

## ON OPTIMAL PRODUCT-MIX FOR PROFIT OPTIMIZATION OF SHARKS BAKERY COMPANY

### ABSTRACT

In this paper, linear programming model was applied to Sharks bread Production Company to determine the right product-mix and quantities that maximize the company's daily profit. The data collected on the products and resources were analyzed. The result showed that 30 loaves of coconut, 41 loaves of fruit, 50 loaves of almond and 270 loaves of wheat bread maximize the company's profit. Furthermore, the sensitivity analysis showed the lower and upper limits within which optimal profit of the company is maintained.

**Keywords:** Product-mix, Optimal profit, Linear programming, Sensitivity analysis

### 1.1. Introduction

The greatest challenge of decision maker(s) in production planning is how best production resources can be combined so as to attain optimality in customers' satisfaction, cost minimization, profit maximization and business sustenance. This "best way" is called optimization. Every production Company needs to understand the concept behind the optimization problem of product-mix so as to be able to focus on her core business, meet customers' needs and have a good inventory keeping and management.

The product-mix problem occurs in an industry where it is possible to manufacture a variety of products. The product-mix determination is very important as it helps a company to focus its production on relevant products that enhance business optimization: See [13]. Nevertheless, a company may be tempted to add more product lines in their quest to have more customers, thereby entering into the risk of including such products that appeal only to a little fraction of its customer base: See [6]. A quantitative decision making technique called linear programming can be used to effectively solve the product-mix problem of any production company.

Linear programming is therefore defined as a mathematical technique that can determine the right product-mix that will maximize the total profit, considering the fact that different products require different amounts of production resources, having different costs and revenues at different stages of production: See for example [1],[3] and [9]. [10] reported that, linear programming plays an important role in improving managerial decisions being that it is capable of solving problems such as production planning, allocation of resources, inventory control and advertisement. In solving linear programming problems, a well known mathematical technique called simplex algorithm which uses progressive iterative steps to arrive at optimal solution plays a very important role.

The simplex algorithm solution technique of linear programming has been used by several researchers in the determination of product-mix: See for example [3],[5],[16],[1],[14],[9],[13],[6] and [4]. [2] and [7] used M-method in solving their linear programming problems. [8] used big M and dual-simplex methods as alternative methods of finding solutions to linear programming that can reduce the number of iterations and also save valuable time. [12] applied linear programming for production planning and noted that it could reduce production cost to the barest minimum. [11] used LP in Software company to determine the number of projects

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of each type a company should take in one time period in order to maximize profit given the resources and the constraints. [15] used LP model to schedule drivers in a transport company so as to determine the minimum number of drivers needed for each shift in a day in order to reduce the amount of money spent for the reserved drivers.

In this study, we want to generate a production template for **Sharks bakery production company** that will bring to their knowledge the right product-mix with their profit limit specifications, quantities of the needed resources to be made available for their daily production and the very resources that could bring production to a halt due to their scarcity (so that there could be provision of extra units of such resources kept stand-by).

**Comment [K5]:** I presume Sharks Bakery Company Ltd is a proper noun

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### 1.2. The Sharks Bakery Production Company

Sharks bakery is a food and confectionary company that produces different kinds of bread and some other small chops like meat pie, doughnut and buns. They also have the food section where they prepare both local and continental dishes. This company is located in Kaduna and has been in existence for about nine months as at the time the data for this work were collected. This study focuses on the bread section of the company because of the customers' affection for their bread. This company has not been consistent in their production quantities and as a result, customers come sometimes only to be told that there is no bread available; and sometime, they produce more than can be exhausted in a day. Their manager cannot even say for sure that this is what they make as profit per day. The resources are not being well managed. The abovedescribed scenario prompted the carrying out of this research so as to provide a production template to be followed in order to optimize the business.

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**Comment [K8]:** "because of customers' preference" is suggested

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## 2.0 Materials and Methods

### 2.1 Materials.

The data used in this work were obtained from Sharks bakery company, Kaduna. The data collected include the raw materials used for the production of different types of bread and the profit made from each of the products. The table below shows the raw materials and their specified quantities.

