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Reseach Paper

Optimizing Banana Chips Production Planning in MSMEs Through the Goal Programming Approach

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Abstract: The UMKM Keripik Umi is a micro-scale enterprise that produces banana chips but currently lacks a structured and systematic production planning approach. Production decisions are still based on historical demand trends, leading to inefficiencies, especially when customer demand fluctuates. This study aims to optimize production quantities, minimize total production costs, and maximize sales revenue for three product variants: original, balado (spicy), and chocolate-flavored banana chips. To achieve these objectives, the Goal Programming method is utilized due to its effectiveness in solving multi-objective optimization problems, especially when there are conflicting goals. The results of the optimization show that the ideal production quantities are 4,191 packs for the original flavor, 8,187 packs for the balado flavor, and 5,434 packs for the chocolate flavor. With this production allocation, the minimum total production cost is achieved at IDR 123,479,100, while the maximum projected annual sales revenue reaches IDR 54,640,900. These findings demonstrate that the Goal Programming method can be a valuable decision-support tool for Micro, Small, and Medium Enterprises (MSMEs), particularly in managing limited resources while pursuing multiple business objectives. By implementing structured production planning using this method, MSMEs like Keripik Umi can significantly improve their operational efficiency, adapt more effectively to market dynamics, and enhance profitability in a competitive business environment.

Keywords: Goal Programming, Production Planning, MSMEs, Banana Chips, Optimization.

1. Introduction

Micro, Small, and Medium Enterprises (MSMEs) are crucial drivers of economic development, particularly in developing nations such as Indonesia [1]. In the food processing sector, banana chips represent a promising product due to the abundance of raw materials and increasing market demand. However, many MSMEs lack effective production planning strategies [2], [3]. This often leads to inefficient resource utilization, production imbalances, and financial losses. Without systematic planning, businesses struggle to align production output with fluctuating consumer demand [4], [5]. To address these challenges, optimization models such as Goal Programming offer a strategic advantage [6]. This approach allows enterprises to simultaneously consider multiple objectives under resource and market constraints [7].

UMKM Keripik Umi is a small enterprise specializing in banana chips with three main variants: original, balado, and chocolate. The enterprise currently relies on historical demand to guide production decisions without applying analytical planning methods. As a result, it faces frequent mismatches between supply and demand [8], [9]. Surplus production during low-demand periods and

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shortages during peak seasons disrupt operations and affect profitability. Additionally, inconsistent production planning hinders cost control and inventory management [10], [11]. These issues underline the importance of adopting a structured and data-driven planning approach. The implementation of an optimization method can help overcome such operational inefficiencies.

While production optimization methods are well-documented in academic literature, most studies focus on large-scale industries with substantial resources [12]. In contrast, limited attention has been given to MSMEs operating in the food sector, particularly those producing banana-based products. These small businesses often operate with limited budgets, workforce variability, and minimal planning tools. Furthermore, MSMEs commonly face multiple conflicting objectives, such as reducing costs while maximizing revenue [13]. Goal Programming is a suitable method for managing such trade-offs [14]. However, empirical applications in small-scale enterprises remain scarce. This study aims to fill that gap by applying Goal Programming in a real-world MSME setting.

This study aims to optimize the production planning process at UMKM Keripik Umi by applying the Goal Programming method [6], [15]. The research focuses on three main objectives: (1) determining the optimal production quantities for each banana chip variant, (2) minimizing total production costs, and (3) maximizing annual sales revenue. By developing a model tailored to the enterprise's constraints and goals, the study provides practical insights for improving production efficiency. Furthermore, the research demonstrates how small businesses can adopt mathematical optimization tools without needing complex systems or expertise, making it relevant and replicable for similar MSMEs in the food industry.

