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TOFU PRODUCTION OPTIMIZATION USING INTEGER LINEAR PROGRAMMING THROUGH BRANCH AND BOUND APPROACH

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ABSTRACT

This research optimizes tofu production at Sumedang Mas Poninin Tofu Factory, Medan, which produces white tofu, yellow tofu, and pong tofu. Facing the challenges of production efficiency and profit improvement due to manual methods, an optimization model was developed using simplex and branch and bound methods. Primary and secondary data were used to evaluate raw material availability, production capacity, and profitability. The results showed an increase in daily production from 118 to 142 boards and an increase in profit from Rp1,888,500 to Rp2,263,500. This research confirms the effectiveness of applying mathematical optimization methods in improving operational efficiency and decision-making in the food industry.

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1. INTRODUCTION

Micro, Small, and Medium Enterprises (MSMEs) play an important role in the Indonesian economy. This sector not only absorbs a lot of labor, but also serves as a driver of innovation and entrepreneurship [1]. The flexible characteristics of MSMEs and their ability to adapt quickly to market changes make them more resilient in the face of the global economic crisis [2]. With a variety of products on offer, MSMEs contribute to improving local and national economic competitiveness. Based on data from the Central Bureau of Statistics (BPS), micro-enterprises are defined as business units that have a maximum number of permanent workers of 4 people, while small businesses have a number of workers between 5 to 19 people, and medium-sized businesses consist of 20 to 99 people. Meanwhile, companies with more than 99 workers are categorized as large businesses [3]. One type of MSME that is growing rapidly is the food industry [4]. Among the various food products produced, tofu making has a special position because tofu is made from its main raw material, soybeans, which is one of the most popular sources of vegetable protein for the Indonesian people. Based on data obtained from the Central Statistics Agency (BPS), the average consumption of tofu per capita in Indonesia in 2023 reached 0.295 kg per week, an increase of 2.43% compared to last year's 0.288 kg per week [5]. This increase in consumption reflects the high demand for tofu, making tofu production business promising business opportunity.

One of the tofu producers located in Medan City is Mas Ponimin's Sumedang Tofu Factory. The production of tofu in the tofu factory consists of three types of tofu, including white tofu, yellow tofu and pong tofu. This research builds a model that accommodates both conditions. Sumedang tofu factory Mas Ponimin has been operating since 1995 until now and is one of the tofu producers that utilizes the main raw materials such as soybeans for its production process. Soybeans as the main raw material are very important in determining the quality of the tofu produced. Therefore, the selection of quality soybeans is a top priority for the tofu factory to ensure tofu products that meet the nutritional and taste standards expected by consumers.

After conducting research, it is known that the Sumedang Mas Ponimin Tofu Factory still relies on manual calculation methods or simply estimates to determine the profits obtained. Delays in management and ineffectiveness in planning production quantities have an impact on the profits generated, making them not optimal and difficult to predict [6]. To achieve maximum profit, factories require proper planning to determine the optimal production quantity. In the context of business and economics, many applications use a process known as optimization to find the maximum or minimum value of a variable, taking into account various constraints. One method that can be applied to obtain profit is the Branch and Bound method. This method is used in Integer Linear Programming (ILP) to solve optimization problems with decision variables that must be integers [7]. Before using the branch and bound method, the first step is to apply the simplex method. The simplex method helps tofu factories find the optimal solution to Linear Programming (LP) problems related to production. After obtaining a solution from the simplex method, if the solution is a fractional number, the branch and bound method will be used to find a solution that satisfies the integer requirement [8]. In the case of Ponimin's Sumedang Mas Tofu Factory, these two methods will help analyze the factors that affect production with the available raw materials. This research offers a new approach in optimizing tofu production at Sumedang Mas Ponimin Tofu Factory by applying a combination of simplex and branch and bound methods. This combination of methods is rarely applied to small industries such as tofu factories, especially considering specific variables such as types of tofu products, limited raw materials and limited daily production capacity. In addition, this study uses real data from Sumedang Mas Ponimin Tofu Factory which allows for a more accurate optimization model and can be applied directly to the conditions of the tofu industry. Thus, this research not only contributes to the production optimization literature but also offers applicative solutions for more efficient production management in the MSME sector, especially the tofu industry.

