International Journal of Enhanced Research in Management & Computer Applications
ISSN: 2319-7471, Vol. 12 Issue 11, November-2023, Impact Factor: 7.751

Optimizing cake production: a real-world application of linear programming for bakery efficiency

Phanindra. G[1], Anitha Jandhyala[2]

[1]Student, BBA Department, PES University, Karnataka, India
[2]Associate Professor, BBA Department, PES University, Karnataka, India

ABSTRACT

In a world where the bakery industry strives to balance profit maximization with resource efficiency, this research paper explores the practical application of Linear Programming (LP) to optimize cake production. With a focus on Vanilla, and Black Forest cakes, the primary objective is to achieve maximum profitability while making effective use of resources. The paper delves into the bakery business, the foundations of LP, and the real-world application of LP techniques to cake production. It demonstrates that, just like in any other industry, the right mathematical recipe can lead to a symphony of success. There were 2 methods used which were graphical method LPP and solver LP

Keywords: Bakery efficiency, Linear Programming, Cake production, Profit maximization, Resource allocation, Bakery industry Resource efficiency, Mathematical modelling, Optimization techniques, Resource optimization, Real-world application, Bakery management, Production processes

INTRODUCTION

In a world where culinary delights and sweet indulgences hold a cherished place in the hearts of consumers, the art of baking stands as a testament to both tradition and innovation. The bakery industry is a realm where creativity meets precision, offering a wide array of confectionery delights that tantalize taste buds. Among the stars of this sugary galaxy Vanilla and Black Forest cakes—two beloved classics that have delighted cake enthusiasts for generations. However, beyond the sensory pleasure they bring, these delectable creations are also a subject of economic significance.

Baking Industry like any other industries faces the challenge of optimizing production processes to enhance their profitability while maintaining the highest standards of product quality.

In context to this Linear Programming (LP) comes up as a powerful tool that can revolutionize the way businesses or in reference to this paper “bakeries” can manage their resources, costs, and production strategies effectively.

Linear Programming, at its core, is a mathematical technique used to find the best possible outcome in a given mathematical model while adhering to a set of constraints. In the context of bakery management, LP provides a systematic and mathematical approach to decision-making. In this case it allows for the optimization of cake production by considering various factors, such as ingredient costs, labour hours, and production capacity, to maximize profits. LP provides a structured framework for bakery owners and managers to make informed decisions that strike a harmonious balance between two critical objectives: profit maximization and resource efficiency.

This paper embarks on a flavourful journey through a local bakery in Btm layout, where Vanilla and Black Forest cakes take centre stage. The primary objective is clear: profit maximization. The goal is to leverage the principles of Linear Programming to optimize the production of these two iconic cakes, with a keen focus on maximizing revenue. By doing so, this research project endeavours to demonstrate the practical application of LP in a real-world setting and show how it can transform the bakery landscape into a more profitable venture.

However, the pursuit extends beyond mere profit. Efficiency in resource allocation is equally vital, and in this case, it's paramount. A bakery's success hinges not only on its ability to generate revenue but also on how effectively it manages its budget and labour hours. This dual objective—maximizing profits while making the best use of resources—is the defining essence of the Linear Programming Problem (LPP). Through this research, the aim is to uncover the optimal

quantities for each cake type, ensuring that resources are allocated efficiently and that the delicate balance between flavour, cost, and labour is struck to perfection.

As we delve into the intricacies of this research, we will explore the bakery business, the foundations of Linear Programming, and the real-world application of LP techniques to cake production. Through a blend of mathematics and culinary artistry, the goal is to demonstrate that in the world of baking, just as in any other industry, the right mathematical recipe can lead to a symphony of success that's as sweet as the cakes themselves.

Dependent Variable:

- **Profit:** The central focus of this investigation is to enhance the bakery's revenue. It is a testimony to both tradition and innovation within the bakery industry.

Independent Variables:

- **Cake Varieties (Vanilla and Black Forest):** These signify the range of products produced by the bakery. This paper explores the optimal quantities for each cake variety.
- **Allocation of Resources (Flour, Eggs, Labor Hours, etc.):** This paper delves into how resources are allocated to each cake type, examining the impact of resource distribution on profitability.
- **Expenditures (Ingredient Costs, Labor Expenses, Overheads):** The financial outlays linked to the production of each cake variety are pivotal, directly influencing the bakery's profit margin.
- **Limitations (Resource Availability, Time, Ingredient Procurement):** This paper scrutinizes constraints such as resource availability and time, gaining insight into their implications on production and profitability.
- **Production Capability:** The bakery's ability to meet demand and maximize profits is influenced significantly by its production capacity.

