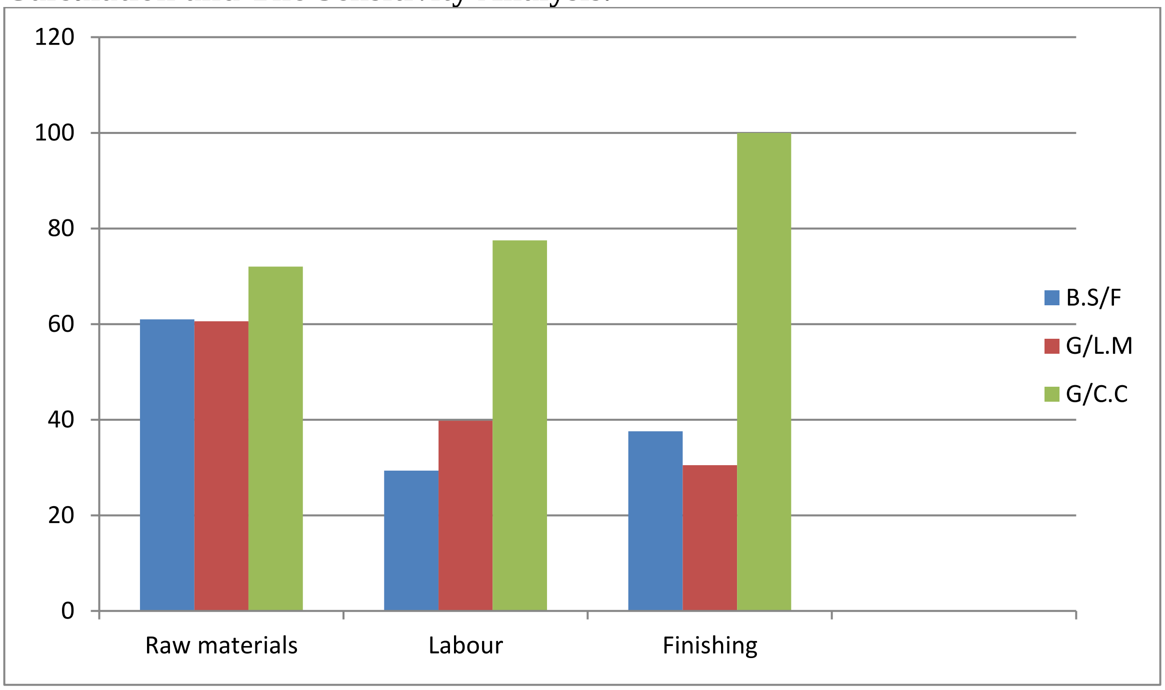
			Monthly resources consumption		**Percentage % of usage**	
Type	Unit	Value	Demands	Sensitivity Analysis	Demands	LPP
Raw material	Gram	1,350,000	822,905	60.58	60.96	72
Labor	Naira	1,300,000	381,453	39.81	29.34	77.5
finishing	Hours	1,650,000	620,453	30.497	37.60	100

Ability to use resources (resource utilization) was recorded as the major constraint in the Amo Byng manufacturing industry. The profits comparison between the actual production and production using LPP models shows a sizeable differences. From this point of view, it can be concluded that the apparel company should use quantitative research methods of linear programming to determine their optimal product mix. Thus, it will be possible to obtain the following results:

- The profit of the company can be improved by 9.1% (from 26,520,300 naira per month to 29.192 million per month).
- Not denying customer orders and adopting the LPP solution provides the products but the profit of the company can be improved tremendously

The figure 7 bellow shows the relationship between the linear programming problem calculation and the sensitivity analysis. It shows that there are no differences in the both analysis but the company can do well in making products available.

Figure 2; The Relationship Between the Linear Programming Problem Calculation and The Sensitivity Analysis.



Summary of the Findings

According to the data analysis in the previous section, summary of the findings is presented as follows. The study shows that the LPP resource utilization in producing and finishing the chicken feed relatively improved by 72%75.5%, 100%. Thus, Figure 1 shows that production based on customer orders lead to efficient resource utilization since most of the resources are not idle.

Although the respondents believe that their customers are satisfied with their product quality and continuous improvement on quality, the interview results and other secondary documents shows that, the sector encounters quality problem which resulted in bad image and loose competitive advantage in the global market.

There was a difference between the LPP solutions obtained to satisfy customer orders using the reverse simplex method and actual production in Table 3. In the former case, the product mix was the broiler starter and broiler finisher, grower and layer mash and grower and chick concentrate with volumes of 822,905.00, 381453.00 and 620,453.00 respectively, and with a total profit of 29.192m per month upon selling. In the latter case, the product mix was broiler starter and broiler finisher, grower and layer mash and grower and chick concentrate with optimal volumes of 822,905.00, 381453.00 and 620,453.00 respectively, and with a total profit of 26,520,300 naira per month. At optimality, resources consumed by the reverse simplex method result were compared with the customer orders during the month. In this case, the profit of the company could be improved by 9.1%. From Table 2, the monthly consumption values of customer orders for each available resource were gathered from the company's records. These consumption values and LPP consumption values are summarized in Table 4. The ratios of monthly consumption of the resources held were calculated to find the percentage usage by each chicken feed productions.

Conclusions

The evidence from this study indicates that Amo Byang chicken feed industry has a problem of quality and competitive advantage and a supply chain. The main reason behind this poor performance is lack of knowledge of linear programming and customer integration within the chicken feed industry. Since all the independent variables (supply, customer, and internal integration) have positive correlation with the dependent variables (product quality and competitive advantage), they have the potential to affect the quality and competitive advantage of the sector. This means, the higher the production of feeds the better for the industry and they can improve their product quality and competitive advantage.

Recommendations

Based on the conclusions dawn above, some recommendations are proposed as a means of alleviating the problems founded.

- A The industry should approach every step-in production with a professional in linear programming knowledge.
- In order to improve the poor product quality and loose competitive advantage of the sector, have to start to see supply integration as performance improvement approach.

- To integrate the supply side of the industries, the sector should engage in creating awareness or acquisition with their suppliers.
- So as to maintain customer relationship, instead of producing products and searching for markets, better use pulls- based supply chain which is production and distribution are demand driven. If the industry use pulls- based supply chain, they could cut inventory carrying cost, decrease lead-times through the ability to better anticipate incoming orders from the retailers.
- In order to have a good LPP as well as the product mix, IT is a crucial tool along the entire value. Therefore, Amo byang chicken feed industry should be able to develop this infrastructure in order to connect individual stores with the production and procurement departments. This will allow central departments to follow sales, thus feeding an intelligent procuring system. If communications between departments takes place electronically, including design and product development, it will help the industry to bring a better internal integration.

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