A Model for Process Optimization of Small-Scale Industry for Competitive Production.

A. K. Ogunkoya, M.Eng.[1*] and A. A. Aderoba, Ph.D.[2]

[1]Engineering Materials Development Institute, Akure, Ondo State, Nigeria
[2]Federal University of Technology, Akure, Nigeria

E-mail: tjoguns607@yahoo.com*

ABSTRACT

In this study, a generalized model was developed for process optimization of small-scale industries for competitive production within the acceptable quality level of production. It was observed that most small-scale industries do not lend themselves to flexible production processes, therefore making it difficult for them to optimize production when there are fluctuations in prices of production inputs.

Linear optimization approach was used to simplified the mathematical models developed and used to develop a program, using C++ programming language to evaluate production data of a small-scale swine feed mill. It was found that the three different types of swine feed formulated yielded optimum profits and qualities when compared with old feed swine feed formulations. In four cases of fluctuation in unit costs of process variables, the model yielded 1.12%, 22.58%, 8.30%, and 17% respective increment in profits against the old feed formulations.

(Keywords: small-scale industries, process, linear optimization, formulations, models)

INTRODUCTION

Small industrial units are industries with limited scale of manufacturing operations, producing a product or few products with limited levels of employment and investment and are many in number than large scale industries. In many developing countries, the roles of these industries are crucial as they provide employment to a large number of people. Breaking the size barrier (limited levels of employment and investment) is a measure of success of the small-scale industries (Aderoba, 1995).

Small-scale industries are dependent for their equipment and process technology on a limited number of resources that start with:

(a) the entrepreneurs' own technical expertise probably gained during earlier stages of paid employment;

(b) large firms that provide the technology as a component within a sub-contracting arrangement; and

(c) government institutions desirous to support a measure of indigenous Technology (El-Namaki, 2004).

The demand for the products of small-scale industries is crucial to their growth. Therefore this work focuses on process re-engineering of a small-scale industry for economical and competitive production, using a small-scale swine feed production industry as a case study.

METHODOLOGY

A small-scale industry typically produces a product or few products with limited levels of employment and investment, the cost structure of such an industry consists of fixed cost and variable cost. The fixed inputs give rise to fixed costs, the amount which depends on the quantity of each of the various fixed input and respective prices paid for them. Salaries of top management officials, property taxes, and interest on loans, depreciation charges, and rents on office/factory use, cost of use of equipment and machineries, cost of transportation services and cost of utilities are examples of fixed cost.

The inputs that are variable give rise to variable cost. Variable cost depends on the amount spent on variable input employed in the production process. Examples of variable cost include payroll expenses and raw materials outlay cost. Therefore, total cost of production is the sum of total fixed cost and total variable cost. In order to realize revenue, a small-scale industry must sell in the product market. The product market structures which small-scale industries belong are those with either perfect competition or monopolistic competition.

Model Formulation

The items to be accounted for as variable cost in the model building are cost of raw materials and labor only.

Model Nomenclature

Z= Net Profit
P= Unit Price of product
Q= Quantity of product unit produced / sold.
F= Fixed cost per period
V = Variable cost per period
N= Number of Raw material required for production
c_i= Cost of unit quantity of i th raw material
x_i= Quantity of the i th raw material required
M= Numbers of categories of labor
d_j = Salary per period of category j^{th} labor
l_j = Number of labor in j^{th} category
P_M = Expected profit margin percentage

Mathematical formulation

The objective function is net Profit per Period, which is given as:

Z (Net Profit) = Sales Return – Cost of production **(1)**

Where Sales Return = PQ

$$Q = \sum_{i=1}^{N} x_i \quad \textbf{(2)}$$

Cost of Production = F + V **(3)**

V = cost of raw materials (C) + cost of labor (D) **(4)**

$$\text{Cost of raw materials (C)} = \sum_{i=1}^{N} c_i x_i \quad \textbf{(5)}$$

$$\text{Cost of labor (D)} = \sum_{j=1}^{M} c_j l_j \quad \textbf{(6)}$$

Substituting Equations (5) and (6) into Equation (4), then:

$$V = \sum_{i=1}^{N} c_i x_i + \sum_{j=1}^{M} c_j l_j \quad \textbf{(7)}$$

Therefore the overall objective function is given as:

$$Z = PQ - F - \left(\sum_{i=1}^{N} c_i x_i + \sum_{j=1}^{M} c_j l_j \right) \quad \textbf{(8)}$$

Production Process

In order to optimize the objective function:

$$Z = PQ - F - \left(\sum_{i=1}^{N} c_i x_i + \sum_{j=1}^{M} c_j l_j \right)$$

The constraints of the production process in relation to the objective function are given as:

(i) For good pricing policy of the product.
$P \le P_1$

Where:

P= unit selling price of product under review, given as:

$P = ((P_M/100)(F+C+D))/Q$

P_1 = unit selling Price of the best similar product in market.

(ii) Raw materials requisition is given as:
$\delta_{i\,min} \le x_i \le \delta_{i\,max}$ for all i

Where:

$\delta_{i\,min}$ ....is the minimum % of i^{th} raw material that could be used based on production process technology.

$\delta_{i\,max}$ .... is the maximum % of i^{th} raw material that could be used based on production process technology.

(iii) Labor is not too significant in the model but must be kept below a certain empirical percentage to the total cost of production which is given as:

$$D \leq \phi / 100 \ (F + C + D) \quad \textbf{(9)}$$

Where,

Φ = Empirical percentage of cost of labor to the total cost of production.

As indicated by the production process constraints, with variable techniques of production using linear optimization approach, the producer can choose various proportions of raw materials combinations all of which will yield the same output. Thus, simply by re-adjustment of process variables when there are fluctuations in price of one or more raw material to ensure production at the lowest cost possible, it will be able to decrease total cost of production without affecting total revenue and thus increase profits.

Optimizing the objective function (net profit) especially through continual re-adjustment of process variables when there are fluctuations in prices of raw materials to ensure competitiveness within an acceptable quality level, will be achieved by converting the mathematical models above into computer programming code to obviate the rigor of mathematical iterations.

CASE STUDY: A SMALL CASE SWINE FEED MILL

Swine Feed Formulation

Feed represents 60 to 75 percent of the total cost of pork production. Therefore, all the ingredients of swine feed must be provided and balanced to meet the pig's requirements. Thus, a thorough knowledge of the principles of swine nutrition is essential in order to maintain a profitable enterprise.

There is no perfect feed ingredient that can be fed to pigs by itself, and some feeds, if added to the diets in excess amounts, will decrease performance. The amount of feed per unit of gain is not the most important factor in formulating swine diets. Cost per unit of gain is more important; therefore, it is necessary to use the most economical energy sources in swine diets. The relative feeding values for different growth of pig are listed in Table 1 can be used to calculate the most economical feed formulation.

In formulating diets to meet recommended nutrient requirements of pigs, it is necessary to know the nutrient composition of each ingredient used. Table 2 gives Composition of ingredients commonly used in pig diets. Individual ingredients can vary widely in composition because of the variation in species or variety, storage conditions, climate, soil moisture, and agronomic differences.

Table 1: Active Nutrient Requirements for Different Growth of Pigs (Goodband et al., 2006)

Name of Feed	Feed Destined for:	Direct Energy Kcal/kg min	Protein % min	Lysine %min	Fat %min	Fiber %min	Calcium %min %max	Phosphorous %min
Starter	Fattening pigs & replacement stock. (15- 45kg)	3200	20.04	0.92	7.00	6.00	0.80 0.90	0.56
Grower - Finisher	Fattening pigs From 45kg to Slaughter	3100	13.60	0.73	8.00	6.00	0.70 0.85	0.48
Sow	Sow and Boar from 45kg – above	3000	13.00	0.72	8.00	9.00	0.80 0.90	0.54

Table 2: Starter Feed Ingredients with their Calculated Unit Nutritional Compositions (Adedeji, 2006).