OBJECTIVES

Profit Maximization:

In my Linear Programming Problem (LPP), the primary aim is profit maximization. I intend to optimize the production of Vanilla, and Black Forest cakes to maximize revenue.

This objective is reflected in the objective function, where the goal is to achieve the highest profit by determining the ideal quantities for each cake type.

Resource Efficiency:

LPP also focuses on resource efficiency. It's crucial to utilize the available budget and labor hours effectively.
The constraints set ensure that resources are allocated efficiently. This dual objective is the essence of my LPP: optimizing profits while making the best use of resources.

LITERATURE REVIEW

This study delves into the optimization of raw material usage in a local bakeshop in the Philippines, which specializes in producing small, medium, and large loaf bread. The bakery faces challenges with its static raw material planning approach, leaving it susceptible to sudden market price fluctuations. The aim is to leverage integer linear programming (ILP) to identify the most profitable production plan. The study utilizes 2022 data on raw material costs and bakery profits to construct the ILP model, resulting in a daily production plan of 80 units of medium-sized loaves, 28 units of small-sized loaves, and 17 units of large-sized loaves. This optimized plan yields a daily profit of ₱2,445 for the bakery. **(Pangan, 2023)**

This study investigates the pursuit of maximum profit at Maesa Cake and Bakery Shop, specifically the Permata Legenda Branch. The shop offers two product types, Banana Bolu (X1) and Banana Bolen (X2), in response to increasing demand for cake at various events. To achieve maximum profits, the study employs linear programming, applying the simplex method and the POM for Windows application. Data collection involved direct interviews with the shop owner. The research process involves creating a simplex table, inputting objective function and constraint coefficients, identifying key columns, rows, and numbers, and iterating to achieve positive coefficients in the objective function row. **(Rorim Panday, 2023)**

Many companies encounter challenges in optimizing the utilization of their production materials, which can lead to suboptimal profits. This research employs Linear Programming (LP) techniques to address this issue. The study focuses on Ani Hanim bakery and utilizes primary data. Linear programming involves the formulation of mathematical models to allocate resources effectively. These models, solved using LP techniques, help determine the optimal production quantities of various bakery products. In this specific case, the LP approach suggests producing specific quantities of different types of bread, each contributing to the overall profit. The outcome is an optimized production plan that maximizes profit while considering resource constraints. **(Mardia, 2023)**

The bakery industry, whether small or large, faces the challenge of resource allocation to maximize profit. Often, smaller bakeries rely on trial-and-error methods for this purpose, impacting gross profit and gross profit margin (GPM). This study focuses on achieving several objectives: determining the optimal production quantities for selected products at Templicious Enterprise, comparing results using Linear Programming (LP), Integer Linear Programming (ILP), and trial-and-error methods, and conducting sensitivity analysis to establish product limits. The study employs manual calculations and QM for Windows software for LP and ILP methods. **(Nasir, 2022)**

Linear programming serves as a valuable operational research technique for managerial decision-making, particularly in optimizing resource allocation for production. However, many organizations still rely on a trial-and-error approach, struggling to allocate limited resources for profit maximization. This study addresses this challenge by implementing optimization principles, utilizing linear programming to assess production costs and achieve optimal benefits. The research employs bakery data for five marketable bread products: chicken loaf, spicy loaf, curry chicken bun, sausage bun, and a doughnut. A mathematical model is built and solved using Excel software. **(Abu, 2022)**

This research introduced novelty by focusing on the fundamental principles of linear programming, specifically for identifying product mixes using accessible tools like Excel (Solver) and LINGO. It highlighted the cost-effectiveness and accessibility of Excel compared to more expensive software solutions, making it a practical option for small businesses. **(Chanda, 2022)**

This research aims to determine the most efficient allocation of limited raw materials in a sample bakery in Nigeria to optimize resource usage and maximize profit. The study is guided by the Diffusion of Innovation Theory and relies on data collected from Bread Mall in Port Harcourt, Nigeria. The data includes the total quantities of raw materials available (such as soybean oil, wheat gluten, sugar, yeast, flour, salt, and butter) for daily production of three different bread sizes (small loaf, big loaf, and family size), along with the profit contribution per unit size of bread produced. Using a formulated model and Microsoft Excel Solver for data analysis, the optimal solution indicates that producing only one size of bread, the big loaf, with a quantity of 71, results in a maximum profit of N5,000.00. **(Micah, 2022)**
This study focuses on optimizing bread production at Alheri Bread in Danja, Katsina State, Nigeria, using the Simplex algorithm of linear programming. The research aims to allocate raw materials effectively among competing variables, including large bread, medium bread, and small bread, with the objective of profit maximization. **(Yusuf, 2021)**