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**Table 1: Raw materials and their available and required quantities**

Ingredients	Quantity Required (Per Product)						Available Resources
	x1	x2	x3	x4	x5	x6	
All Purpose flour (Kg)	0.2	0.21	0.2	0.22	0	0	150
Sugar (g)	0.17	0.15	0.21	0.2	0.22	0.18	500
Yeast (Kg)	0.02	0.02	0.02	0.02	0.02	0.02	20
Salt (g)	0.0011	0.002	0.003	0.0027	0.0015	0.0013	10

Wheat gluten (g)	0.00015	0.0018	0.002	0.002	0.00016	0.0019	15
Olive oil (L)	0.0152	0.02	0.021	0.0167	0.0152	0	10
Butter (g)	0.03	0	0.046	0.054	0	0.05	500
Milk (L)	0.015	0	0	0.0175	0	0.0148	4.0
Coconut Milk (L)	0	0.05	0	0	0	0	1.5
Almond Flour (Kg)	0	0	0	0	0.21	0	50
Dried Fruit (Kg)	0.0026	0	0.0054	0	0	0	3.5
Wheat Flour (Kg)	0	0	0	0	0	0.23	100
Almond Milk (L)	0	0	0	0	0.02	0	1.0

The profits made from the bread types are as follows: A loaf each of special bread yields a profit of ₦150, coconut bread yields a profit of ₦130, fruit bread yields a profit of ₦85, buttered bread yields a profit of ₦110, almond bread yields a profit of ₦175 while wheat bread yields a profit of ₦200 on daily basis

## 2.2 Methodology

The fundamental aim of optimization is to arrive at the best possible decision in any given circumstance. LP is an operation research technique for solving optimization problems. It maximizes or minimizes a linear function having a number of decision variables and constraints or restrictions stated in the form of **linear equations**. The general LP problem with  $n$  decision variables and  $m$  constraints can be expressed as follows:

**Comment [K12]:** should it be linear inequalities?

$$\text{Max}(\text{Min})Z = p_1x_1 + p_2x_2 + \dots + p_nx_n = \sum_{i=1}^n p_i x_i$$

Subject to

$$\begin{aligned} r_{11}x_1 + r_{12}x_2 + \dots + r_{1n}x_n & (\leq, =, \geq) b_1 \\ r_{21}x_1 + r_{22}x_2 + \dots + r_{2n}x_n & (\leq, =, \geq) b_2 \\ & \vdots \\ r_{m1}x_1 + r_{m2}x_2 + \dots + r_{mn}x_n & (\leq, =, \geq) b_m \\ x_i & \geq 0 \text{ for } i = 1, 2, \dots, n \end{aligned}$$

$$b_j \geq 0 \text{ for } j = 1, 2, \dots, m$$

where

$Z$  represents the measure of performance which is either to maximize profit or to minimize cost.

$p_1, p_2, \dots, p_n$  represent the per unit profit of the decision variables.

$x_1, x_2, \dots, x_n$  represent the quantity of each type of bread to be produced.

$r_{11}, r_{12}, \dots, r_{2n}, r_{m1}, r_{m2}, \dots, r_{mn}$  represent the amount of resource used for the production of a unit of each bread type.

$b_1, b_2, \dots, b_n$  represent the total available of each of the resources (raw materials or ingredients).