	RAW MATERIALS(INGREDIENTS) AVAILABLE FOR PIG FEED										
Codes	Maize X_1	Soya Beans X_2	Ground Nut Cake X_3	Palm Kernel Cake X_4	Maize Bran X_5	Brewery Waste X_6	Wheat Offal X_7	Oyster Shell X_8	Pre-mix X_9	Salt X_{10}	Nutrition Req. of Starter Grower Sow
Digest. Energy (Cal/kg)	31.89	40.35	19.97	31.60	31.81	21.00	25.82	0.00	0.00	0.00	≥ 3200 ≥ 3100 ≥ 3000
Protein %	0.0885	0.44	0.35	0.173	0.076	0.17	0.155	0.00	0.00	0.00	≥ 20.04 ≥ 13.60 ≥ 13.00
Lysine %	0.0025	0.0285	0.013	0.0059	0.0039	0.008	0.0069	0.00	0.00	0.00	≥ 0.92 ≥ 0.73 ≥ 0.72
Fat %	0.036	0.018	0.085	0.081	0.042	0.057	0.046	0.00	0.00	0.00	≤ 7 ≤ 8 ≤ 8
Fibre %	0.023	0.087	0.086	0.177	0.09	0.165	0.04	0.00	0.00	0.00	≤ 6 ≤ 6 ≤ 9
Calcium %	0.00	0.0058	0.0022	0.0027	0.0004	0.0026	0.0045	0.39	0.00	0.00	≥ 0.80 ≥ 0.70 ≥ 0.80
Calcium %	0.00	0.0058	0.0022	0.0027	0.0004	0.0025	0.0045	0.39	0.00	0.00	≤ 0.90 ≤ 0.85 ≤ 0.90
Phosphorus %	0.0028	0.0061	0.0075	0.0063	0.005	0.006	0.1117	0.091	0.00	0.00	≥ 0.56 ≥ 0.48 ≥ 0.54
Premix %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	= 0.25 = 0.25 = 0.25
Salt (Nacl) %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	= 0.25 = 0.25 = 0.25
Unit Cost ₦	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	

Variations in chemical analytical procedure also affect values obtained. Therefore, the values given are an average and are subject to variation. In order to obtain ingredient variability and mineral/vitamin stability, we must state the nutritional composition and cost of each unit (kg) of available ingredients that could be employed in feed formulation. The challenge is to find diets (a choice of the percentage composition of the listed ingredients) that meet all nutritional requirements at minimal cost.

Mathematical Description Of The Swine Feed Mill

As derived above, the objective function of an industry like this is given as,

$$Z = (P * Q) - FC - \left(\sum_{i=1}^{N} C_i X_i + \sum_{j=1}^{M} C_j L_j \right)$$

P(unit selling price) = (% profit margin*(FC+ CX+ CL) + (FC+ CX+ CL))/ Q

Q = Volume of production.

FC = Total fixed cost incurred during production of the feed.

CL = Total cost of labor employed in the production.

CX = Total Minimum cost (within quality level) of raw materials employed.

This is to be achieved by applying linear optimization tool to the feed production variables as stated in Table 3, to minimize the cost of raw materials (total cost of production) of each of the feed type.

