Optimal Raw Materials Mix through Linear Programming in Tehinnah Cakes and Craft

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ABSTRACT
This study investigated the optimal raw materials mix through linear programming in Tehinnah Cakes and Crafts. This research utilizes linear programming technique to distribute raw materials to the different variables (Scones, Jam roll, Massil balls and Spanish tarts) in Tehinnah Cakes and Crates for profit maximization. The data was analyzed with Mat-Lab software using simplex algorithm which shows that 52.7026 units of Scones, 0.00 units of Jam roll, 19.3437 units of Masil balls and 21.6636 units of Spanish tarts can be manufactured to have a maximum profit of ₦8,550.80k. Hence, from the analysis, it was seen that more of Scones followed by Spanish tart and Massil ball should be produced for profit maximization.

KEYWORDS: *Optimal raw materials, Simplex method algorithm, Optimum result, Maximization and Linear programming model.*

I. INTRODUCTION

Linear programming as a mathematical algorithm is centered on limited resources distribution to competing variables with a view of achieving optimal ending. It determines a means of achieving best outcome ranging from profit maximization in a given mathematical model and given some various necessities as a linear function. It is also the most widely used techniques for decision making in industries and businesses which can applied to areas like in Agriculture, Military, Production Product, Financial, Engineering, Marketing and Personnel Management and in other various disciplines. Several scholars have investigated the application of this concept. Akpan and Iwok (2016) studied the application of linear programming for optimal mix of raw materials in bakery and recommended that Goretta bakery limited should produces all three sizes of bread raging from giant, big, small loaf. In order to attain maximum profit and to please her customers, additional of the small loaf would be produced followed by the big loaf. Determination of optimal mix for profit maximization using linear programming was studied by Debajyoti (2016). Yahya et al (2012) examined profit maximization in a product mix company using linear programming. One of the key results is the availability of proper information to obtain an optimal result. OLadejo et. al. (2012) conceptualizes an idea on the importance of linear programming for optimum production planning in Maidabino Investment Nigeria Limited, Katsina to concentrate on optimal production and profitable performance. Ailobhio et. al. (2018) examine an aspect of optimizing profit in Lace Baking Industry Lafia with linear programming model. One of the key results is that poor collection of data can affect the optimum expected profit of the product. Linear programming has become a problem of distributing limited resources to product in a way that profit is at its maximal or minimal cost. (Yahya, 2004).

Production company manager usually undergo some difficulties in decision making relating to the use of limited resources. This process of verdict construction is always partial which led to a drop in the precision of predicting the upcoming, such as value change and scarcity of raw resources. Due to its significant several scholars have embarked on research as it concerns optimal raw material mix Oluwaseyi et. al. (2020) conceptualizes an idea on profit maximization in a product mix bakery using the method of linear programming techniques to maximize the profit of the amount of bread produced in a day subject to the limitation in the production process. Balogun et. al. (2012) established the area of using linear programming model to formulate the optimal profit from the production soft drinks in Coca-Cola Company. During the course of research, it was shown that two of the products should be produced more to satisfy demand and also to maximized profit. Mahesh (2020) studied profit maximization in bakery by optimal allocation of raw materials. Jain et. al. (2020) examined profit maximization of a pharma company using linear programming. Their aim was to maximize profit for the company and minimize the cost of transportation of cough syrup from different plants of the company to the different market (customers) situated at different location. According to Yami et. al. (2017) studied linear programming model in Services Company's production cost management. They utilize the limited resources available to satisfy the demand and also optimize the production at the same time. Ezema and Amakom (2012) conceptualize an idea of enhancing profit with the linear programming model in Golden Plastic Industry. They formulated a model to allocate products in a way that will guarantee revenue maximization or minimization of cost. The application of linear programming model has actually been seen as a powerful tool in resolving the problem of verdict making founded on the usage of inadequate resources by all decision makers before achieving effective decision.