For  $n$  decision variables and  $m$  constraints, the standard form of the linear programming model is formulated as follows;

$$\text{Max}(\text{Min})Z = p_1x_1 + p_2x_2 + \dots + p_nx_n + 0s_1 + 0s_2 + \dots + 0s_m$$

subject to

$$\begin{aligned} r_{11}x_1 + r_{12}x_2 + \dots + r_{1n}x_n + s_1 & = b_1 \\ r_{21}x_1 + r_{22}x_2 + \dots + r_{2n}x_n + s_2 & = b_2 \end{aligned}$$

$$r_{m1}x_1 + r_{m2}x_2 + \dots + r_{mn}x_n + s_m = b_m$$

$$x_1, x_2, \dots, x_n, s_1, s_2, \dots, s_n, b_1, b_2, \dots, b_m \geq 0 \quad (\text{Non-negativity conditions})$$

In matrix or vector notation, the standard linear programming problem can be expressed as:

$$\text{Max}(\text{Min})Z = P'X$$

$$s.t. RX \leq B$$

$$X \geq 0$$

where

$$R = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} & 1 \\ \vdots & \vdots & & \vdots & \vdots \\ r_{m1} & r_{m2} & \dots & r_{mn} & 1 \end{bmatrix}$$

$$B = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_m \end{bmatrix}, P = \begin{bmatrix} p_1 \\ p_2 \\ \vdots \\ p_n \end{bmatrix} \quad \text{and } X = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix}$$

where

$R$ , an  $(m \times n)$  matrix, is the amount of the production resources which serves as the coefficient of each decision variable

$X$  is an  $n$  column vector which indicates the decision variables.

$B$  is an  $m$  column vector which represents the available resource constraints.

$P$  is an  $n$  column vector, is the (profit) objective functions coefficient of the decision variables.

### 2.3 Sensitivity Analysis

Sensitivity analysis also known as post optimality analysis helps to determine the limits within which the LP model parameters can be changed without affecting the current optimal solution. In this work, sensitivity analysis was carried out on the profit coefficients of the objective function and right hand side (RHS) resource constraint.

### 2.4 Mathematical Formulation of the Model for the Analyses

(i) Decision variables: The decision variables are defined as follows

$x_1$  represent the quantity of special bread to be produced

$x_2$  represent the quantity of coconut bread to be produced

$x_3$  represent the quantity of fruit bread to be produced

$x_4$  represent the quantity of buttered bread to be produced

$x_5$  represent the quantity of almond bread to be produced

$x_6$  represent the quantity of wheat bread to be produced.

(ii) Objective function:

$$\text{Maximize } Z = p_1x_1 + p_2x_2 + p_3x_3 + p_4x_4 + p_5x_5 + p_6x_6$$

Where

$p_1, p_2, p_3, p_4, p_5, p_6$  are the profit coefficients of special, coconut, fruit, buttered, almond and wheat breads respectively.

(iii) Constraints: The constraints are basically the raw materials (ingredients) used for the production of the six types of bread by the company. They are as shown in table 1 above.

**Comment [K13]:** What function is this objective function? Is it the profit function? If it is, what do the variables  $p_k, k=1, 2, 3, 4, 5, 6$  represent?

### 3.0 Data Analysis

#### 3.1 The linear programming model for the collected data.

The linear programming model for this work is given as:

$$\text{Maximize } Z = 150x_1 + 130x_2 + 85x_3 + 110x_4 + 175x_5 + 200x_6$$

S. t

$$0.2x_1 + 0.21x_2 + 0.20x_3 + 0.22x_4 \leq 150 \quad (\text{Flour})$$

$$0.17x_1 + 0.15x_2 + 0.21x_3 + 0.20x_4 + 0.22x_5 + 0.18x_6 \leq 500 \quad (\text{Sugar})$$

$$0.02x_1 + 0.02x_2 + 0.02x_3 + 0.02x_4 + 0.02x_5 + 0.02x_6 \leq 20 \quad (\text{Yeast})$$

$$0.0011x_1 + 0.002x_2 + 0.003x_3 + 0.0027x_4 + 0.0015x_5 + 0.0013x_6 \leq 10 \quad (\text{Salt})$$

$$0.00015x_1 + 0.0018x_2 + 0.002x_3 + 0.002x_4 + 0.00016x_5 + 0.0019x_6 \leq 15 \quad (\text{Wheatgluten})$$