This study addresses the challenges faced by Small and Medium Enterprises (SMEs), particularly in Malaysia, regarding production planning and profit maximization. The focus is on optimizing the product mix to enhance business performance. The research employs a linear programming model to determine the ideal combination of products that would maximize profitability. **(Baki, 2021)**

The study explores the application of Linear Programming, an optimization technique for managerial decision-making, in the context of a university bakery in Benin City, Nigeria. The objective is to maximize daily profit while adhering to production constraints. By collecting data on raw material quantities used for various bread sizes and employing mathematical modeling and Linear Programming Solver (LIPS) **(Kayode Olakunle Oluwaseyi, 2020)**

The study focuses on the Nigerian Bottling Company's quest for an efficient and structured production process to optimize revenue. It employs linear programming to allocate raw materials to various product lines, seeking the ideal product mix that maximizes profit. Using the simplex algorithm through Tora Software, the research determines that the daily sale of 1,732 crates of Dubic Malt, 144 cartons of Orijin Bitter Sachets, and 8,227 crates of Mac-dowel Spirit generates a profit of ₦9,129,117.24. Sensitivity analysis explores the range of unit profits and resource quantities for optimal profit, revealing the shadow price for additional resources. **(Ezra, 2020)**

This paper aims to maximize the profit of a construction company involved in developing a housing society and shopping mall. The project involves constructing three types of houses (Flats) and shops with various specifications. The linear programming technique is applied to optimize the profit while considering constraints related to the number of houses and shops, the materials used, flooring tiles, coloring, and available man-hours. The study's objective is to enhance the company's profitability in this construction venture. **(Pandit, 2020)**

The XYZ bakery in Mumbai, like many other businesses, is primarily focused on achieving profitability to sustain its operations and flourish in a competitive market. In this era of industrialization, bakeries face the challenge of producing high-quality products in the right quantities and on time while minimizing costs and maximizing profits. To thrive and grow, it's essential for bakeries to enhance their productive efficiency. This study aims to leverage linear programming (LP) to create a mathematical model for maximizing the bakery's income. The research employs the Integer Programming Method algorithm to allocate raw materials, including cupcakes, pastries, and cakes, as variables in the bakery's production process to achieve the goal of income maximization. **(Naik M. S., 2020)**

This research paper employs the Simplex algorithm, a component of Linear Programming, to optimize the allocation of raw materials among competing bakery products, including bread, cookies, cakes, and macarons, with the goal of profit maximization. The results of the analysis recommend producing 103 units of bread, 368 units of cakes, 42 units of macarons, and no cookies to achieve a profit of Rs. 3,24,488. Notably, cakes, followed by bread and macarons, contribute significantly to profit. Therefore, the study suggests prioritizing the production of cakes over other products to achieve maximum profitability.**(Naik, 2020)**

This study addresses the challenge of efficiently utilizing limited resources in a feed mill production company. The production manager needs to make decisions on optimal resource allocation, and linear programming techniques are employed to tackle this issue. Using data from the company's operations diary and the Management Scientist Version 5.0, a linear programming model is formulated. The study reveals that streamlining the product range and discontinuing less productive products leads to improved profit. This suggests that implementing the outcomes of linear programming techniques in production planning could enhance monthly profits. The research highlights the power of linear programming in assisting managers with decision-making and the allocation of limited resources, ultimately contributing to operational and profit improvements. **(Solaja, 2019)**

RESEARCH METHODOLOGY

The data was collected from a local bakery situated in BTM Layout, Bangalore.
Non probability sampling was the method which was used for this research that means the data is not random and it has been collected for the primary purpose which is the conduction of the study and to reach a conclusion with the correct values

Convenience sampling was the technique applied for this paper. It is a non-probability sampling method where the units are selected for inclusion in the sample because they are the most convenient for the researcher to access.
Let, x be vanilla cakes produced per month.
Let, y be black forest cakes produced per month
The constraints have been formed on the basis of the following information

Objective Function:
Z = 228x + 278y
The profits for vanilla are Rs. 228 and the profits of black forest is Rs, 278

Resource Time Constraints:
30x + 60y ≤ 5340
Time for Vanilla cake: 30 minutes per cake.
Time for Black Forest cake: 60 minutes per cake.

