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APPLICATION OF LINEAR PROGRAMMING IN PRODUCTION OPTIMISATION USING SIMPLEX METHOD: A CASE STUDY OF MAIZUBE FARM LIMITED

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ABSTRACT

Efficient allocation of limited production resources is a major challenge faced by manufacturing and agro-processing industries seeking to maximise profit. This study examines the application of linear programming techniques in optimising production decisions at the dairy section of Maizube Farm Limited, with emphasis on the production of three yoghurt products: Big Yoghurt, Medium Yoghurt, and Small Yoghurt. The study investigates how available resources such as labour, production time, and raw materials can be optimally allocated among these products to achieve maximum profitability. A linear programming model was formulated to represent the production system, with profit maximisation as the objective function and production constraints reflecting the limited availability of key resources. The formulated model was solved using the Simplex tableau method, which iteratively evaluates feasible solutions until the optimal production plan is obtained. The results show that the optimal solution was obtained at the first tableau iteration with (X_2= 5.5), yielding a maximum profit value of (Z=12,100). The results demonstrate the effectiveness of linear programming as a decision support tool for optimising production planning and improving resource utilisation in dairy processing operations. The study therefore highlights the practical relevance of mathematical optimisation techniques in enhancing productivity and profitability in agro-industrial systems.

Keywords: Linear programming, Simplex method, Optimal solution, Feasible solution, Optimisation

INTRODUCTION

Production planning and resource allocation are fundamental components of efficient management in modern organizations. Firms operating in competitive environments must determine how to allocate scarce resources such as raw materials, labour, production time, and capital among competing activities in order to maximise profit or minimize cost. In many production systems, especially in agro-industrial operations, managers are faced with the challenge of deciding the optimal combination of products that should be produced given limited resources. Mathematical optimisation techniques provide structured tools that support such decision-making processes. One of the most widely used optimisation approaches is linear programming (LP)**,** which provides a systematic framework for determining the best allocation of limited resources among competing activities subject to certain constraints (Christinal and Jiji, 2025; Zhang *el al.*, 2024).

Linear programming is a quantitative decision-making technique used to determine the optimal value of an objective function, such as profit maximisation or cost minimization, subject to a set of linear constraints representing limited resources or operational restrictions (Krithi and Jandhyala, 2023). Empirical studies have shown that the application of linear programming models significantly improves production efficiency and profitability in real-life industrial systems. In the Nigerian context, similar findings have been reported where linear programming models enhanced production decisions and profit outcomes in manufacturing firms (Njoku and Gambo, 2022). The technique has been extensively applied in production planning, agriculture, transportation, scheduling, finance, and supply chain management. Modern studies highlight that LP remains one of the most powerful analytical tools in operations research because it enables decision-makers to translate complex production problems into structured mathematical models that can be solved efficiently (Miow *et al.*, 2025; Bertsimas and Tsitsiklis, 2021). Through the formulation of objective functions and constraints, LP models allow organizations to determine the optimal mix of products that yields the best economic outcome while respecting production limitations.

The origin of linear programming can be traced to the work of George B. Dantzig, who developed the Simplex Method in 1947 while addressing logistical planning problems in the United States Air Force (Huang *et al.*, 2021). Since its development, the Simplex method has become one of the most influential algorithms in operations research and mathematical optimisation. The method operates through an iterative procedure that systematically evaluates feasible solutions until the optimal solution is obtained. According to contemporary research, the Simplex method remains a foundational algorithm for solving linear optimisation problems due to its robustness, computational efficiency, and practical applicability in large-scale industrial decision problems (Bazaraa *et al.*, 2021).

In production environments, firms typically manufacture multiple products using shared resources such as machinery, labour hours, raw materials, and processing time. Because these resources are limited, producing more of one product often reduces the capacity to produce another. Without a scientific decision framework, production planning may rely on intuition or trial-and-error strategies, which may lead to inefficient utilisation of resources and reduced profitability (Ahamad and Bharadwaj, 2026; Mula *et al.,* 2022). Linear programming provides a rigorous mathematical framework for addressing such challenges by identifying the optimal production levels for each product that maximise profit under existing constraints. Recent studies emphasize that LP models significantly improve decision quality in manufacturing and agro-processing industries by providing optimal production strategies and better resource utilisation (Hillier and Lieberman, 2021).

