MIMS Majalah Ilmiah Matematika dan Statistika 24 (2), 2024, 123 – 136
eISSN 2722-9886 pISSN 1411-6669
https://jurnal.unej.ac.id/index.php/MIMS/index

Optimizing banana production in Aroma Lumajang business using goal programming method and sensitivity analysis

Aurelly Meidy Bramastary, Selly Anastassia Amellia Kharis*

Department of Mathematics, Faculty Sains and Technology, Universitas Terbuka

*corresponding: selly@ecampus.ut.ac.id

Received: 20-02-2024, accepted: 10-09-2024

Abstract

Lumajang regency, located in the East Java Province, Indonesia, is renowned for its extensive banana cultivation. Aroma Business, situated in Kalibendo Village, Pasirian District, Lumajang Regency, specializes in banana processing. The company faces challenges including suboptimal production levels, underutilization of resources, raw material shortages, and escalating production costs. These issues contribute to financial instability and unmet market demand. This study aims to establish optimal production planning strategies to address these critical challenges. The research employs the goal programming method, which is selected for its suitability in addressing multi-objective problems. Optimization of production is essential for achieving desirable outcomes, ensuring both quantity and quality of products. Research conducted with the aid of LINDO software reveals that production costs can be reduced from IDR 6,647,400 to IDR 6,417,000. Additionally, raw material availability can be increased by 1,512 pieces and the production of banana stem chips can be increased from 240 pieces to 372 pieces, resulting in an increase in company profits from IDR 10,506,000 to IDR 11,727,000. Sensitivity analysis indicates that variations in the right-hand side ranges value do not impact the obtained optimal results.

Keywords: Banana production, goal programming, optimization, sensitivity analysis, LINDO software

MSC2020: 90B30

1. Introduction

Aroma business is one of the banana processing enterprises situated in Lumajang Regency, East Java Province, Indonesia. Established in 2016, this enterprise produces a diverse range of banana-based products, utilizing not only the fruit itself but also its stems and peels. Since its inception, Aroma business has experienced substantial growth and flourished until 2023. Despite its growth and success, the company faces several significant challenges in its production process. These challenges include suboptimal production levels, underutilization of resources, raw material shortages, and escalating production costs. These issues contribute to financial instability and unmet market demand. Addressing these challenges is critical for ensuring the company's long-term sustainability and competitiveness in the market. To address these issues, this study aims to establish optimal production planning strategies.

Production planning is a crucial aspect of operations management. It is essential to conduct thorough production planning, taking into account the volume of customer requests and the resources or capacity available to the company [1]. The quantity of production at Aroma Business is determined by the number of orders received from the previous period. However, a drawback of this approach is the potential for some customers to not receive their desired products due to insuffiicient production levels, resulting in suboptimal utilization of available raw materials. The production activities of this company are influenced by resource availability and market demand, thus necessitating production planning for effective operation. Production planning involves pre-organization of individuals, resources, machinery, other equipment, and capital required to conduct production activities within a specific future period as estimated beforehand.

Production planning and control (PPC) encompasses the tasks of loading, scheduling, sequencing, monitoring, and managing the utilization of resources and materials throughout the production process [2]. Production planning is a component of operations management, one of the most crucial disciplines in the manufacturing industry. Production planning is at the center of operations for any productive and profitable company [3,4]. PPC activities are formulated based on the constraints and objectives set at a company's or supply chain's strategic level. They also consider demand forecasts, customer orders, inventory levels, and ongoing work orders [5]. It is also defined as a process to determine the overall manufacturing output level aimed at meeting sales plans. Production planning is expected to be realistic and applicable. Production planners must first understand the company's capacity to implement production planning effectively and achieve production objectives in terms of quality, quantity, and cost [6,7].

Production planning is a crucial aspect of company management. This underscores the need for effective production planning, considering various factors to ensure optimal implementation. Optimization is a mathematical discipline that focuses on achieving minimum or maximum values to attain the optimal conditions satisfying the user needs and system constraints [8]. Optimization involves a broad range of techniques from operations research, artificial intelligence, computer science, and machine learning to enhancing business processes across nearly all fields and industries [9,10]. The optimization of production planning allows for multiple objectives or targets to be pursued simultaneously. For instance, if a company aims to achieve optimal profits while minimizing production costs, reducing raw material usage, and maximizing the quantity of products proceduced. In this study, the objective is to attain optimal production planning for the company, which involves maximizing production, optimizing raw material utilization, minimizing production costs, and maximizing profits.