Resource Eggs Constraints:
6x + 3y ≤ 834
Eggs for Vanilla cake: 6 eggs per cake
Eggs for Black Forest cake: 3 eggs per cake

Resource Flour Constraints:
250x + 250y ≤ 40000
Flour for Vanilla cake: 250 units
Flour for Black Forest cake: 250 units

Linear programming problem is to maximize profits
Maximize Z = 228x + 278y
Subjected to:
30x + 60y ≤ 5340 (Time constraint)
6x + 3y ≤ 834 (Eggs constraint)
250x + 250y ≤ 40000 (Flour constraint)
x ≥ 0 &y ≥ 0 (Non negative constraint)

DATA ANALYSIS AND INTERPRETATION

Solving the problem by the following 2 methods:

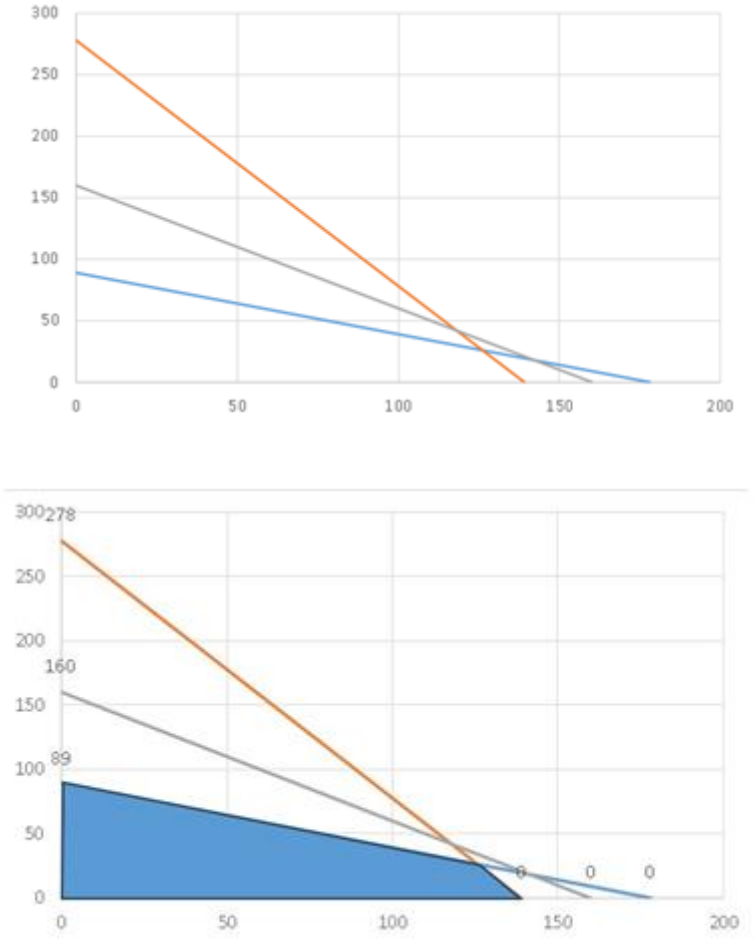
Method I: Graphical Method
Step 1: Converting Inequalities into equalities and substituting x and y as zero.

C1 (Time)		
x	0	178
y	89	0

C2 (Eggs)		
x	0	139
y	278	0

C3 (Flour)		
x	0	160
y	160	0

Step 2: Graphical representation



The above Graph shows the feasible points have been obtained by solving the problem graphically

Step 3: Feasible points

feasible points	**Z = 228x+278y**
(0,0)	0
(139,0)	31692
(126,26)	35956
(0,89)	24742

The above table shows the feasible region points that have been recived from the graphical solution
Max Z= 35956
When x = 126
and y = 26
From the graph it can be told that the bakery should manufacture 126 units of X which is vanilla cakes and it should make 26 units of y which is black forest cake (per month).

Method II: Simplex Method
Problem in simplex method using excel solver"

Table 1: Constraints formed by the data before solving:

Decision variables	x	y			
values	0	0	**Objective: Maximize**		
coefficients	228	278		0	
			LHS		**RHS**
Time	30	60	0	≤	5340
Eggs	6	3	0	≤	834
Flour	250	250	0	≤	40000

Table 2: Solved data through Excel Solver:

Decision variables	**x**	**y**			
values	126	26	**Objective: Maximize**		
coefficients	228	278		35956	
			LHS		**RHS**
Time	30	60	5340	≤	5340
Eggs	6	3	834	≤	834
Flour	250	250	38000	≤	40000

The above table shows the solution of the constraints which was solved by the "data solver" in excel
Max Z= 35956
When x = 126
and y = 26

FINDINGS

Both the methods used produced the same results.
Solved Data:
Quantity of Vanilla cakes (x) in the solution: 126 cakes.
Quantity of Black Forest cakes (y) in the solution: 26 cakes.