The research employs the Goal Programming method to solve multi-objective production planning problems [5], [16]. The model incorporates data from UMKM Keripik Umi, including production costs, forecasted demand, sales prices, and resource capacities. These variables are formulated into a linear optimization model, solved using appropriate computational tools [17]. Previous research applied Goal Programming to manage production planning with conflicting objectives, such as minimizing costs, meeting demand, and maximizing profit [13]. Using real UMKM data, the model provided optimal solutions and proved adaptable through sensitivity analysis, making it effective for decision-making under limited resources and market uncertainty [18]. The model balances multiple objectives within practical limitations. Additionally, a sensitivity analysis is conducted to examine the model's responsiveness to changes in constraints or target values. This methodological approach ensures that the model not only produces optimal solutions but also remains adaptable to real-world uncertainties commonly faced by MSMEs [19].

This study offers both practical and theoretical contributions. Academically, it extends the application of Goal Programming within MSME contexts, particularly in the Indonesian food processing sector. Practically, it provides a structured decision-making tool for small business owners to enhance production efficiency. By applying an optimization-based approach, the study encourages MSMEs to shift from intuition-based to data-driven planning [20]. The remainder of this paper is organized as follows: Section 2 reviews related literature, Section 3 outlines the research methodology, Section 4 presents the results and discussion, and Section 5 concludes with key findings and recommendations for future research.

2. Research and Methodology

This study was conducted at UMKM Keripik Umi, located in Balimas Hamlet, Lakawali Village, Malili Sub-district, East Luwu Regency, for approximately one month. The research focuses on optimizing production planning using the Goal Programming method. The primary objective is to determine optimal production quantities for each banana chip variant while minimizing production costs and maximizing sales revenue. The methodology begins with collecting operational data such as demand history, production costs, and resource availability [7], [14], [15]. Forecasting future demand is the first step, followed by defining decision variables, which represent the number of units to be produced for each product.

After identifying decision variables, the next steps include formulating the objective function, identifying constraints, and establishing goal priorities based on the enterprise's operational targets. The model is constructed using a linear programming structure and solved using LINGO 20.0 software, which is well-suited for handling multi-objective optimization problems. By incorporating real data from UMKM Keripik Umi, the model ensures accuracy and relevance to actual production conditions. A sensitivity analysis is also conducted to test the model's robustness under changing input conditions, making the solution both practical and adaptable for small-scale food processing enterprises.

3. Results and Discussion

3.1 Recapitulation of Production Results

In optimizing production planning, UMKM Keripik Umi aims to maximize production volume to meet market demand, minimize production costs, and achieve maximum profit. To support this objective, the study utilized historical data including sales records from June 2022 to May 2023, detailed production cost components, and selling prices for each banana chip variant. Based on these data inputs, the production plan was formulated and optimized using the Goal Programming method [17]. The recap of production results reflects the optimal quantity for each product variant that aligns with the enterprise's financial and operational targets, ensuring efficient resource allocation and improved profitability.