If feed type is starter feed, CX is obtained by,

Minimizing:

$$CX = C_1X_1 + C_2X_2 + C_3X_3 + C_4X_4 + C_5X_5 + C_6X_6 + C_7X_7 + C_8X_8 + C_9X_9 + C_{10}X_{10} \quad \textbf{(10)}$$

Subject to Constraints:

Digestible Energy: $31.89X_1 + 40.35X_2 + 19.97X_3 + 31.60X_4 + 31.81X_5 + 21X_6 + 25.82X_7 \geq 3200$

Crude Protein: $0.085X_1 + 0.44X_2 + 0.35X_3 + 0.173X_4 + 0.076X_5 + 0.17X_6 + 0.155X_7 \geq 20.4$

Lysine: $0.0025X_1 + 0.0285X_2 + 0.013X_3 + 0.0059X_4 + 0.0039X_5 + 0.008X_6 + 0.0069X_7 \geq 0.92$

Fat: $0.036X_1 + 0.018X_2 + 0.085X_3 + 0.081X_4 + 0.042X_5 + 0.057X_6 + 0.046X_7 \leq 7$

Fiber: $0.23X_1 + 0.087X_2 + 0.086X_3 + 0.177X_4 + 0.09X_5 + 0.165X_6 + 0.04X_7 \leq 6$

Calcium: $0.0058X_2 + 0.002X_3 + 0.0027X_4 + 0.0004X_5 + 0.0026X_6 + 0.0045X_7 + 0.39X_8 \leq 0.90$

Calcium: $0.0058X_2 + 0.002X_3 + 0.0027X_4 + 0.0004X_5 + 0.0026X_6 + 0.0045X_7 + 0.39X_8 \geq 0.80$

Phosphorus: $0.0028X_1 + 0.0061X_2 + 0.0075X_3 + 0.0063X_4 + 0.005X_5 + 0.006X_6 + 0.0117X_7 + 0.091X_8 \geq 0.56$

Premix: $X_9 = 0.25$

Salt: $X_{10} = 0.25$

Total Composition: $X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 + X_{10} = 100$

$X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10} \geq 0$

If feed type is Grower-Finisher feed, CX is obtained by,

Minimizing:

$$CX = C_1X_1 + C_2X_2 + C_3X_3 + C_4X_4 + C_5X_5 + C_6X_6 + C_7X_7 + C_8X_8 + C_9X_9 + C_{10}X_{10} \quad \textbf{(11)}$$

Subject to Constraints:

Digestible Energy: $31.89X_1 + 40.35X_2 + 19.97X_3 + 31.60X_4 + 31.81X_5 + 21X_6 + 25.82X_7 \geq 3100$

Crude Protein: $0.085X_1 + 0.44X_2 + 0.35X_3 + 0.173X_4 + 0.076X_5 + 0.17X_6 + 0.155X_7 \geq 13.60$

Lysine: $0.0025X_1 + 0.0285X_2 + 0.013X_3 + 0.0059X_4 + 0.0039X_5 + 0.008X_6 + 0.0069X_7 \geq 0.73$

Fat: $0.036X_1 + 0.018X_2 + 0.085X_3 + 0.081X_4 + 0.042X_5 + 0.057X_6 + 0.046X_7 \leq 8$

Fiber: $0.23X_1 + 0.087X_2 + 0.086X_3 + 0.177X_4 + 0.09X_5 + 0.165X_6 + 0.04X_7 \leq 6$

Calcium: $0.0058X_2 + 0.002X_3 + 0.0027X_4 + 0.0004X_5 + 0.0026X_6 + 0.0045X_7 + 0.39X_8 \leq 0.85$

Calcium: $0.0058X_2 + 0.002X_3 + 0.0027X_4 + 0.0004X_5 + 0.0026X_6 + 0.0045X_7 + 0.39X_8 \geq 0.70$

Phosphorus: $0.0028X_1 + 0.0061X_2 + 0.0075X_3 + 0.0063X_4 + 0.005X_5 + 0.006X_6 + 0.0117X_7 + 0.091X_8 \geq 0.48$

Premix: $X_9 = 0.25$

Salt: $X_{10} = 0.25$

Total Composition: $X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 + X_{10} = 100$