In the dairy industry, production planning is particularly important because dairy products often involve perishable raw materials and time-sensitive processing activities. Milk obtained from dairy cattle must be processed quickly into value-added products such as yoghurt, cheese, or butter. The allocation of milk and other processing resources among different product varieties therefore becomes a critical managerial decision. In many dairy processing firms, yoghurt is produced in different packaging sizes to meet varying consumer demands. These product varieties usually differ in production cost, resource consumption, and selling price, making it necessary to determine the optimal production mix that maximises profitability (Javadi *et al.*, 2024).

Maizube Farm Limited, located along the Minna–Bida road in Niger State, Nigeria, operates a diversified agricultural enterprise that includes crop farming, livestock production, and dairy processing. The dairy section of the farm processes milk obtained from Holstein cattle into dairy products such as fresh milk and yoghurt. The yoghurt produced by the farm is packaged in three different sizes: Big Yoghurt, Medium Yoghurt, and Small Yoghurt**.** Each of these product categories requires different quantities of production inputs such as milk, labour time, packaging materials, and processing capacity. Since these resources are limited, the farm must determine how much of each yoghurt type should be produced in order to maximise overall profit. Many production decisions in agro-industrial firms, however, are often made without the support of rigorous optimisation techniques. Managers may rely on experience or market demand alone when deciding production quantities, which may lead to suboptimal allocation of resources. This situation can result in increased production costs, inefficient utilisation of raw materials, or reduced profitability. In the context of Maizube Farm Limited, the challenge lies in determining the best combination of Big Yoghurt, Medium Yoghurt, and Small Yoghurt that should be produced using the available production resources. Addressing this problem requires the application of mathematical optimisation methods capable of evaluating multiple constraints simultaneously.

The problem investigated in this study is therefore the optimal allocation of limited production resources in the dairy section of Maizube Farm Limited for the purpose of maximising profit from yoghurt production. Specifically, the study seeks to develop a linear programming model that represents the production process of the three yoghurt products and to determine the optimal production quantities using the Simplex method. By formulating the production system as a linear optimisation problem, the study aims to identify the most profitable combination of Big, Medium, and Small yoghurt products while considering constraints such as milk availability, processing capacity, labour requirements, and packaging resources.

This **study** aims to apply linear programming techniques using the Simplex method to determine the optimal production mix of yoghurt products at Maizube Farm Limited. To achieve this aim, the study formulates a mathematical model representing the production process, identifies the relevant constraints affecting yoghurt production, and solves the resulting optimisation problem to obtain the profit-maximising solution. Through this approach, the study demonstrates how quantitative optimisation methods can support effective decision-making in dairy production systems. Previous studies have shown that the integration of optimisation models into production planning significantly improves operational efficiency and profit performance in manufacturing and agricultural enterprises (Chvátal, 2021).

Beyond addressing the immediate production problem, this study also contributes to the broader application of operations research techniques in agricultural and agro-industrial management. Many agricultural enterprises in developing economies face persistent challenges related to inefficient resource allocation, rising production costs, and increasing market competition. The application of mathematical optimisation tools such as linear programming provides a practical means of improving production efficiency and profitability. According to recent research by Adeyemo and Akinwale, 2022, optimisation-based decision models have become essential tools for improving resource management in agricultural production systems and agro-processing industries.

The contribution to knowledge of this study lies in demonstrating the practical application of linear programming and the Simplex method in optimising yoghurt production within a real agricultural enterprise. By developing a mathematical model tailored to the operational structure of Maizube Farm Limited, the research provides a quantitative framework that can guide production planning decisions in the dairy section of the farm. Furthermore, the study contributes to the growing body of literature on the use of operations research techniques in agricultural production management, particularly within the Nigerian context where such analytical tools are still underutilised.

In addition, the findings of this study may serve as a decision-support framework for managers in similar dairy processing firms seeking to improve profitability through optimal resource allocation. By identifying the optimal production mix of Big, Medium, and Small yoghurt products, the study demonstrates how mathematical modelling can enhance managerial decision-making and improve production efficiency. Ultimately, the application of linear programming techniques offers a powerful tool for addressing complex production planning problems and supporting sustainable growth in agro-industrial enterprises.