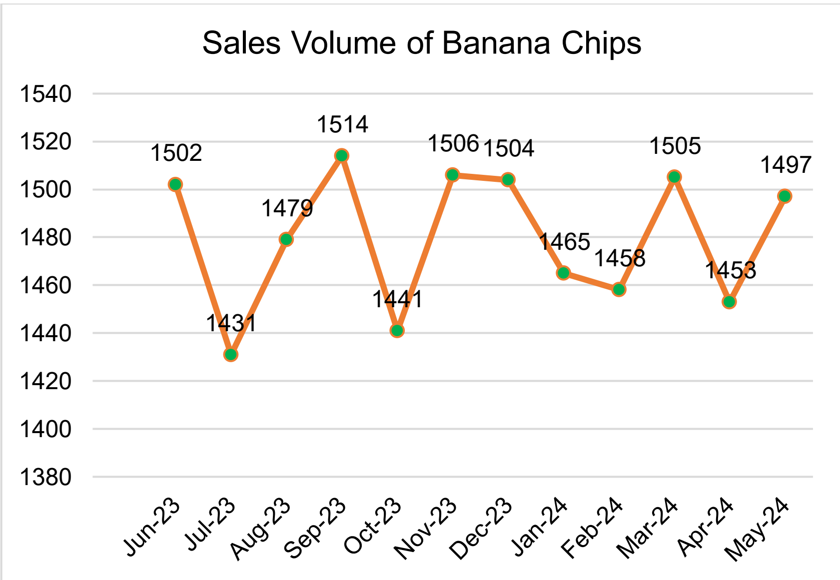


Figure 1. Monthly Sales Volume of Banana Chips (June 2023 – May 2024)

Figure 1 illustrates the monthly sales volume of banana chips over one year. The data shows fluctuating demand, with the highest sales occurring in September 2023 (1,514 units) and the lowest in July 2023 (1,431 units). Overall, the trend remains relatively stable, ranging between 1,431 and 1,514 units. These variations emphasize the importance of accurate demand forecasting and production planning to meet market needs effectively.

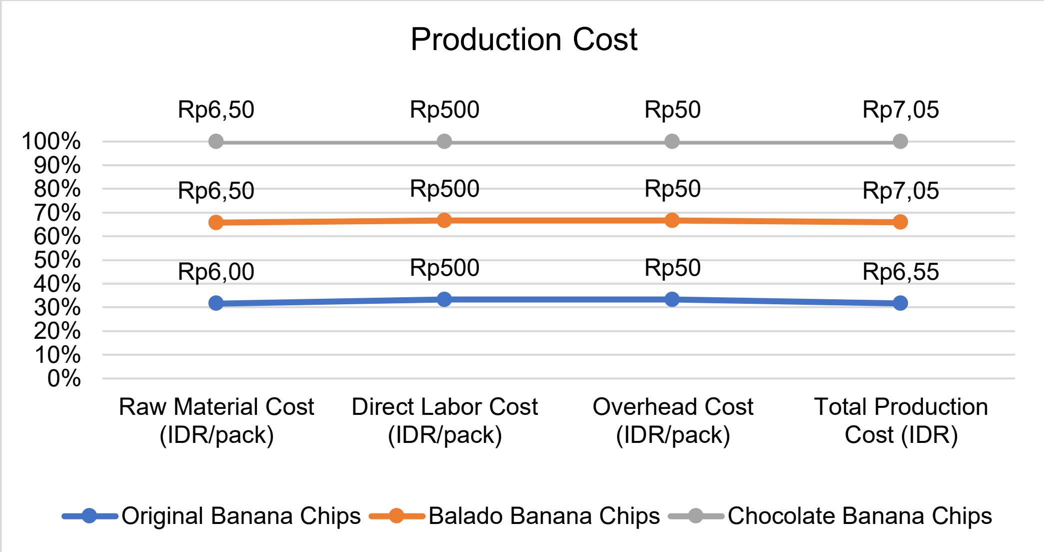


Figure 2. Comparison of Production Cost Components per Product Type

Figure 2 presents the breakdown of production costs for three banana chip variants: Original, Balado, and Chocolate, each measured per pack. The cost components include raw materials, direct labor, overhead, and total production cost. The Original Banana Chips have the lowest total cost at Rp6,550 per pack, while both Balado and Chocolate variants cost Rp7,050 per pack due to higher raw material expenses. Each product is sold at Rp10,000 per pack, resulting in a profit margin of Rp3,450 for Original and Rp2,950 for both Balado and Chocolate. This cost structure highlights the importance of managing raw material expenses to maximize profitability across product variants.

3.2 Sales Forecasting

Sales forecasting was conducted using the moving average method based on historical sales data.