$X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10} \geq 0$

If feed type is Sow Feed, CX is obtained by,

Minimizing

$$CX = C_1X_1 + C_2X_2 + C_3X_3 + C_4X_4 + C_5X_5 + C_6X_6 + C_7X_7 + C_8X_8 + C_9X_9 + C_{10}X_{10} \quad \textbf{(12)}$$

Subject to Constraints:

Digestible Energy: $31.89X_1 + 40.35X_2 + 19.97X_3 + 31.60X_4 + 31.81X_5 + 21X_6 + 25.82X_7 \geq 3000$

Crude Protein: $0.085X_1 + 0.44X_2 + 0.35X_3 + 0.173X_4 + 0.076X_5 + 0.17X_6 + 0.155X_7 \geq 13$

Lysine: $0.0025X_1 + 0.0285X_2 + 0.013X_3 + 0.0059X_4 + 0.0039X_5 + 0.008X_6 + 0.0069X_7 \geq 0.0.72$

Fat: $0.036X_1 + 0.018X_2 + 0.085X_3 + 0.081X_4 + 0.042X_5 + 0.057X_6 + 0.046X_7 \leq 8$

Fiber: $0.23X_1 + 0.087 X_2 + 0.086 X_3 + 0.177 X_4 + 0.09 X_5 + 0.165 X_6 + 0.04 X_7 \leq 9$

Calcium: $0.0058 X_2 + 0.002 X_3 + 0.0027 X_4 + 0.0004 X_5 + 0.0026 X_6 + 0.0045 X_7 + 0.39 X_8 \leq 0.90$

Calcium: $0.0058 X_2 + 0.002 X_3 + 0.0027 X_4 + 0.0004 X_5 + 0.0026 X_6 + 0.0045 X_7 + 0.39 X_8 \geq 0.80$

Phosphorus: $0.0028X_1+0.0061X_2 + 0.0075X_3 + 0.0063X_4 + 0.005X_5 + 0.006X_6 + 0.0117 X_7+ 0.091 X_8 \geq 0.54$

Premix: $X_9 = 0.25$

Salt: $X_{10} = 0.25$

Total Composition: $X_1+ X_2 + X_3 + X_4 + X_5 + X_6 +X_7 +X_8 +X_9 +X_{10} = 100$

$X_1 , X_2 , X_3 , X_4 , X_5 , X_6 , X_7 , X_8 , X_9 , X_{10} \geq 0$

Note: C_1 to C_{10} are unit prices of the raw materials to be input into the model.

While $X_{1 \text{ to }} X_{10}$ are percentage compositions of the raw materials expected as output of the model.

Summarily, the variable inputs into the model are:

1. Name or type of pig feed
2. Volume of Production; Q
3. Period of production (i.e., daily, weekly, monthly or yearly)
4. Total fixed cost of production; FC
5. Total cost of Labor; CL
6. Unit cost of each of the 10 raw materials; $C_{1 \text{ to }} C_{10}$
7. Profit margin %; PM
8. Unit price of prevailing similar product in market.

The expected outputs of the model are:

1. Optimized % composition of each of the raw materials; $X_{1 \text{ to }} X_{10}$ to be used in production.

2. Quantity of each of the raw materials based on given volume of production (Q)

3.Recommended unit selling price (P) based on given profit margin (PM)

4. Optimized Profit (Z)

RESULTS AND DISCUSSIONS

When the production data were entered into the developed model software, the results obtained are tabulated in Table 4.