By employing the goal programming method, the study seeks to optimize production levels, enhance raw material utilization, reduce production costs, and maximize profits. Goal programming is chosen for its capability to handle multi-objective optimization probles, making it suitable for the complex production requirements of Aroma Business. By employing this method, the study seeks to optimize production levels, enhance raw material utilization, reduce production costs, and maximize profits. Goal programming is a method derived from linear programming, first introduced by Charnes and Cooper in 1961, to optimize by modeling a problem with multiple objectives/goals [11]. The difference between goal programming and linear programming lies in the fact that goal programming involves not only a single objective function but also a set of goals or objectives, reffered to as constraints with relatively flexible right-hand side values [12,13]. The goal programming method is particularly effective when a mathematical model has numerous objective functions. This method sets a specific target for each objective function, making it more efficient in such scenarios [14]. The goal programming method was created to facilitate supplier selection based on the client's specific goals, including costs, quality, and delivery [15].

A previous study utilizing modified Goal programming was conducted by Nayeri, Gangraj, and Emami [16]. Nayeri et.al. use Multi-Choice Goal Programming (MCGP) approach for allocation and scheduling of the rescue units in natural disasters with time windows. A bi-objective mixed integer linear programming model (BIMILP) in Nayeri's research was introduced to allocate and schedule the rescue efforts during natural disaster. Similarly, Jadidi, Cavalieri, and Zolfaghari [17] using MCGP approach for supplier selection problem. In other research, a goal programming model use for stability analysis to a multi-product maritime inventory routing problem (MIRP). Solving 30 instances with CPLEX shows that considering all metrics together improves vendor-retailer decision-making. A cost analysis indicates that a 5% cost increase results in 7.5% fewer changes to replanned solutions, compared to much smaller improvements when metrics are considered individually. However, these studies did not address the specific challenges faced by small and medium enterprises in the food processing industry, particularly those utilizing raw materials with varying availability and costs. This gap in the literature presents an opportunity to explore the application of goal programming in the context of Aroma business, aiming to optimize production planning while considering the unique constraints and objectives of this enterprise. In this study, goal programming will be used to model the production process at Aroma Business. The objectives include maximizing production output, minimizing production costs, and optimizing the utilization of available raw materials.

Changes in each variation of parameter values will affect the optimal solution obtained. Therefore, to understand these changes, sensitivity analysis is conducted in this study. Sensitivity analysis is used to measure the effect of input species and parameters on output variables in complex models [18]. The objective of sensitivity analysis to minimize re-calculations if there are changes in the formulation after obtaining the optimal solution [19]. Several changes that can occur in sensitivity analysis include changes in the right-hand side of resource constraints, changes in the coefficients of the objective function, changes in technology coefficients, addition of new variables, and addition of new constrains [20,21]. Sensitivity analysis examines how variations in parameter values impact the optimal solution, allowing for a more robust and flexible production plan [22].

This research aims to optimize the Aroma business in Lumajang using goal programming and conducting sensitivity analysis. The expected results of this study will provide a comprehensive production planning strategy that addresses the current production challenges. The research will benefit Aroma business by improving resource utilization, reducing costs, and enhancing overall production efficiency. Additionally, it will help in meeting market demand more effectively and ensuring financial stability. The findings of this study can also serve as a reference for other small and medium enterprises in the food processing industry facing similar challenges, thereby contributing to the broader field of production optimization and operations management.

2. Methods

Figure 1 show the research flow diagram that outlines the process from data collection to results for optimizing banana production using goal programming in Aroma business. The research begins by identifying the problems faced by Aroma business, such as suboptimal production levels, underutilization of resources, raw material shortages, and escalating production costs. These problems necessitate the development of effective production planning strategies. The types of data used in this research are primary and secondary data. Primary data consists of direct interviews conducted with the founder and owner of Aroma Lumajang Business. Secondary data includes the production quantity of each product, raw material availability, production costs, selling prices, and profits obtained by Aroma Lumajang Business from 2020 to 2022.

Based on the objectives of maximizing profits, maximizing production quantity, minimizing production costs, and maximing the utilization of raw material availability, this company has multiple objectives or goals. Having multiple objectives necessitates an optimization technique in the form of a mathematical method called goal programming or also known as target programming [11]. Goal programming is chosen due to its capability to handle complex problems involving several competing goals, unlike the Simplex method, which is primarily suited for linear programming with a single objective function. The general form of the goal programming model is formulated using equations to represent the production quantities of various products and their respective goals.