Table 1. Sales Forecast of Banana Chips for the Period June 2023 – May 2024

No	Period	Flavor			Total
		Original	Balado	Chocolate	
1	Jun-23	332	469	681	1,482
2	Jul-23	365	450	687	1,502
3	Aug-23	356	446	679	1,481
4	Sep-23	351	445	684	1,48
5	Oct-23	367	451	682	1,5
6	Nov-23	349	443	685	1,477
7	Dec-23	358	445	681	1,484
8	Jan-24	359	456	676	1,491
9	Feb-24	343	457	683	1,483
10	Mar-24	334	455	686	1,475
11	Apr-24	344	456	684	1,484
12	May-24	333	461	681	1,475
Total		**4,191**	**5,434**	**8,187**	**17,812**

Table 1 presents the forecasted sales of banana chips at UMKM Keripik Umi from June 2023 to May 2024, categorized by flavor: original, balado, and chocolate. The total projected sales for the 12-month period are 17,812 packs, with chocolate flavor showing the highest demand at 8,187 packs, followed by balado with 5,434 packs, and original with 4,191 packs. Monthly demand remains relatively stable, ranging between 1,475 and 1,502 packs. These forecasts provide a crucial basis for production planning, allowing the enterprise to allocate resources efficiently and align production volume with market demand to minimize losses and meet customer needs effectively.

3.3 Decision Variables and Model Formulation

The decision variables represent the number of units to be produced for each product. The model aims to minimize production costs and maximize revenue, subject to available resources.

Table 2. Target Constraints for Each Banana Chips Product Variant

No	Month	Original (IDR)	Balado (IDR)	Chocolate (IDR)	Total (IDR)
1	June	Rp 2,174,600	Rp 3,306,450	Rp 4,801,050	Rp 10,282,100
2	July	Rp 2,390,750	Rp 3,172,500	Rp 4,843,350	Rp 10,406,600
3	August	Rp 2,331,800	Rp 3,144,300	Rp 4,786,950	Rp 10,263,050
4	September	Rp 2,299,050	Rp 3,137,250	Rp 4,822,200	Rp 10,258,500
5	October	Rp 2,403,850	Rp 3,179,550	Rp 4,807,600	Rp 10,391,000
6	November	Rp 2,285,950	Rp 3,123,150	Rp 4,815,150	Rp 10,224,250
7	December	Rp 2,344,900	Rp 3,137,250	Rp 4,801,050	Rp 10,283,200
8	January	Rp 2,351,450	Rp 3,214,800	Rp 4,765,800	Rp 10,332,050
9	February	Rp 2,246,650	Rp 3,221,850	Rp 4,815,150	Rp 10,283,650
10	March	Rp 2,187,700	Rp 3,207,750	Rp 4,836,300	Rp 10,231,750
11	April	Rp 2,253,200	Rp 3,204,600	Rp 4,832,200	Rp 10,290,000
12	May	Rp 2,181,150	Rp 3,250,050	Rp 4,801,050	Rp 10,232,250
	Total	**Rp 27,451,050**	**Rp 38,309,700**	**Rp 57,718,350**	**Rp 123,479,100**

Table 2 illustrates the monthly target cost constraints for each banana chips variant—original, balado, and chocolate—at UMKM Keripik Umi from June 2023 to May 2024. The total projected production cost for the entire period amounts to IDR 123,479,100, with chocolate flavor contributing the highest at IDR 57,718,350, followed by balado at IDR 38,309,700 and original at IDR 27,451,050. Monthly production costs range between IDR 10,224,250 and IDR 10,406,600, indicating relatively stable operational expenses. These values serve as cost limitations in the Goal Programming model to ensure that production planning remains within budget while optimizing the allocation of available resources.