II. MATERIALS AND METHODS

Linear Programing Model

The general form of a linear model with n decision variable and m constraints can be expressed as follows

Optimized (Max or Min) $Z = c_1x_1 + c_2x_2 + \dots\dots\dots + c_jx_j$

Subject to the linear constraints

$$a_{11}x_1 + a_{12}x_2 + \dots\dots\dots + a_{1j}x_j (\le, =, \ge)\ b_1$$
$$a_{21}x_1 + a_{22}x_2 + \dots\dots\dots + a_{2j}x_j (\le, =, \ge)\ b_2$$
$$\vdots \qquad \vdots \qquad \vdots$$
$$\vdots \qquad \vdots \qquad \vdots$$
$$a_{i1}x_1 + a_{i2}x_2 + \dots\dots\dots + a_{ij}x_j (\le, =, \ge)\ b_i$$

The above formulation can be stated in a compressed form as follows

Optimized (Max or Min) $Z = \sum_{n=1}^{j} c_n x_m \dots\dots$ (objective function)

Subject to the linear constraints

$\sum_{n=1}^{j} a_{mn} x_n (\le, =, \ge)\ b_m, m = 1, 2, \dots\dots\dots i$ and $x_n \ge 0, n = 1, 2, \dots\dots\dots j$

Where $c_1, c_2, \dots\dots c_j$ denote the unit per profit or cost of decision variables $x_1, x_2, x_3 \dots., x_j$ to evaluate the objective functions. $a_{11}, a_{12} \dots\dots.,$ $a_{21}, \dots\dots\dots, a_{i1,}\ a_{i2}, \dots\dots\dots a_{ij}$ denotes the amount of existing resource expended per unit of the decision variables. The b_m denotes the total accessibility of the mth resource. Z denote the course of production which can be either profit or cost.

Standard form of a Linear Programming Model

With the simplex method solving a linear programming problem requires that the problem first be converted into a standard form. The standard form of a linear programming problem should obey the following criterion.

I. All the constraints should be expressed as equations by adding surplus or slack variables.
II. The right-hand side of each constraints should be made non-negative (if not). This is attained by multiplying both sides of the resulting constraints by (-1).
III. The objective function should be of a maximization type.

For j decision variables and i constraints, the standardized form of the linear programming model can be can be expressed below.

Optimize (max) $Z = c_1x_1 + c_2x_2 + \dots\dots\dots + c_jx_j + 0s_1 + 0s_2 + \dots\dots\dots + 0s_i$

Subject to the linear constraints.

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + \dots\dots\dots + a_{1j}x_j (\leq, =, \geq)\ b_1 \\ a_{21}x_1 + a_{22}x_2 + \dots\dots\dots + a_{2j}x_j (\leq, =, \geq)\ b_2 \\ \vdots \qquad\quad \vdots \qquad\quad \vdots \\ \vdots \qquad\quad \vdots \qquad\quad \vdots \\ a_{i1}x_1 + a_{i2}x_2 + \dots\dots\dots + a_{ij}x_j (\leq, =, \geq)\ b_i \\ x_1, x_{2,\dots\dots\dots}, x_j, s_1, s_2, \dots\dots\dots, s_i \geq 0 \end{aligned}$$

Linear programming model can be expressed in a compacted form as follows

Optimize (maximize or minimize) $Z = \sum_{n=1}^{j} c_n x_n + \sum_{m=1}^{i} 0s_m$ (objective function)

Subject to the linear constraints

$$\sum_{m=1}^{j} a_{mn}x_n + s_m = b_m, \qquad m = 1,\ 2, \dots \dots . i \qquad \text{(constraints)}$$

And $x_n, s_m \geq 0$ (for all m and n) (non-negativity condition)

Assumptions

i. It is supposed that the raw materials accessible for the production of snacks are limited (scarce)
ii. It is supposed that an effective distribution of raw materials to the variables (Scones, Masil Balls, Jam Roll, Spanish Tart)
iii. It is supposed that the qualities of raw materials used in Scones, Masil Balls, Jam Roll and Spanish Tart production are standard.