$$0.0152x_1 + 0.02x_2 + 0.021x_3 + 0.0167x_4 + 0.0152x_5 \leq 10 \quad (\text{Oliveoil})$$

$$0.03x_1 + 0.046x_3 + 0.054x_4 + 0.05x_6 \leq 500 \quad (\text{Butter})$$

$$0.015x_1 + 0.0175x_4 + 0.0148x_6 \leq 4.0 \quad (\text{Milk})$$

$$0.050x_2 \leq 1.5 \quad (\text{Coconutmilk})$$

$$0.21x_5 \leq 50 \quad (\text{Almondflour})$$

$$0.0026x_1 + 0.0054x_3 \leq 3.5 \quad (\text{Driedfruits})$$

$$0.23x_6 \leq 100 \quad (\text{Wheatflour})$$

$$0.02x_5 \leq 1.0 \quad (\text{AlmondMilk})$$

$$x_j \geq 0 \text{ for } j = 1, 2, \dots, 6$$

To solve the above problem, Simplex method was applied using Micro Excel-Solver software.

#### 3.1 Conversion of the linear programming model to a standard form

This is done by introducing the slack and surplus variables where necessary and conversion of inequality sign to equality sign. The standard model for the linear programming problem is given below;

$$\text{Maximize } Z - 150x_1 - 130x_2 - 85x_3 - 110x_4 - 175x_5 - 200x_6 + 0S_1 + 0S_2 + 0S_3 + \dots + 0S_{13} = 0$$

S. t.

$$0.2x_1 + 0.21x_2 + 0.20x_3 + 0.22x_4 + S_1 = 150$$

$$0.17x_1 + 0.15x_2 + 0.21x_3 + 0.20x_4 + 0.22x_5 + 0.18 + S_2 = 500$$

$$0.02x_1 + 0.02x_2 + 0.02x_3 + 0.02x_4 + 0.02x_5 + 0.02x_6 + S_3 = 20$$

$$0.0011x_1 + 0.002x_2 + 0.003x_3 + 0.0027x_4 + 0.0015x_5 + 0.0013x_6 + S_4 = 10$$

$$0.00015x_1 + 0.0018x_2 + 0.002x_3 + 0.002x_4 + 0.00016x_5 + 0.0019x_6 + S_5 = 15$$

$$0.0152x_1 + 0.02x_2 + 0.021x_3 + 0.0167x_4 + 0.0152x_5 + S_6 = 10$$

$$0.03x_1 + 0.046x_3 + 0.054x_4 + 0.05x_6 + S_7 = 500$$

$$0.015x_1 + 0.0175x_4 + 0.0148x_6 + S_8 = 4.0$$

$$0.050x_2 + S_9 = 1.5$$

$$0.21x_5 + S_{10} = 50$$

$$0.0026x_1 + 0.0054x_3 + S_{11} = 3.5$$

$$0.23x_6 + S_{12} = 100$$

$$0.02x_5 + S_{13} = 1.0$$

$x_j \geq 0$  for  $j = 1, 2, \dots, 6$  and  $S_i \geq 0$  for  $i = 1, 2, 3, \dots, 13$

Where;

$S_1, S_2, S_3, \dots, S_{13}$  are the added slack variables.

The solution to the linear programming problem in section 3 is given below:

**Table 2: The summary of the optimum solution**

S/N	Product (Variable)	Quantity (loaves)	Profit (Coefficient)	Profit in (₦)	Contribution
1	Special Bread	0.00	150	0.00	
2	Coconut Bread	30.00	130	3,900.00	
3	Fruit Bread	411.43	85	34,971.55	
4	Buttered Bread	0.00	110	0.00	
5	Almond Bread	50.00	175	8,750.00	
6	Wheat Bread	270.27	200	54,054.00	

**Table 3: The used and unused resource quantities**

S/N	Constraint	R.H. S	Slack	Used
1	<=	150	61.41	88.59
2	<=	500	349.45	150.55
3	<=	20	4.77	15.23