Input (Production Data of Swine Feed Mill)

1. Type of feed: Case1: Starter feed, Case2: Grower- finisher, Case3: Sow feed.

2. Volume of production (Q):1000kg

3. Period of production: Monthly

4. Total fixed cost of production (F_C): ₦ 4,640

5. Total cost of Labor (CL): ₦ 2,000

6. Current Unit cost of each of the 10 raw materials;

- Maize (C_1): ₦38,
- Soyabean (C_2): ₦65,
- Groundnut cake (C_3): ₦45,
- Palm kernel cake (C_4): ₦38,
- Maize Bran(C_5): ₦28,
- Brewery waste(C_6): ₦10,
- Wheat offal(C_7): ₦17,
- Oyster shell(C_8):₦10,
- Premix(C_9):₦450,
- Sodium Chloride (C_{10}): ₦30

7. Profit margin %(PM): 20%

Results

To validate the developed model software, values of percentage composition of starter feed result on Table 4 is referred to as control or old formulation. While the new formulation is being referred to as the formulation as a result of re-adjustment by the model to obtain the cheapest formulation, when there were variation (increase or decrease) in the unit cost of some of the raw materials with reference to initial prices used to experiment the model in Table 4.

Table 4: Optimized Process Variables of Different Types of Pig Feed (Model Estimate).

Ingredient	Percentage Composition Starter Feed (%)	Percentage Composition G/finisher Feed (%)	Percentage Composition Sow Feed (%)	Production Volume. Starter Feed (kg)	Production volume. G-Finisher Feed (kg)	Production Volume. Sow feed (kg)
Maize Meal	37.9023	46.6283	21.9067	379.023	466.283	219.067
Soya beans	25.5305	12.6698	8.1417	255.305	126.698	81.417
Groundnut Cake	0	0	0	0	0	0
Palm Kernel Cake	11.075	16.544	36.9513	110.75	165.44	369.513
Maize Bran	0	0	0	0	0	0
Brewery Waste	0	0	0	0	0	0
Wheat Offal	23.6703	22.4247	31.1857	236.703	224.247	311.857
Oyster Shell	1.3218	1.2332	1.3145	13.218	12.332	13.145
Premix	0.25	0.25	0.25	2.5	2.5	2.5
Salt	0.25	0.25	0.25	2.5	2.5	2.5
Total	100%	100%	100%	1000kg	1000kg	1000kg
Unit Cost(₦)				52.9216	47.2609	36.7018
Revenue (₦)				52,921.60	47,260.90	36,701.80
Raw material cost (₦)				37,461.40	32,744	23,944.80
Production cost (₦)				44,101.40	39,384	30,584.80
Profit(₦)				8,820.27	7,876.81	6,116.96s

The results obtained are as tabulated below. (Note: they are based on 100kg formulation).

Discussions

The results on Table 4 show that for the same input parameters, the model gave different optimized percentage composition of raw materials for the three types of pig feed required. What this implies is that, the three feed types had to satisfy different constraints (quality assurance levels) at minimum cost possible, thereby resulting in ingredients (maize, soya bean, GNC, PKC, Maize bran, brewery waste, wheat offal and oyster shell) variability and vitamin/mineral (premix and salt) stability. The results on Tables 5, 6, and 7 are output of the model when there were fluctuations in unit prices of some of the raw materials with reference to initial unit prices used to obtain results on Table 4.

Table 5 shows re-adjustment of optimized process variables composition when there was a change in price of maize. When unit cost of maize increased to ₦ 45, cost of raw material reduction of 1.12% was made against using the old formulation. While a 22.58% raw material cost reduction was obtained against using old formulation when unit cost of maize was ₦76.

On Table 6, re-adjustment of optimized process variable and raw material cost reduction of 8.30% was obtained against using old formulation; when unit cost of soya bean decreased to ₦40.

As shown on Table 7 When unit cost of soya bean decreased to ₦50 and that of maize and wheat offal increased to ₦50 and ₦38 respectively, re-adjustment of optimized process variable compositions (raw materials) and raw material cost reduction of 17% was obtained against using old formulation. All the raw material cost reduction being obtained resulted in minimized total cost of production which in turn optimized net profit with maintenance of good quality assurance level and good pricing policy for competitiveness.