Constraint Satisfaction:
The bakery's time constraint ($30x + 60y \leq 5340$) is met, indicating that the production time for cakes does not exceed the available time.

The bakery's eggs constraint ($6x + 3y \leq 834$) is exactly met, meaning that the number of eggs used is within the available limit.

There's an underutilization of the bakery's flour constraint ($250x + 250y \leq 40000$), meaning that the bakery could potentially increase flour usage to produce more cakes and further maximize profits within the available limit.
In summary, the Linear Programming model has determined that the bakery should produce 126 Vanilla cakes and 26 Black Forest cakes to maximize profits.

+he bakery efficiently allocates production time and uses eggs within the available limits. However, there is an opportunity to use more flour to produce additional cakes, potentially leading to higher profits without violating constraints.

CONCLUSION

The results were the same both from the LPP solver and the graphical method
The objective of this study was to apply the simplex method and the graphical method for finding the optimum solution for a profit maximization problem for a local bakery in BTM layout with the help of MS Excel. The bakery, should produce a total of 126 units of vanilla cake and 26 units of black forest cake per month in order maximize their profits. The reviews and the study show that the use of simplex method for companies and businesses helps in obtaining an optimum solution for the problems like profit maximization and cost minimization. The evaluations and research findings indicate that the utilization of the simplex method in corporate and business contexts proves advantageous for achieving optimal outcomes in scenarios such as profit maximization and cost reduction.

REFERENCES

[1]. Abu, M. S. (2022). Simplex method for profit maximization in bakery store. . International Journal of Advanced Research in Technology and Innovation, 92-98.
[2]. Baki, S. M. (2021). A linear programming model for product mix profit maximization in a small medium enterprise company. International Journal of Industrial Management,, 64-73.
[3]. Chanda, R. P. (2022). A Study on Application of Linear Programming on Product Mix for Profit Maximization and Cost Optimization. Indian Journal of Science and Technology, 1067-1074.
[4]. Ezra, P. N. (2020). Application of linear programming on the profit maximization of Nigerian Bottling Company. American Journal of Operational Research, ,39-43.
[5]. Kayode Olakunle Oluwaseyi, A. E. (2020). Profit Maximization in a Product Mix Bakery Using Linear . Programming Technique. Journal of Investment and Management. Vol. 5, No. 1.
[6]. Mardia, A. Z. (2023). Analysis of product combination results and sales levels to maximize profits using the simplex method at the Ani Hanim sandwichesbi bakery. . AIP Conference Proceedings.
[7]. Micah, N. U. (2022). Linear Programming Utilization and Optimization of Raw Materials in Bread Baking Industry in Nigeria. International Journal of Academic Management Science Research (IJAMSR).
[8]. Naik, M. S. (2020). Enhancing the production in processin a bakery using optimization techniques. . International Journal of Engineering, Science and Mathematics, 66-72.
[9]. Naik, M. S. (2020). Profit maximization in bakery by optimal allocation of raw materials. . Aegaeum Journal, 8(5), , 391-393.
[10]. Nasir, D. S. (2022). Comparison of Linear and Integer Linear Programming for the Profit Optimization in Bakery Production: A Case Study at Temptlicious Enterprise. Journal of Computing Research and Innovation, 142-152.
[11]. Pandit, A. (2020). .Application of Linear programming for Profit maximization of a Housing construction company: Case study of Urbanization of Millennials. International Journal of Engineering Applied Sciences and Technology, .
[12]. Pangan, R. A. (2023). AN INTEGER PROGRAMMING APPROACH FOR OPTIMIZING RAW MATERIALS FOR LOAF BREAD PRODUCTION IN A SMALL-SCALE LOCAL BAKERY. Sci.Int.(Lahore) , 599-603.
[13]. Rorim Panday, M. A. (2023). Profit Optimization and Production of Maesa Cake and Bakery Shops with Linear Programming-Simplex Metho. DOI: 10.47191/ijcsrr/V6-i1-54, Impact Factor: 5.99.
[14]. Solaja, O. A. (2019). Application of linear programming techniques in production planning.. International Journal of Applied Operational Research-An Open Access Journal, 11-19.
[15]. Yusuf, G. &. (2021). An Empirical Study of Linear Programming for Optimal use of Raw Materials in Bakery: A Study of Alheri Bread Danja, Katsina State. . UMYU Journal of Accounting and Finance Research, 2(2),, 83-94.