Table 3. Sales Profit Targets from June 2023 to May 2024

No	Month	Original (IDR)	Balado (IDR)	Chocolate (IDR)	Total (IDR)
1	June	Rp 1,145,400	Rp 1,383,550	Rp 2,008,950	Rp 4,537,900
2	July	Rp 1,259,250	Rp 1,327,500	Rp 2,026,650	Rp 4,613,400
3	August	Rp 1,228,200	Rp 1,315,700	Rp 2,003,050	Rp 4,546,950
4	September	Rp 1,210,950	Rp 1,312,750	Rp 2,017,800	Rp 4,541,500
5	October	Rp 1,266,150	Rp 1,330,450	Rp 2,011,900	Rp 4,608,500
6	November	Rp 1,204,050	Rp 1,306,850	Rp 2,014,850	Rp 4,525,750
7	December	Rp 1,235,100	Rp 1,312,750	Rp 2,008,950	Rp 4,556,800
8	January	Rp 1,238,550	Rp 1,345,200	Rp 1,994,200	Rp 4,577,950
9	February	Rp 1,183,350	Rp 1,348,150	Rp 2,014,850	Rp 4,546,350
10	March	Rp 1,152,300	Rp 1,342,250	Rp 2,023,700	Rp 4,518,250
11	April	Rp 1,186,800	Rp 1,345,200	Rp 2,017,000	Rp 4,549,000
12	May	Rp 1,148,850	Rp 1,359,950	Rp 2,008,950	Rp 4,517,750
	Total	**Rp 14,458,950**	**Rp 16,030,300**	**Rp 24,151,650**	**Rp 54,640,900**

Table 3 displays the projected monthly sales profit for each banana chip variant from June 2023 to May 2024. The total estimated annual profit is IDR 54,640,900, with the chocolate variant contributing the highest share at IDR 24,151,650, followed by balado at IDR 16,030,300, and original at IDR 14,458,950. Monthly profits remain relatively stable, ranging from IDR 4,517,750 to IDR 4,613,400. These projections reflect the significant market preference for the chocolate variant and highlight the importance of aligning production volume with profitability. The data serves as a reference for setting revenue goals in the Goal Programming optimization model.

3.4 Goal Prioritization and Weight Assignment

The Goal Programming model for production planning at UMKM Keripik Umi is formulated through several structured steps. These include the definition of decision variables and parameters, constraint formulation, objective function construction, and the assignment of goal priorities. The decision variables are defined as follows:

x_1 = quantity of original banana chips to be produced
x_2 = quantity of balado banana chips to be produced
x_3 = quantity of chocolate banana chips to be produced

a. The associated parameters are:

a_{jk}= forecasted sales of banana chip variant *j* in month *k*
b_k = production cost in month *k*
c_k = expected profit from sales in month *k*
d_{i^+}= positive deviation, indicating the amount exceeding the set target for constraint *i*
d_{i^-}= negative deviation, indicating the amount short of the set target for constraint *i*
p_k = priority level *k*
b_i = right-hand side value (target level to be achieved)

b. Constraint Formulation:

1. Market Demand Constraints
   These ensure that production levels align with forecasted demand for each product:

   $X_1 + d_{1^-}$ - $d_{1^+} = a_{1k}$

   $X_2 + d_{2^-}$ - $d_{2^+} = a_{2k}$

   $X_3 + d_{3^-}$ - $d_{3^+} = a_{3k}$

   Objective: $Minimize\ \ Z = \sum_{i=1}^{3}(d_{1^-}\ +\ d_{1^+})$
2. Production Cost Constraint

   $6550\ X_1 + 7050\ X_2 + 7050\ X_3 + d_{4^-}$ - $d_{4^+} = b_k$

   Objective: $Minimize\ \ Z = d_{4^+}$
3. Profit Target Constraint

   $3450\ X_1 + 2950\ X_2 + 2950\ X_3 + d_{5^-}$ - $d_{5^+}= c_k$

   Objective: $Minimize\ \ Z = d_{5^-}$

c. Goal Priority Levels:

To reflect the business objectives of UMKM Keripik Umi, priorities are assigned using a preemptive goal programming approach, where higher-priority goals are satisfied before addressing lower ones. The priorities are as follows:

1. Priority 1 (P_1): Ensure monthly production meets market demand targets.
2. Priority 2 (P_2): Ensure that monthly production costs do not exceed the available budget.
3. Priority 3 (P_3): Achieve the expected monthly profit level.

d. Overall Objective Function:

Integrating the above priorities, the complete preemptive goal programming objective function is expressed as:

$$Minimize\ Z = P_1 \sum_{i=1}^{3} \quad (d_1{-} + d_1{+}) + (P_2 d_4{+}) + (P_3 d_5{-})$$

e. Model Implementation:

The formulated goal programming model is solved using LINGO 20.0 software. The input data includes monthly production costs, sales forecasts, and target profits from June 2023 to May 2024. The output provides optimal production quantities for each banana chip variant while respecting cost limitations and maximizing overall profit based on the defined goal hierarchy.

3.5 Solution Results Using LINGO 20.0

The Goal Programming model input interface in LINGO 20.0 software. This input defines the objective function, constraints, and non-negativity conditions used to optimize production planning for three banana chip variants at UMKM Keripik Umi, based on demand, cost, and profit targets.

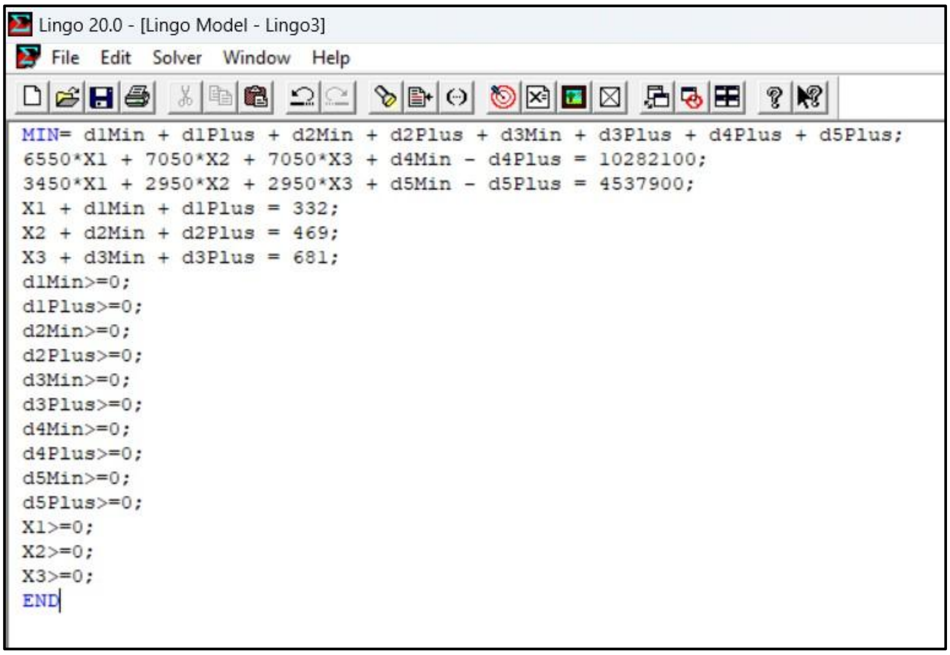
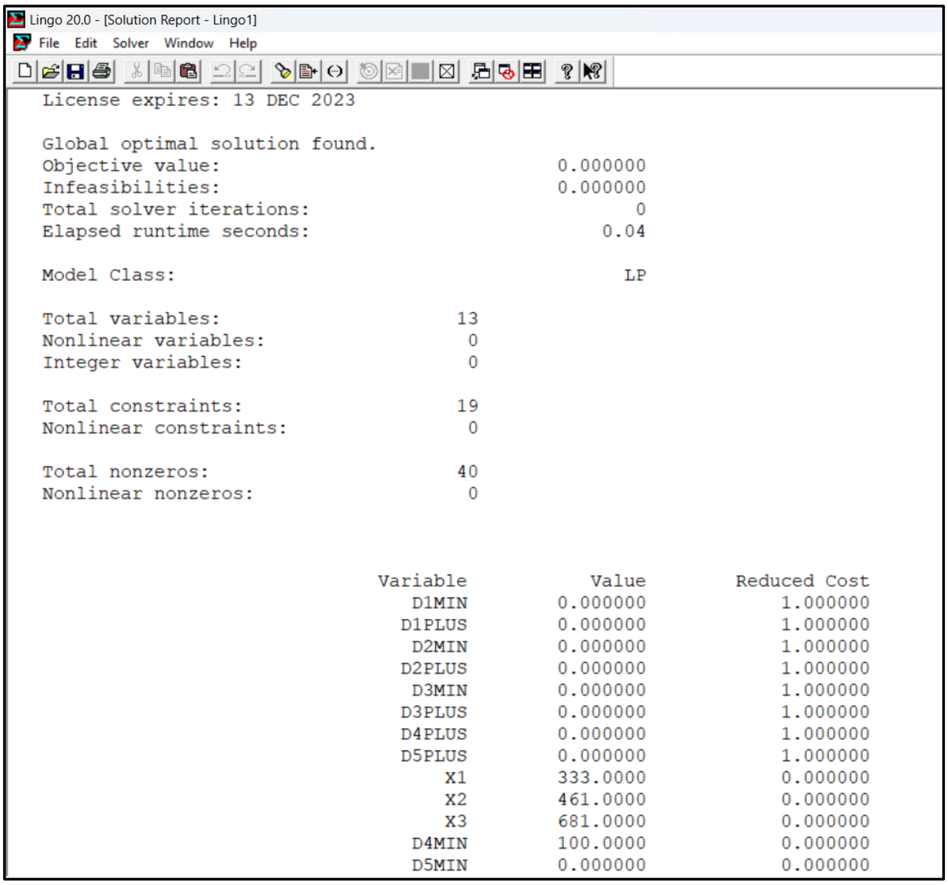