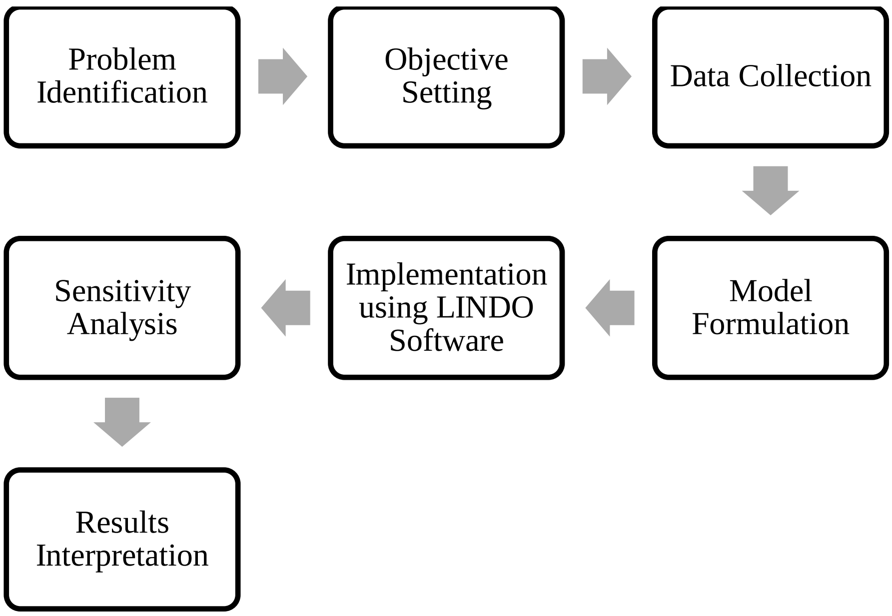

Figure 1. Research flow diagram

Based on the issues faced by Aroma Lumajang Business, the optimization problem in this case is addressed using the goal programming method with the assistance of LINDO software. LINDO software was chosen for this research due to several key advantages it offers over other optimization software. LINDO provides an intuitive and user-friendly interface, making it accessible for users with varying levels of expertise in optimization [23]. LINDO is known for its efficiency and speed in solving linear programming and goal programming problems. It can handle complex optimization models quickly, providing timely solutions which is crucial for business decision-making. LINDO delivers accurate and reliable results, which are essential for making informed and effective production planning decisions. Additionally, LINDO supports goal programming and offers robust tools for sensitivity analysis, which are crucial for understanding how changes in parameters impact the optimal solution. This versatility and comprehensive solution capability are significant improvements over the Simplex method. While the Simplex method is highly efficient for solving linear programming problems with a single objective, it falls short when dealing with multiple objectives. The utilization of LINDO software facilities the resolution of linear programming problems easily, quickly, and accurately, even handling problems with up to 150 constraints, 300 continuous variables, and 30 integer variables [24].

The general form of goal programming can be formulated as Equation (1) with constraints as Equation (2) for $i = 1,2,3,\dots,m$ and $j = 1,2,3,\dots,n$ with Z as objective function, d_i^+ as positive deviation i, d_i^- as negative deviation i, x_j as decision variable j, a_{ij} as technology coefficient/ coefficient related to x_j for objective i, b_i as total resources available for objective i, and $x_j, d_i^+, d_i^- \geq 0$.

$$Z = \sum_{i=1}^{m} (d_i^+ + d_i^-) \quad (1)$$

$$\sum_{j=1}^{n} a_{ij}\, x_j - d_i^+ + d_i^- = b_i \quad (2)$$

Subsequently, the goal programming modeling is adjusted to fit the Aroma Banana Business. The first step is to determine the decision variables. The decision variables selected in this study are the quantities of each banana processed product produced by Aroma Lumajang Business: x_1 as the quantity of balado banana stick products, x_2 as the quantity of sambal dower banana stick products, x_3 as the quantity of cheese banana stick products, x_4 as the quantity of barbeque banana stick product, x_5 as the quantity of chocolate banana chips products, x_6 as the quantity of strawberry banana chips products, x_7 as the quantity of durian banana chips products, x_8 as the quantity of lime banana chips products, x_9 as the quantity of banana skin crackers, x_{10} as the quantity of banana stem chips products, x_{11} as the quantity of banana roll sale products.