Presentation of Data and Data Analysis

The research work data was obtained from Tehinnah cake and craft. The data comprises of total amount of raw materials (flour, butter, sugar, baking powder, nut-meg, vanilla flavor, milk flavor, salt, real milk, vegetable oil, water and egg) available for daily production of four different types of snacks (scones, jam roll, masil ball, Spanish tart) and the profit contributed by each products of snacks produced. The data analysis was executed with Mat-Lab software using simplex method algorithm. Each raw material contained per each unit of snacks produced is as follows.

Profit Contributions Per each unit Product of Snacks Produced

Each unit of scones = ₦100
Each unit of jam roll = ₦70
Each unit of masil ball = ₦80
Each unit of Spanish tart = ₦80

The data can be analyzed in the table format.

Table 1: Products, Unit Cost, Selling Prices and Unit Profit.

Products	Unit Cost of Production (₦)	Units Selling Price (₦)	Unit Profit (₦)	% Unit Profit
Scones	150	250	100	66.67
Jam Roll	130	200	70	53.85
Masil Ball	120	200	80	66.67
Spanish Tart	120	200	80	66.67

Table 2: Quantity of Raw Materials used per Unit Product in Gram(g)

Raw Materials (g)	Scones (g)	Jam Roll (g)	Masil Ball (g)	Spanish Tart (g)	Total Available Raw Materials (g)
flour	57.69	46.58	50.00	68.18	5500
Butter	14.42	11.72	4.17	17.05	1210
Sugar	7.67	4.69	4.00	7.77	650
Vegetable oil	46.15	37.50	60.00	54.55	4800
Water	13.46	10.94	17.50	15.91	1450
Egg	1.92	1.56	2.50	4.55	250
Baking powder	0.92	0.75	0.73	1.09	88
Real Milk	1.54	1.25	2.00	1.82	160
Milk Flavor	0.62	0.50	0.80	0.73	64
Nut Meg	0.04	0.03	0.00	0.05	6
Salt	0.29	0.23	0.38	0.34	30
Vanilla Flavor	0.27	0.22	0.35	0.00	21

Formulation of Model

Let the amounts of scones to be produces $= x_1$
Let the amounts of jam roll to be produces $= x_2$
Let the amounts of masil ball to be produces $= x_3$
Let the amounts of Spanish tart to be produces $= x_4$
Let Z denote the profit (income) to be maximize
The linear programming model for data produced above is given by
Max $Z = 100x_1 + 70x_2 + 80x_3 + 80x_4$
Subject to

$$57.69x_1 + 46.58x_2 + 50.00x_3 + 68.18x_4 \leq 5500$$
$$14.42x_1 + 11.72x_2 + 4.17x_3 + 17.05x_4 \leq 1210$$
$$7.67x_1 + 4{,}69x_2 + 4.00\,x_3 + 7.77x_4 \leq 650$$
$$46.15x_1 + 37.50x_2 + 60.00x_3 + 54.55x_4 \leq 4800$$
$$13.46x_1 + 10.94x_2 + 17.50x_3 + 15.91x_4 \leq 1400$$
$$1.92x_1 + 1.56x_2 + 2.50x_3 + 4.55x_4 \leq 250$$
$$0.92x_1 + 0.75x_2 + 0.73x_3 + 1.09x_4 \leq 88$$
$$1.54x_1 + 1.25x_2 + 2.00x_3 + 1.82x_4 \leq 160$$
$$0.62x_1 + 0.50x_2 + 0.80x_3 + 0.73x_4 \leq 64$$
$$0.04x_1 + 0.03x_2 + 0.00x_3 + 0{,}05x_4 \leq 6$$

$$0.29x_1 + 0.23x_2 + 0.38x_3 + 0.34x_4 \leq 30$$
$$0.27x_1 + 0.22x_2 + 0.35x_3 + 0.00x_4 \leq 21$$
for $\quad x_1,\, x_2,\, x_3,\, x_4 \geq 0$