It should be noted that the main feed stuff of swine are maize and soya bean (for energy and protein), premix and salt (for vitamins and minerals), while others are by-products usually

Table 5: Starter Feed Formulation when Price of Maize Increased (Model Estimate)

	Maize	Soya bean	GNC	PKC	Maize Bran	Brewery Waste	Wheat offal	Oyster shell	Premix	Salt	Cost(₦)
Old ₦ 45 formulation (%) ₦ 76	37.9023	25.5305	0	11.075	0	0	23.6703	1.3218	0.25	0.25	4,011.51 5,186.42
Model formulation(%) maize= ₦ 45	20.5288	28.0568	0	0	22.0409	0	27.5803	1.2032	0.25	0.25	3,966.43
Model formulation(%) maize= ₦ 76	1.4969	44.1859	0	0	0	0	53.035	0.7822	0.25	0.25	4,015.26

Table 6: Starter Feed Formulation when Price of Soya Bean Decreased (Model Estimate).

	Maize	Soya bean	GNC	PKC	Maize Bran	Brewery Waste	Wheat offal	Oyster shell	Premix	Salt	Cost(₦)
Old formulation (%)	37.9023	25.5305	0	11.075	0	0	23.6703	1.3218	0.25	0.25	3,107.87
Model formulation (%) Soya = ₦ 40	1.4969	44.1859	0	0	0	0	53.035	0.7822	0.25	0.25	2,850

Table 7: Starter Feed Formulation when Unit Price of Soya bean Decreased and Maize and Wheat Offal Increased, Respectively (Model Estimate).

	Maize	Soya bean	GNC	PKC	Maize Bran	Brewery Waste	Wheat offal	Oyster shell	Premix	Salt	Cost(₦)
Old formulation (%)	37.9023	25.5305	0	11.075	0	0	23.6703	1.3218	0.25	0.25	5,076.01
Model formulation (%)	20.9215	28.3231	0	0	22.1354	0	26.5627	1.5573	0.25	0.25	4226.98

added to reduce cost and their usage may be limited. This explains why their unit prices were not being varied to validate the model.

CONCLUSIONS

The development of a model for process re-engineering of a small-scale industry for economical and competitive production is very essential. A major reason being that it reduces total cost of production by principally formulating production variables (raw materials) at minimum cost possible with an acceptable quality level, thereby allowing for competitiveness of the industry by way of good pricing policy of her product and ultimately optimizing profit.

The overall importance of the model was shown through the following procedure:

- Necessary mathematical model were determined and formulated.
- The formulated model was converted to computer codes using visual C++ programming language for rapid iteration of the model.
- The reliability of the program was tested by a case study through;
    a. Experimentation of the model using specific swine feed formulation data

b. Validation of the model by varying the unit cost of production variables.

The model was verified by entering production process data of a small-scale swine feed mill. The results obtained showed different optimized raw material percentage compositions being formulated at minimum cost possible for the production of the three types of pig feed.

The model was also verified when result obtained showed readjusted feed formulations at minimum cost possible within quality assurance range when there were fluctuations input price(s) of raw material(s), which also resulted in 1.12%, 22.58%, 8.30, and 17% respective increment in profits at different occasions of fluctuations in unit prices of one or more raw materials.

All the raw materials composition readjustments and reductions in total cost production by the model resulted in optimized net profit with maintenance of good quality assurance level and good pricing policy, this is an indicator for long term competitiveness of any small-scale industry that employs this model for its process formulation.

REFERENCES

1. Ackoff, R. 1999. *Ackoff's Best: His Classic Writings on Management*. Wiley Publications: New York, NY.

2. Adam, E.E. and Ebert, R.J. 1998. *Production and Operations Management*. Prentice Hall Inc.: NJ.

3. Adejuyigbe, S.B. 2002. *Production Management (Design, Planning, Implementation and Control)*. Topfun Publications: Akure, Nigeria.

4. Aderoba, A.A. 1995. *Tools of Engineering Management, Vol.I Engineering Project Management*. Besade Publications: Ondo, Nigeria.