The next step is to determine the goal constraint. The objective of maximizing the production of balado banana sticks can be formulated as shown in Equation (3) with d_1^+ as positive deviation from the production quantity of balado banana sticks, d_1^- as negative deviation from the production quantity of balado banana sticks, and b_1 as quantity of production for balado banana sticks.

$$x_1 + d_1^- - d_1^+ = b_1 \quad (3)$$

The objective of maximizing the production of sambal dower banana sticks can be formulated as shown in Equation (4) with d_2^+ as positive deviation from the production quantity of sambal dower banana sticks, d_2^- as negative deviation from the production quantity of sambal dower banana sticks, and b_2 as quantity of production for sambal dower banana sticks.

$$x_2 + d_2^- - d_2^+ = b_2 \quad (4)$$

The objective of maximizing the production of cheese banana sticks can be formulated as shown in Equation (5) with d_3^+ as positive deviation from the production quantity of cheese banana sticks, d_3^- as negative deviation from the production quantity of cheese banana sticks, and b_3 as quantity of production for cheese banana sticks.

$$x_3 + d_3^- - d_3^+ = b_3 \quad (5)$$

The objective of maximizing the production of barbeque banana sticks can be formulated as shown in Equation (6) with d_4^+ as positive deviation from the production quantity of barbeque banana sticks, d_4^- as negative deviation from the production quantity of barbeque banana sticks, and b_4 as quantity of production for barbeque banana sticks.

$$x_4 + d_4^- - d_4^+ = b_4 \quad (6)$$

The objective of maximizing the production of barbeque banana sticks can be formulated as shown in Equation (7) with d_5^+ as positive deviation from the production quantity of chocolate banana sticks, d_5^- as negative deviation from the production quantity of chocolate banana sticks, and b_5 as quantity of production for chocolate banana sticks.

$$x_5 + d_5^- - d_5^+ = b_5 \tag{7}$$

The objective of maximizing the production of strawberry banana sticks can be formulated as shown in Equation (8) with d_6^+ as positive deviation from the production quantity of strawberry banana sticks, d_6^- as negative deviation from the production quantity of strawberry banana sticks, and b_6 as quantity of production for strawberry banana sticks.

$$x_6 + d_6^- - d_6^+ = b_6 \tag{8}$$

The objective of maximizing the production of durian banana sticks can be formulated as shown in Equation (9) with d_7^+ as positive deviation from the production quantity of durian banana sticks, d_7^- as negative deviation from the production quantity of durian banana sticks, and b_7 as quantity of production for durian banana sticks.

$$x_7 + d_7^- - d_7^+ = b_7 \tag{9}$$

The objective of maximizing the production of lime banana sticks can be formulated as shown in Equation (10) with d_8^+ as positive deviation from the production quantity of lime banana sticks, d_8^- as negative deviation from the production quantity of lime banana sticks, and b_8 as quantity of production for lime banana sticks.

$$x_8 + d_8^- - d_8^+ = b_8 \tag{10}$$

The objective of maximizing the production of banana skin crackers can be formulated as shown in Equation (11) with d_9^+ as positive deviation from the production quantity of banana skin crackers, d_9^- as negative deviation from the production quantity of banana skin crackers, and b_9 as quantity of production for banana skin crackers.

$$x_9 + d_9^- - d_9^+ = b_9 \tag{11}$$

The objective of maximizing the production of banana stem chips can be formulated as shown in Equation (12) with d_{10}^+ as positive deviation from the production quantity of banana stem chips, d_{10}^- as negative deviation from the production quantity of banana stem chips, and b_{10} as quantity of production for banana stem chips.

$$x_{10} + d_{10}^- - d_{10}^+ = b_{10} \tag{12}$$

The objective of maximizing the production of banana roll sale can be formulated as shown in Equation (13) with d_{11}^+ as positive deviation from the production quantity of banana roll sale, d_{11}^- as negative deviation from the production quantity of banana roll sale, and b_{11} as quantity of production for banana roll sale.

$$x_{11} + d_{11}^- - d_{11}^+ = b_{11} \tag{13}$$

The objective of minimizing production costs can be formulated as shown in Equation (14) with $a_{n(1)}$ as the production cost for product x_n , $n \in 1,2,\dots,11\}$, d_{12}^{+} as positive deviation in production cost, d_{12}^{-} as negative deviation in production cost, and b_{12} as available production cost amount.

$$a_{1(1)}x_1 + a_{2(1)}x_2 + a_{3(1)}x_3 + a_{4(1)}x_4 + a_{5(1)}x_5 + a_{6(1)}x_6 + a_{7(1)}x_7 + a_{8(1)}x_8 + a_{9(1)}x_9 + a_{10(1)}x_{10} + a_{11(1)}x_{11} + d_{12}^{-} - d_{12}^{+} = b_{12} \quad (14)$$