MATERIALS AND METHODS

For the purpose of this study, primary data were collected from the production unit of Maizube Farm limited. The data collected shows that the company produces three varieties of yoghurt namely: Small-sized yoghurt, Medium-sized yoghurt, and Big-sized yoghurt. In analyzing the data collected, the simplex tableau method was used. This method is an iterative approach which follows the procedure below:

i. Covert the linear programming problem into its standard form:

$Minimise\ Z = \sum C_i X_i$

Such that $\sum A_{ij} X_j \leq B_j$

$X_j \geq 0$

Where:

Z is the total profit to be maximise

C_i is the profit contribution or cost coefficient associated with the i^{th} decision variable

X_i is the i^{th} decision variable representing the quantity of a particular product to be produced

A_{ij} is the amount of the i^{th} resource required to produce one unit of the j^{th} product

B_j is the total availability of the i^{th} resource or the right-hand side value if the i^{th} constraint

X_j is the quantity of the i^{th} product included in the solution of the linear programming model

ii. Construct the tableau for recording the result.

iii. The iterative procedure of the simplex method is applied, noting the entry and leaving variables. The entry variable is the most negative value of the Z-row and the leaving variable is least positive value gotten from performing the minimum ratio test (MRT).

iv. The values of the objective function Z and the variables are also determined.

Data Presentation and Tabulation

The data collected are presented in tabular form below for descriptive and analytical purpose. This will help in focusing on the accurate description of the variables in the problem, (source of data: Production Department of Maizube Farm limited).

Table 1: Table Showing the Products and Material Resources Required to Produce a Carton of Each of the Product

Products	Sugar (kg)	Flavor (liter)	Culture (kg)
Big Yoghurt	0.05	0.48	0.12
Small Yoghurt	0.05	0.80	0.20
Medium Yoghurt	0.08	0.02	0.14

Table 2: Table Showing the Total Available Resources Per Month

Sugar (kg)	Flavor (liter)	Culture (kg)
495	1320	330

Table 3: Table Showing the Total Machine Labour Hours Per Month

Machine	Dissolver	Pasteurizer	Incubator	Sealing machine	Total
Time average (hrs)	165	16.5	_	16.5	198
Number of machines	1	1	1	1	4
Total Number of hours	165	16.5	_	16.5	198

Table 4: Table Showing the Time Spent by Each Type of Production on the Machine Per Minute

Machine/product	Dissolver	pasteurizer	Incubator	Sealing machine	Total
Big yoghurt	30	3	_	3	36
Small yoghurt	30	3	_	3	36
Medium yoghurt	30	3	_	3	36

Table 5: Table Showing the Cost of Production, Selling Price and Profits Made Per Carton of Each Product

Product	Cost of product	Selling price	Quantity/carton	Profit/carton (₦)
Big yoghurt	4000	6000	12	2000
Small yoghurt	4200	6400	40	2200
Medium yoghurt	3200	4000	40	800

Given the products; big yoghurt, small yoghurt and medium yoghurt;

Let x_1 represent the quantity of big yoghurt produced

x_2 represent the quantity of small yoghurt produced

x_3 represent the quantity of medium yoghurt produced

The objective function is given as the function to be maximised. Therefore, let Z represent the profit.

Hence the objective function is given by:

$Maximise\ Z = 2000.4x_1 + 2200x_2 + 800x_3$

In this case, there are two constraints affecting the production of the products under consideration; resource (raw material) constraints and time constraints. These constraints are stated below mathematically as;

$0.05x_1 + 0.05x_2 + 0.08x_3 \leq 495$

$0.48x_1 + 0.80x_2 + 0.02x_3 \leq 1320$

$0.12x_1 + 0.20x_2 + 0.14x_3 \leq 330$

$36x_1 + 36x_2 + 36x_3 \leq 198$

The complete formulation is therefore given as:

$Maximise\ Z = 2000.4x_1 + 2200x_2 + 800x_3$

Such that;

$0.05x_1 + 0.05x_2 + 0.08x_3 \leq 495$

$0.48x_1 + 0.80x_2 + 0.02x_3 \leq 1320$

$0.12x_1 + 0.20x_2 + 0.14x_3 \leq 330$

$36x_1 + 36x_2 + 36x_3 \leq 198$

$x_1, x_2, x_3 \geq 0$

RESULTS AND DISCUSSION

The formulated linear programming model was solved using the simplex tableau method in order to determine the optimal production combination of the three yoghurt products produced at the dairy section of Maizube Farm Limited. The decision variables were defined as x_1, x_2, and x_3, representing the quantities of Big Yoghurt, Small Yoghurt, and Medium Yoghurt respectively. The objective of the model was to maximise total profit subject to constraints representing limitations in raw materials, processing time, and other operational resources. Since the model is a system of inequalities of the form ≤ sign, a slack variable was introduced in other to convert the problem to a standard form LP problem.