5. Arsham, H. 1997. "An Artificial-Free Simplex Algorithm for General LP Models". *Mathematical and Computer Modeling*. 25(1):107-123.

6. Arsham, H. 2005. "Sixpap Linear Programming Solver". www.sixsap.com.

7. Adedeji, J.O. 2006. *Revised Pig Ration Formulation.* Obafemi Awolowo University Press: Ile Ife, Nigeria.

8. Adedeji, J.O. 2004. *Livestock Management*. Obafemi Awolowo University Press: Ile Ife, Nigeria.

9. Bender, E. 2004. *Introduction to Mathematical Modeling*. Dover Publications: London, UK.

10. Beroggi, G. 2002. *Decision Modeling in Policy Management: An Introduction to the Analytic Concepts*. Kluwer Academic Publishers: Boston, MA.

11. Catlow, B. 1993. *Qualitative Methods for Computing Students*. DP Publication: Wolverhampton, UK.

12. Copper, S.A. 1993. *Business Mathematics and Statistics*. Palmer Publications: Kansas City, KS.

13. Chuta, E. 1983. *Upgrading the Managerial Process of Small Entrepreneurs in West Africa*. Vol. 3. University of Nigeria: Nsukka, Nigeria.

14. El-Namaki, M.S.S. 2004. "Development and Promoting Technology and Technical Skills in Small Scale Rural Manufacturing Enterprises". Paper Presented at Research Institute for Management Science: Amsterdam, Holland.

15. Food and Agriculture Organization. 1985. "The Contribution of Small-Scale Forest-Based Processing Enterprises to Rural Non-Farm Employment and Income in Selected Developing Countries". Rome.

16. Goodband, R.D., Dritz, S.S., Tokach, M.D. and Nelseen, J.L. 2006. *Livestock Management*. Kansas State University Press, Kansas.

17. Houston, S.K. and Blum, W. 1997. *Quantitative Analysis*. Albion Publishing: Chichester, UK.

18. Lucy, T. 2002. *Quantitative Techniques, Fourth Edition*. DP Publications: Shepherd Bush Green, London, UK.

19. Riggs, J.L. 2005. *Production Systems, Third Edition*. John Wiley and Sons, New York, NY.

20. Stewart, F. 1982. *Technology and Underdevelopment*. Macmillan Press: London, UK.

21. Stewart, F. and Paul, S. 2001. "Conflicts between Output and Employment Objectives in Developing Countries". *Oxford Economic Papers*. 23(2).

22. Tokach, M.D. and Nelseen, J.L. 2005. *Swine Management*. Agricultural Experiment Station and Cooperative Extension Service, Kansas State University, Kansas.

ABOUT THE AUTHORS

A. K. Ogunkoya is a research and development officer at Engineering Materials Development Institute, Akure, Ondo State, Nigeria. He holds a Master of Engineering (M.Eng.) in mechanical engineering (production option) and is also a registered mechanical Engineer (R.17,140) with the council for the regulation of engineering in Nigeria (COREN). His research interests are in the areas of operation research, design, modeling and simulation.

A. A. Aderoba is a Professor in the Department of mechanical Engineering and Production, Federal University of Technology; Akure, Nigeria. He has been in the academics for a very long time. He has to his credit numbers of local and international journals published in the area of industrial engineering and production management. He is a member of Nigerian Society of Engineers and also a registered Engineer with the Council for Regulation of Engineering in Nigeria (COREN). He has successfully supervised many masters and doctoral students. He has also served as external examiner to some Nigerian universities. His research interests are in the areas of operation research, production Techniques and Engineering Management.

SUGGESTED CITATION

Ogunkoya, A.K. and A.A. Aderoba. 2010. "A Model for Process Optimization of Small-Scale Industry for Competitive Production". *Pacific Journal of Science and Technology*. 11(2):366-375.

Pacific Journal of Science and Technology