Figure 3. LINGO 20.0 Optimization Model Input for Banana Chips Production Planning

Figure 3 shows the implementation of the Goal Programming model in LINGO 20.0 software for optimizing banana chips production at UMKM Keripik Umi. The objective function (MIN=) is formulated to minimize deviations from three main goals: meeting market demand, controlling production costs, and achieving target profit levels. The model includes three main decision variables (X1, X2, X3) representing production quantities of Original, Balado, and Chocolate banana chips, respectively. Constraints are established for demand fulfillment, cost limits, and profit targets, each with their corresponding positive and negative deviation variables (e.g., d1Min, d1Plus). Non-negativity constraints are applied to all decision and deviation variables to ensure feasibility. The LINGO syntax reflects the structured mathematical model developed earlier and serves as the basis for generating optimal production quantities that satisfy the predefined goals according to their priority level. This figure demonstrates how theoretical models are translated into computational optimization using real business data.



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Lingo 20.0 - [Solution Report - Lingo1]
File  Edit  Solver  Window  Help

License expires: 13 DEC 2023

Global optimal solution found.
Objective value:                              0.000000
Infeasibilities:                              0.000000
Total solver iterations:                             0
Elapsed runtime seconds:                          0.04

Model Class:                                        LP

Total variables:                     13
Nonlinear variables:                  0
Integer variables:                    0