4	<=	10	8.28	1.72
5	<=	15	13.60	1.40
6	<=	10	0	10.00
7	<=	500	467.56	32.44
8	<=	4.0	0	4.00
9	<=	1.5	0	1.50
10	<=	50	39.50	10.50
11	<=	3.5	1.28	2.22
12	<=	100	37.84	62.16
13	<=	1.0	0	1.00

**Table 4: The summary of the sensitivity analysis on the objective function profit coefficients**

S/N	Variable	Profit coefficient	Lower limit	Upper limit
1	Special Bread	150	$-\infty$	114.2265
2	Coconut Bread	130	49.0476	$\infty$
3	Fruit Bread	85	85	51.5
4	Buttered Bread	110	$-\infty$	194.0817
5	Almond Bread	175	113.4762	$\infty$
6	Wheat Bread	200	112.7035	$\infty$

**Table 5: Result of Sensitivity Analysis on the Resource Constraints (RHS)**

S/N	Constraints	RHS Constraint	Lower limit	Upper limit	Dual Price
1	<=	150	61.4143	$\infty$	0
2	<=	500	349.4514	$\infty$	0
3	<=	20	4.7660	$\infty$	0
4	<=	10	8.2794	$\infty$	0
5	<=	15	13.6016	$\infty$	0
6	<=	10	8.64	4.9711	4047.6191
7	<=	500	467.5608	$\infty$	0
8	<=	4.0	4.0	2.4348	13513.51
9	<=	1.5	1.5	21.6	980.9524
10	<=	50	39.5	$\infty$	0
11	<=	3.5	1.2783	$\infty$	0
12	<=	100	37.8378	$\infty$	0
13	<=	1.0	1.0	3.7619	5673.8095

#### 4.0 Discussion

Microsoft Excel-Solver software was used to analyze the data in table 1 and daily optimal profit of ₦101,675.48k was obtained. The respective contributions of the products to this optimal profit are as follows:

30 loaves of coconut bread ( $x_2$ ) contributed ₦3,900, 411.43 loaves of fruit bread ( $x_3$ ) contributed ₦34,971.55, 50 loaves of almond bread ( $x_5$ ) contributed ₦8,750 and 270.27 loaves of wheat bread ( $x_6$ ) contributed ₦54,054. The profit contribution of special bread ( $x_1$ ) and buttered bread ( $x_4$ ) is zero each meaning that their contribution to the profit of the company is so insignificant that the company can still succeed and without such products. The results in table 3 showed that at the optimal solution, the available quantities of such ingredients (raw materials) as olive oil, milk, coconut milk and almond milk were exhausted or used up while the available quantities of all purpose flour, sugar, yeast, salt, wheat gluten, butter, almond flour, dried fruit and wheat flour were not all used up, meaning excess supply. The results of the sensitivity analysis in table 4 showed the specified lower and upper limits of the profits made from the bread types within which the daily profit of the company remains optimal. Table 5 provides the allowable limits in the resources for the daily production with their dual or shadow prices (in case the company runs short of any). Finally, the study revealed olive oil, milk, coconut milk and almond milk (with zero dual prices) as scarce resources that can lead to a halt in production processes when lacked.

## 5.0 Conclusion

This study aims at using linear programming model to distribute raw materials to the production of different bread types in Sharks bakery company in order to know the right product-mix that actually maximizes the company's daily profit and in what capacity. The company produces six different types of bread as given below: the special, coconut, fruit, buttered, almond and wheat breads. The data collected from the company were analyzed using Microsoft Excel-Solver software and the results provided a template that will enable the company maintain optimality in their daily profit making. Based on the findings made from this study, it is concluded that LP model is a robust one that can be adopted by the production unit of any organization, company or firm since it makes known the right product-mix, their exact quantities and the amount of resources that can guarantee optimality in their profit making.

## COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

**Comment [K14]:** The content of the conclusion does not follow from the findings of the research. It should tell exactly what came out from the research referring to the data collected. What has been done here is a rehash of the abstract.

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