Convert the linear programming into standard form by introducing non-negative slack variables $s_1, s_2, s_3, \dots \dots \dots \dots \dots \dots, s_{12}$.
Maximize$Z = 100x_1 + 70x_2 + 80x_3 + 80x_4 + 0s_1 + 0s_2 + 0s_3 + 0s_4 + 0s_5 + 0s_6 + 0s_7 + 0s_8 + 0s_9 + 0s_{10} + 0s_{11} + 0s_{12}$
Subject to

$$57.69x_1 + 46.58x_2 + 50.00x_3 + 68.18x_4 + s_1 = 5500$$
$$14.42x_1 + 11.72x_2 + 4.17x_3 + 17.05x_4 + s_2 = 1210$$
$$7.67x_1 + 4{,}69x_2 + 4.00\,x_3 + 7.77x_4 + s_3 = 650$$
$$46.15x_1 + 37.50x_2 + 60.00x_3 + 54.55x_4 + s_4 = 4800$$
$$13.46x_1 + 10.94x_2 + 17.50x_3 + 15.91x_4 + s_5 = 1400$$
$$1.92x_1 + 1.56x_2 + 2.50x_3 + 4.55x_4 + s_6 = 250$$
$$0.92x_1 + 0.75x_2 + 0.73x_3 + 1.09x_4 + s_7 = 88$$
$$1.54x_1 + 1.25x_2 + 2.00x_3 + 1.82x_4 + s_8 = 160$$
$$0.62x_1 + 0.50x_2 + 0.80x_3 + 0.73x_4 + s_9 = 64$$
$$0.04x_1 + 0.03x_2 + 0.00x_3 + 0{,}05x_4 + s_{10} = 6$$
$$0.29x_1 + 0.23x_2 + 0.38x_3 + 0.34x_4 + s_{11} = 30$$
$$0.27x_1 + 0.22x_2 + 0.35x_3 + 0.00x_4 + s_{12} = 21$$
for $\quad x_1,\, x_2,\, x_3,\, x_{4,}s_1, s_2, s_3, s_4, s_5, s_6, s_7, s_8, s_9, s_{10}, s_{11}, s_{12} \geq 0$

Table 3: the initial table.

		C j→	100	70	80	80	0	0	0	0	0	0	0	0	0	0	0	0	
C_B	B	BV	x_1	x_2	x_3	x_4	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}	s_{11}	s_{12}	Min - ratio
0	s_1	5500	57.61	46.58	50.00	68.18	1	0	0	0	0	0	0	0	0	0	0	0	95.45
0	s_2	1210	14.42	11.72	4.17	17.05	0	1	0	0	0	0	0	0	0	0	0	0	83.91
0	s_3	650	7.67	4.69	4.00	7.77	0	0	1	0	0	0	0	0	0	0	0	0	84.75
0	s_4	4800	46.15	37.50	60.00	54.55	0	0	0	1	0	0	0	0	0	0	0	0	104.01
0	s_5	1400	13.46	10.94	17.50	15.91	0	0	0	0	1	0	0	0	0	0	0	0	104.21
0	s_6	250	1.92	1.56	2.50	4.55	0	0	0	0	0	1	0	0	0	0	0	0	130.21
0	s_7	88	0.92	0.75	0.73	1.09	0	0	0	0	0	0	1	0	0	0	0	0	95.65
0	s_8	160	1.54	1.25	2.00	1.82	0	0	0	0	0	0	0	1	0	0	0	0	103.90
0	s_9	64	0.62	0.50	0.80	0.73	0	0	0	0	0	0	0	0	1	0	0	0	103.23
0	s_{10}	6	0.04	0.03	0.00	0.05	0	0	0	0	0	0	0	0	0	1	0	0	150.00

0	s_{11}	30	0.29	0.23	0.38	0.34	0	0	0	0	0	0	0	0	0	0	1	0	107.14
0	s_{12}	21	0.27	0,22	0.35	0.00	0	0	0	0	0	0	0	0	0	0	0	1	77.78
Z= 0			100 ↑	70	80	80	0	0	0	0	0	0	0	0	0	0	0	0	