The objective of maximizing the availability of raw materials can be formulated as shown in Equation (15) with $a_{n(2)}$ as the availability of raw materials for product x_n , $n \in \{1,2,\dots,11\}$, d_{13}^{+} as positive deviation in raw material availability, d_{13}^{-} as negative deviation in raw material availability, and b_{13} as available raw material quantity.

$$a_{1(2)}x_1 + a_{2(2)}x_2 + a_{3(2)}x_3 + a_{4(2)}x_4 + a_{5(2)}x_5 + a_{6(2)}x_6 + a_{7(2)}x_7 + a_{8(2)}x_8 + a_{9(2)}x_9 + a_{10(2)}x_{10} + a_{11(2)}x_{11} + d_{13}^{-} - d_{13}^{+} = b_{13} \quad (15)$$

The objective of maximizing profit can be formulated as shown in Equation (16) with $a_{n(3)}$ as the coefficient profit for product x_n , $n \in 1,2,\dots,11\}$, d_{14}^{+} as positive deviation from the profit, d_{14}^{-} as negative deviation from the profit, and b_{14} as minimum profit amount.

$$a_{1(3)}x_1 + a_{2(3)}x_2 + a_{3(3)}x_3 + a_{4(3)}x_4 + a_{5(3)}x_5 + a_{6(3)}x_6 + a_{7(3)}x_7 + a_{8(3)}x_8 + a_{9(3)}x_9 + a_{10(3)}x_{10} + a_{11(3)}x_{11} + d_{14}^{-} - d_{14}^{+} = b_{14} \quad (16)$$

The objective function used in this study is to optimize banana processed product production by minimizing production costs, maximizing the utilization of raw materials, maximizing the production problem can be formulated as shown in Equation (17).

$$\text{Min Z} = \text{d}_1^{-} + \text{d}_2^{-} + \text{d}_3^{-} + \text{d}_4^{-} + \text{d}_5^{-} + \text{d}_6^{-} + \text{d}_7^{-} + \text{d}_8^{-} + \text{d}_9^{-} + \text{d}_{10}^{-} + \text{d}_{11}^{-} + \text{d}_{12}^{+} + \text{d}_{13}^{-} + \text{d}_{14}^{-} \quad (17)$$

3. Results

Based on the results of data collection through interviews, the obtained data are as shown in Table 1. This data includes the minimum production quantities for each product, production costs per package from each product, maximum resources of raw material availability that can be provided by the company in one month, maximum resources of raw material availability that can be provided by the company, and minimum profit resources obtained by the company in one month.

In Table 1, the presented data shows the minimum production quantities for balado banana sticks, sambal dower banana stick, cheese banana stick, and barbeque banana sticks, each with a minimum production quantity of 120 packages per month. Additionally, the minimum production quantities for chocolate banana chips, strawberry banana chips, durian banana chips, lime banana chips, banana skin crackers, banana stem chips, and banana roll sale are each 120, 120, 120, 120, 60, and 240 packages per month, respectively.

Table 1. Result of data collection

Product	Production Quantity (packages)	Production Cost (IDR per package)	Raw Material Availability (recipes per package)	Profit (IDR per package)
Balado banana stick	120	4,800	1	7,200
Sambal dower banana stick	120	4,800	1	7,200
Cheese banana stick	120	4,800	1	7,200
Barbeque banana stick	120	4,800	1	7,200
Chocolate banana chips	120	4,800	1	7,200
Strawberry banana chips	120	4,800	1	7,200
Durian banana chips	120	4,800	1	7,200
Lime banana chips	120	4,800	1	7,200
Banana skin crackers	60	3,500	1	8,500
Banana stem chips	240	2,750	1	9,250
Banana sale rolls	120	4,800	1	7,200

Furthermore, the maximum production cost resource available per month is IDR 6,647,400, with a maximum raw material availability of 1,512 packages per month and a minimum profit resource of IDR 10,506,000 per month. The target constraints in those study can be formulated in equation (18) to (31).