Total constraints:                   19
Nonlinear constraints:                0

Total nonzeros:                      40
Nonlinear nonzeros:                   0

                              Variable           Value        Reduced Cost
                                 D1MIN        0.000000            1.000000
                                D1PLUS        0.000000            1.000000
                                 D2MIN        0.000000            1.000000
                                D2PLUS        0.000000            1.000000
                                 D3MIN        0.000000            1.000000
                                D3PLUS        0.000000            1.000000
                                D4PLUS        0.000000            1.000000
                                D5PLUS        0.000000            1.000000
                                    X1        333.0000            0.000000
                                    X2        461.0000            0.000000
                                    X3        681.0000            0.000000
                                 D4MIN        100.0000            0.000000
                                 D5MIN        0.000000            0.000000
```

Figure 4. LINGO 20.0 Output Solution Report for Banana Chips Production Optimization

Figure 4 presents the solution report produced by LINGO 20.0, confirming that the model has achieved a global optimal solution with an objective value of 0.000000 and no infeasibilities. This indicates that all constraints in the goal programming model have been completely satisfied. The optimal monthly production quantities determined by the model are 333 packs for Original Banana Chips (X1), 461 packs for Balado Banana Chips (X2), and 681 packs for Chocolate Banana Chips (X3). These results demonstrate that the production quantities meet the projected demand from June 2023 to May 2024 without any shortfall, as reflected by the zero values of deviation variables $d1^-$, $d2^-$, and $d3^-$. Additionally, the absence of positive deviation values ($d1^+$, $d2^+$, $d3^+$) indicates that there is no overproduction beyond what is required. The model thus ensures a balanced production output that closely aligns with forecasted market needs, supporting efficient resource utilization while maintaining product availability.

The cost and profit goals set in the model are also successfully achieved. The production cost constraint is satisfied with no excess expenditure, shown by the value of $d4^+=0$, while $d4^-$ records a positive value of 100,000, meaning the actual cost is even lower than the targeted budget. Similarly, the profit goal is met exactly, as indicated by $d5^-=0$, with no shortfall in achieving expected revenue. These results highlight the effectiveness of the preemptive goal programming approach, which allows for a hierarchical prioritization of objectives—first ensuring demand satisfaction, then controlling production costs, and finally achieving the desired profit. The model output serves as compelling evidence that structured multi-objective optimization, when implemented correctly, can provide clear decision-making support. For UMKM Keripik Umi, this optimization strategy results in an ideal production plan that is feasible, cost-efficient, and profit-oriented, enabling the business to meet operational and financial targets more effectively.

4. Conclusion

This study concludes that the implementation of the Goal Programming method in production planning at UMKM Keripik Umi significantly improves decision-making effectiveness by addressing multiple objectives simultaneously. By integrating demand forecasts, production costs, and targeted profits into a structured mathematical model, the business was able to determine the optimal monthly production volumes for its three main product variants: 4,191 packs for Original, 8,187 packs for Balado, and 5,434 packs for Chocolate banana chips. The optimized solution ensures that production fully meets market demand without incurring excess costs or falling short of revenue targets. The minimum total production cost of IDR 123,479,100 and the projected maximum sales revenue of IDR 54,640,900 demonstrate the model's efficiency and accuracy. Furthermore, the solution achieved zero deviations in all primary goal constraints, confirming that the model fulfills all priorities effectively. This research reinforces that Goal Programming is a practical and reliable optimization approach for MSMEs, particularly in managing resource limitations while maintaining profitability and competitiveness. Therefore, it is recommended that small-scale producers adopt similar quantitative methods to enhance production planning and achieve sustainable operational performance.

Author contributions: Yan Herdianzah served as the principal investigator and team leader, responsible for conceptualizing the study design, supervising the research process, and finalizing the manuscript. A. Dwi Wahyuni and Citra Aulian Chalik contributed as research members by supporting data analysis, assisting in model formulation, and reviewing the results. Berliana Febriyanti and Nova Asdi Kurnia Fitri participated as student research assistants, aiding in data collection, preprocessing, and assisting in the preparation of the simulation using LINGO 20.0. All authors contributed to the discussion of the findings and approved the final version of the manuscript.

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Conflict of Interest: The authors declare that there is no conflict of interest regarding the publication of this article. All research activities, data analysis, and manuscript preparation were conducted independently and objectively, without any financial, commercial, or personal relationships that could be perceived to influence the research outcomes.

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