Table 4: Optimal Solution

		C n→	100	70	80	80	0	0	0	0	0	0	0	0	0	0	0	0
CB	B	BV	x_1	x_2	x_3	x_4	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}	s_{11}	s_{12}
0	s_1	20.6446	0	0.4226	0	0	1	-1.7295	0	0	0	0	0	0	0	0	-113.7983	1.3015
80	x_4	21.6636	0	-0.0183	0	1	0	$-8.1365e^{-04}$	0	0	0	0	0	0	0	0	2.9004	-3.1587
0	s_3	0.0677	0	-0.7330	0	0	0	-0.4098	0	0	0	0	0	0	0	0	-2.3006	-4.0478
0	s_4	25.4011	0	-0.8972	0	0	0	-0.0324	1	1	0	0	0	0	0	0	-158.8184	1.3850
0	s_5	7.4396	0	0.2645	0	0	0	-0.0094	0	0	1	0	0	0	0	0	-46.3215	0.4042
0	s_6	1.8822	0	0.0790	0	0	0	-0.0029	0	0	0	1	0	0	0	0	-13.2345	7.2612
0	s_7	1.7793	0	0.0113	0	0	0	-0.0323	0	0	0	0	1	0	0	0	-1.5862	0.0213
0	s_8	0.7228	0	0.0285	0	0	0	-0.0012	0	0	0	0	0	1	0	0	-5.2913	0.0452
0	s_9	0.0350	0	0.0081	0	0	0	$-8.4576e^{-04}$	0	0	0	0	0	0	1	0	-2.1047	0.0094
0	s_{10}	2.8087	0	-0.0021	0	0	0	-0.0036	0	0	0	0	0	0	0	1	0.0315	0.0082
80	x_3	19.3437	0	-0.0194	1	0	0	-0.0679	0	0	0	0	0	0	0	0	3.4051	-0.0308
100	x_1	52.7026	1	0.8400	0	0	0	-00880	0	0	0	0	0	0	0	0	-4.4141	3.7437
C n – Z n				-10.9828				-3.4351									-63.0344	-119.2074

$Z = ₦8550.80k$

The linear programming problem was solved using Mat-Lab software with the simplex method algorithm, which result to an optimum result of: $X_1 = 52.7026$, $X_2 = 0.00$, $X_3 = 19{,}3437$, $X_4 = 21.6636$ and $Z = ₦8550.80k$.

INTERPRETATION OF RESULT

Considering the data gotten from the simplex method iteration, the optimal result derived from the model shows that 52.7026 units of Scones followed by 21.6636 units of Spanish tart, 19.3437 units of Masil ball and 0.00 unit of jam roll should be produced. This will produce a maximum profit of ₦8550.80k.

IV. SUMMARY

The aim and focus of this research work were to use linear programming technique for best raw materials mix in snacks manufacturing. Tehinnah cake and craft is used as our case study. Scones, Jam Roll, Masil Ball and Spanish Tart were the four different decision variables used in the research work. Twelve raw materials namely flour, butter, sugar, vegetable oil, egg, real milk, baking powder, salt, milk flavor, vanilla flavor, nut meg, water where used for the manufacturing and the quantity of raw resources requires for each variable (Scones, Jam roll, Masil ball and Spanish tart). The result shows that 52.7026 unit of Scones, 21.6636 umits of Spanish tart, 19.3437 units of Masil ball, 0.00 units of Jam roll should be produced to obtain a maximum profit of ₦8550.80k.

V. CONCLUSION

The research work has clearly demonstrated the proper use of simplex algorithm in linear programming model in the production planning problem in Tehinnah cake and craft. The study has given understanding on how best the production can be effectively achieved the optimal production cost with resources and materials available. The results show that using Simplex method algorithm in linear programming the optimal results shows that 52.7026 unit of Scones, 21.6636 umits of Spanish tart, 19.3437 units of Masil ball, 0.00 units of Jam roll should be produced to obtain a maximum profit of ₦8550.80k.

VI. RECOMMENDATON

This study recommends that Tehinnah cake and craft should produce Scones, Jam Roll, Masil Ball and Spanish Tart in order to satisfy her customers. More Scones followed by Spanish Tart, Masil Ball and less of Jam Roll can be manufactured for obtaining optimum revenue. ₦8550.80k.

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