$$x_1 + d_1^- - d_1^+ = 120 \tag{18}$$

$$x_2 + d_2^- - d_2^+ = 120 \tag{19}$$

$$x_3 + d_3^- - d_3^+ = 120 \tag{20}$$

$$x_4 + d_4^- - d_4^+ = 120 \tag{21}$$

$$x_5 + d_5^- - d_5^+ = 120 \tag{22}$$

$$x_6 + d_6^- - d_6^+ = 120 \tag{23}$$

$$x_7 + d_7^- - d_7^+ = 120 \tag{24}$$

$$x_8 + d_8^- - d_8^+ = 120 \tag{25}$$

$$x_9 + d_9^- - d_9^+ = 60 \tag{26}$$

$$x_{10} + d_{10}^- - d_{10}^+ = 240 \tag{27}$$

$$x_{11} + d_{11}^- - d_{11}^+ = 120 \tag{28}$$

$$4{,}800x_1 + 4{,}800x_2 + 4{,}800x_3 + 4{,}800x_4 + 4{,}800x_5 + 4{,}800x_6 + 4{,}800x_7 + 4{,}800x_8 + 3{,}500x_9 + 2{,}750x_{10} + 4{,}800x_{11} + d_{12}^- - d_{12}^+ = 6{,}647{,}400 \tag{29}$$

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} + d_{13}^- - d_{13}^+ = 1{,}512 \quad (30)$$

$$7{,}200x_1 + 7{,}200x_2 + 7{,}200x_3 + 7{,}200x_4 + 7{,}200x_5 + 7{,}200x_6 + 7{,}200x_7 + 7{,}200x_8 + 8{,}500x_9 + 9{,}250x_{10} + 7{,}200x_{11} + d_{14}^- - d_{14}^+ = 10{,}506{,}000 \quad (31)$$

The goal programming solution is implemented using LINDO syntax, specifying "min" since the case uder consideration involves minimization. Negative deviations are denoted using the symbol "N", while positive deviations are denoted using the symbol "P" so $d_i^+$is written as DiP and d_i^- is written as DiN. The final results of the goal programming problem calculation obtained using the LINDO software can be written in Table 2.

Table 2. Optimization results summary

Product	Constraints	Objectives	d_i^-	d_i^+	Description
Number of balado banana stick	1	120	0	0	Fulfilled
Number of sambal dower banana stick	2	120	0	0	Fulfilled
Number of cheese banana stick	3	120	0	0	Fulfilled
Number of barbeque banana stick	4	120	0	0	Fulfilled
Number of chocolate banana chips	5	120	0	0	Fulfilled
Number of strawberry banana chips	6	120	0	0	Fulfilled
Number of durian banana chips	7	120	0	0	Fulfilled
Number of lime banana chips	8	120	0	0	Fulfilled
Number of banana skin crackers	9	60	0	0	Fulfilled
Number of banana stem chips	10	240	0	132	Fulfilled
Number of banana sale rolls	11	120	0	0	Fulfilled
Minimize production costs	12	6,647,400	230,400	0	Fulfilled
Maximize the utilization of raw materials availability	13	1512	0	0	Fulfilled
Maximize profits	14	10,506,000	0	1,221,000	Fulfilled

Based on Table 2, the optimized production quantities are as follows: 120 packages of balado banana sticks (x_1), 120 packages of sambal dower banana sticks (x_2), 120 packages of cheese banana sticks (x_3), 120 packages of barbeque banana stick (x_4), 120 packages of chocolate banana chips (x_5), 120 packages of strawberry banana chips (x_6), 120 packages of durian banana chips (x_7), 120 packages of lime banana chips (x_8), 60 packages of banana skin crackers (x_9), 372 packages of banana stem chips (x_{10}), and 120 packages of banana sale rolls (x_{11}). The production of banana stem chips yields the highest production quantity compared to other product types because the optimization results show it upper limit at 372. The optimization results necessitate the company to produce more banana stem chips than the previous production quantity, which was 240 packages, increasing it to 372 packages. This ensures the optimal utilization of raw materials for a total of 1,512 packages.

The production cost obtained a lower limit value of 230,400. This allows for the minimization of production costs from IDR 6,647,400 to IDR 6,417,000. The breakdown for each product is as follows: balado banana sticks IDR 4,800 × 120 = IDR 576,000, sambal dower banana sticks IDR 4,800 × 120 = IDR 576,000, cheese banana sticks IDR 4,800 × 120 = IDR 576,000, barbeque banana stick IDR 4,800 × 120 = IDR 576,000, chocolate banana chips IDR 4,800 × 120 = IDR 576,000, strawberry banana chips IDR 4,800 × 120 = IDR 576,000, durian banana chips IDR 4,800 × 120 = IDR 576,000, lime banana chips IDR 4,800 × 120 = IDR 576,000, banana skin crackers IDR 3,500 × 60 = IDR 210,000, banana stem chips IDR 2,750 × 372 = IDR 1,023,000, and banana sale rolls IDR 4,800 × 120 = IDR 576,000.