The standard formulation is therefore given as thus:

$Maximise\ Z - 2000x_1 - 2200x_2 - 800x_3 = 0$

Such that;

$0.05x_1 + 0.05x_2 + 0.08x_3 + S_4 = 495$

$0.48x_1 + 0.80x_2 + 0.02x_3 + S_5 = 1320$

$0.12x_1 + 0.20x_2 + 0.14x_3 + S_6 = 330$

$36x_1 + 36x_2 + 36x_3 + S_7 = 198$

$x_1, x_2, x_3, S_4, S_5, S_6, S_7 \geq 0$

The LP problem is captured by the simplex table below:

Table 6: Table Showing the Initial Simplex Tableau (Iteration 0)

	x_1	x_2	x_3	S_4	S_5	S_6	S_7	RHS	MRT
Z	-2000	-2200	-800	0	0	0	0	0	
S_4	0.05	0.05	0.08	1	0	0	0	495	$\frac{495}{0.05} = 9900$
S_5	0.48	0.80	0.02	0	1	0	0	1320	$\frac{1320}{0.08} = 1650$
S_6	0.12	0.20	0.14	0	0	1	0	330	$\frac{330}{0.20} = 1650$
S_7	36	36	36	0	0	0	1	198	$\frac{198}{36} = 5.5$

Since the Z-row contain negative values, the most negative value (x_2) becomes the entry variable.
The leaving variable is the minimum ratio from the RHS, gotten by dividing each of the values of the RHS by the corresponding value of the entry variable x_2. Thus, S_7 leaves the basis since it has the least positive ratio of 5.5. A new tableau is therefore constructed to obtain the optimal solution.

Table 7: Table Showing the 1st Iteration (Optima Simplex Tableau)

	x_1	x_2	x_3	S_4	S_5	S_6	S_7	RHS
Z	200	0	1400	0	0	0	61.11	12100
S_4	0	0	0.03	1	0	0	-0.00139	494.725
S_5	-0.32	0	-0.78	0	1	0	-0.0222	1315.6
S_6	-0.08	0	-0.06	0	0	1	-0.0056	328.9
x_2	1	1	1	0	0	0	0.0278	5.5

Since no negative coefficients exist in the Z-row, the solution is optimal. And the corresponding values of the variables are:
x_1 = 0, x_2 = 5.5, x_3 = 0
Hence maximise = 2000.4x_1+2200x_2+800x_3 becomes
= 2000(0) +2200(5.5) +800(0)
= ₦12,100
The result shows that the optimal production strategy under the specified constraints is to allocate available resources entirely to the production of only one product (Small Yoghurt). This outcome is consistent with findings from similar studies, where optimal solutions often favor a dominant product due to binding resource constraints. For instance, Erinle-Ibrahim et al. (2020) reported that optimal production strategies in Nigerian manufacturing systems tend to prioritize specific products that yield higher returns under limited resources. In this optimal solution, Big Yoghurt and Medium Yoghurt are not produced, while 5.5 production units of Small Yoghurt yield the maximum attainable profit of ₦12,100 within the limits of the available resources.
This outcome reflects the relative contribution of each product to the overall profit structure of the production system. Small Yoghurt provides the highest return per unit of constrained resources, making it the most economically efficient product under the prevailing production conditions. Consequently, when the simplex method evaluates the feasible region defined by the constraints, the optimal vertex corresponds to a production plan dominated by Small Yoghurt. It is important to note that the zero values obtained for Big Yoghurt and Medium Yoghurt do not imply that these products lack economic value. Rather, within the current constraint structure, allocating scarce resources to these products reduces the overall profitability of the system. The linear programming model therefore identifies the most profitable allocation of limited resources rather than evaluating the absolute worth of individual products.
From a managerial perspective, the findings highlight the importance of quantitative optimisation tools in production planning. By applying the simplex method, managers can identify the product mix that yields the highest profit while respecting operational limitations. This is particularly valuable in agro-industrial environments where raw materials, labour time, and processing capacity are often limited. The results therefore demonstrate how mathematical optimisation can support strategic production decisions and improve resource utilisation in dairy processing operations.

CONCLUSION

In conclusion, the analysis from this study confirms that linear programming provides an effective framework for determining optimal production strategies. When properly applied, it enables firms such as Maizube Farm Limited to improve decision making, enhance operational efficiency, and maximise profit within existing resource constraints. Future studies may extend this work by incorporating additional production factors such as transportation costs, fluctuating demand, and multi-period planning considerations. Sensitivity analysis may also be carried out to examine how changes in resource availability or market conditions affect the optimal production plan.

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