The profit has an upper limit value of 1,221,000. This results in maximizing the profit obtained from each product as follows: balado banana sticks IDR 7,200 × 120 = IDR 864,000, sambal dower banana stick IDR 7,200 × 120 = IDR 864,000, cheese banana sticks IDR 7,200 × 120 = IDR 864,000, barbeque banana stick IDR 7,200 × 120 = IDR 864,000, chocolate banana chips IDR 7,200 × 120 = IDR 864,000, strawberry banana chips IDR 7,200 × 120 = IDR 864,000, durian banana chips IDR 7,200 × 120 = IDR 864,000, lime banana chips IDR 7,200 × 120 = IDR 864,000, banana skin crackers IDR 8,500 × 60 = IDR 510,000, banana stem chips IDR 9,250 × 372 = IDR 3,441,000, and banana sale rolls IDR 7,200 × 120 = IDR 864,000. The total optimal profit obtained is increased from IDR 10,506,000 to IDR 11,727,000.

The results of sensitivity analysis can be observed from the values of slack or surplus and dual prices, indicating where active constraints exist. In this study, the values of slack or surplus and dual prices yield zero for all rows. This signifies that those constraints are inactive and can be disregarded. If the values of slack or surplus and dual prices are equal to zero, then the condition indicates that adding each unit of the right-hand side ranges or RHS to specified constraints will cause the objective function values to decrease by zero.

4. Conclusion

This research addressed the critical challenges faced by Aroma business, a banana processing enterprise in Lumajarang Regency, Indonesia. The main findings indicated significant improvements in production planning, resource utilization, and cost efficiency. This research using goal programming and LINDO osftware for optimization. Based on the conducted research, sensitivity analysis indicates that changes in the RHS values will not affect the optimal solution. The optimal result obtained from the objective function with positive deviations and negative deviations from each fulfilled target. The production optimization carried out by the company has been optimal with an additional production of 132 packages of banana stem chips, production costs can be minimized from IDR 6,647,400 to IDR 6,417,000, utilization of raw material resources for 1,512 packages of products, and optimal profit that can be increased from IDR 10,506,000 to IDR 11,727,000. The implementation of this optimized plan can significantly enhance production efficiency, meet market demand more effectively, and ensure financial stability for Aroma business. The research focused on optimizing production levels, resource utilization, and cost efficiency, without delving into other operational aspects such as marketing, distribution, or human resources. Additionally, the study was limited to the use of LINDO software for the implementation of goal programming. Future research can explore the integration of goal programming with other advanced optimization techniques and decision-making tools such as machine learning and complex production to develop more sophisticated solutions for complex production. This research contributes to the general public by providing a framework for enhancing production efficiency in small and medium size enterprises.

References

[1] E. Adriantantri, S. Indriani, "Optimization of production planning using linear programming," *International Journal of Software & Hardware Research in Engineering (IJSHRE)*, vol. 9, pp. 41-46, 2021. [GreenVersion]

[2] O.E. Oluyisola, S. Bhalla, F. Sgarbossa, J.O. Strandhagen, "Designing and developing smart production planning and control systems in the industry 4.0 era: a methodology and case study," *J. Intell Manuf*, vol. 33, no. 1, pp. 311-332, 2022. [CrossRef]

[3] S.A. Afolalu *et al.*, "The role of production planning in enhancing an efficient manufacturing system-an overview," in *E3S Web of Conferences*, 309, 01002, 2021. [GreenVersion]

[4] R. Ojstersek, M. Brezocnik, B. Buchmeister, "Multi-objective optimization of production scheduling with evolutionary computation: A review," *International Journal of Industrial Engineering Computations*, 11, 359-376, 2020. [CrossRef]

[5] A. Esteso, D. Peidro, J. Mula, M. Díaz-Madroñero, "Reinforcement learning applied to production planning and control," *International Journal of Production Research*, vol. 61, no. 16, 5772-5789, 2022. [CrossRef]

[6] W.C. Satyro *et al.*, "Sustainable industries: Production planning and control as an ally to implement strategy," *J Clean Prod*, vol. 281, p.124781, 2021. [CrossRef]

[7] M. Rahmani, A. Romsdal, F. Sgarbossa, J.O. Strandhagen, M. Holm, "Towards smart production planning and control; a conceptual framework linking planning environment characteristics with the need for smart production planning and control," *Annu Rev Control*, vol. 53, pp. 370-381, 2022. [CrossRef]

[8] K. Parvin *et al.*, “Intelligent controllers and optimization algorithms for building energy management towards achieving sustainable development: Challenges and prospects,” *IEEE Access*, vol. 9, pp. 41577-41602, 2021. [CrossRef]

[9] A.E. Ezugwu *et al.*, “Metaheuristics: a comprehensive overview and classification along with bibliometric analysis,” *Artif Intell Rev*, vol. 54, no. 6, pp. 4237-4316, 2021. [CrossRef]

[10] S.A.A. Kharis, A.I. Tarigan, D. Idayani, “Classification of lung cancer using support vector machine with feature selection based on artificial bee colony rate of change,” in *AIP Conference Proceedings*, American Institute of Physics Inc., 2023. [CrossRef]

[11] A.M. Rajagukguk, “Optimization of cap rajawali bean bread production capacity using goal programming method with priority,” *Formosa Journal of Applied Sciences*, vol. 1, no. 7, pp. 1463-1488, 2022. [CrossRef]

[12] L.R. Samosir, F. Ahyaningsih, “Application of the goal programming method in nurse scheduling at RSUD Dr. Hadrianus Sinaga Pangururan,” *Indonesian Journal of Advanced Research*, vol. 2, no. 7, pp. 965-982, 2023. [CrossRef]

[13] A. Kumar *et al.*, “A review of multi criteria decision making (MCDM) towards sustainable renewable energy development,” Renewable and Sustainable Energy Reviews, vol. 69, pp. 596-609, 2017. [CrossRef]

[14] A. Khalili Nasr, M. Tavana, B. Alavi, H. Mina, “A novel fuzzy multi-objective circular supplier selection and order allocation model for sustainable closed-loop supply chains,” *J Clean Prod*, vol. 287, 2021. [CrossRef]

[15] M. Braglia, A. Petroni, “A quality assurance-oriented methodology for handling trade-offs in supplier selection,” # MCB University Press, 2000. [GreenVersion]

[16] S. Nayeri, E.A. Gangraj, S. Emami, “Goal programming-based post-disaster decision-making for allocation and scheduling of the rescue units in natural disasters with time windows,” *International Journal of Industrial Engineering & Production Research*, vol. 29, no. 1, pp. 65-78, 2018. [CrossRef]

[17] O. Jadidi, S. Cavalieri, S. Zolfaghari, “An improved multi-choice goal programming approach for supplier selection problems,” *Appl Math Model*, vol. 39, no. 14, pp. 4213-4222, 2015. [CrossRef]

[18] F. Sultan, M. Yaseen, R. Fatima, M. Shahzad, M.M. Alam, “Model simplification and sensitivity analysis of chemical species for oxidation behavior in multi route complex chemical mechanism,” *Heliyon*, vol. 10, no. 12, e32547, 2024. [PubMed]

[19] S. Razavi *et al.*, “The future of sensitivity analysis: An essential discipline for systems modeling and policy support,” *Environmental Modelling and Software*, vol. 137, 2021. [CrossRef]

[20] J. Schulte, V. Nissen, "Sensitivity analysis in constrained evolutionary optimization," in *GECCO 2020 - Proceedings of the 2020 Genetic and Evolutionary Computation Conference*, Association for Computing Machinery, pp. 894-902, 2020. [GreenVersion]

[21] I.T. Abbas, M.N. Ghayyib, "Using sensitivity analysis in linear programming with practical physical applications," *Iraqi Journal of Science*, vol. 65, no. 2, pp. 907-922, 2024. [CrossRef]

[22] J. Więckowski, W. Sałabun, "A new sensitivity analysis method for decision-making with multiple parameters modification," *Inf Sci (N Y)*, vol. 678, 2024. [CrossRef]

[23] R. Yadav, M. Sahu, A. Bala, S. Wadia, M. Rani, "Food designing for Covid-19 patients with the help of applied mathematical optimization technique in LINDO Software," *Revista Colombiana de Ciencias Quimico-Farmaceuticas(Colombia)*, vol. 53, no. 2, pp. 522-536, 2024. [GreenVersion]

[24] J.F.D. Orta *et al.*, "Exact planning for an institutional soccer scheduling problem with time windows," in *Proceedings of the 2019 MULTILOG Conference*, pp. 105-114, 2019. [GreenVersion]