This research aims to assist Sumedang Mas Ponimin Tofu Factory in optimizing the production of various types of tofu produced. Specifically, this research focuses on finding the optimal production quantity combination for each type of tofu, overcoming the challenges of often uncertain production planning by providing a more accurate profit prediction model, and providing strategic recommendations for factory management in terms of raw material management and production planning in order to support better decision making in the future. In addition, this research also contributes to academic studies in optimization and production management, especially in MSMEs in the food sector, so that it can be a reference for other researchers and industries that want to apply similar optimization methods.

This research offers an innovative approach in tofu production optimization by combining simplex and branch and bound methods to meet the needs of Sumedang Mas Ponimin Tofu Factory in maximizing profits. Unlike previous studies that only consider two decision variables, this study uses three decision variables namely white tofu, yellow tofu, and pong tofu. Thus, the resulting model is more complex but also better reflects the reality of production at the factory. In addition, this study introduces an optimization approach that considers additional raw material constraints such as cooking oil and turmeric (for yellow tofu) which have rarely been the focus of previous studies. The use of real data from Mas Ponimin's Sumedang Tofu Factory enables a more accurate and applicable optimization model for MSMEs.

2. RESEARCH METHODE

This research uses a quantitative approach that aims to assist Ponimin's Tofu Factory in optimizing its production process to maximize profits. This quantitative research emphasizes the analysis of numerical data processed using statistical methods [9]. This research was conducted in 2024 at Mas Ponimin Tofu Factory located at Jalan Langgar No. 29A, Medan Polonia District, Medan, Indonesia. The factory has been operating for 29 years and produces white tofu, yellow tofu, and pong tofu every day. This research targets the production process at Ponimin's Tofu Factory, with research subjects including data from production records and reports relating to resource utilization, production volume, and profit.

This research was conducted through several main steps, namely formulating the optimization problem into a Linear Programming (LP) model, solving the model using the simplex method, applying the branch and bound method if the solution obtained is a fractional number to obtain an integer solution, and analyzing and interpreting the results to determine the optimal amount of production and its impact on profits [10]. The data used is fully sourced from secondary data, including journals, books, and factory reports related to production and financial performance. This data provides an in-depth picture of resource availability, production costs, and sales figures.

Data was collected by reviewing documents and reports from Ponimin's Tofu Factory, including historical production records, financial reports, and relevant literature. The data obtained was analyzed using Integer Linear Programming (ILP), where the simplex method was used first to solve the LP model. If the result is a fractional number, the branch and bound method is applied to purify the result. All calculations were performed using POM-QM software to ensure accuracy and efficiency, and the results were then contextualized to answer the problem and achieve the research objectives [10].

3. RESULT AND ANALYSIS

In this study, the data obtained from Mas Ponimin Tofu Factory provided a complete picture of various important things in the tofu production process. Before the data is formulated into a mathematical model for optimization, the research data is presented in tabular format to facilitate understanding. The data on the types of tofu that will be studied are as follows:

Table 1. Type of Tofu

No.	Type of Tofu
1	White Tofu
2	Yellow Tofu
3	Pong Tofu

Table 2. Raw materials for making tofu and availability

No.	Constraints	White Tofu (Board)	Yellow Tofu (Board)	Pong Tofu (Basket)	Availability
1	Soybean	12 kg	9,5 kg	9 kg	3100 kg
2	Salt	15 gr	25 gr	20 gr	2900 gr
3	Water	39 ltr	25 ltr	30 ltr	4400 ltr
4	Turmeric	0	38 gr	0	1953 gr
5	Vinegar	50 ltr	40 ltr	55 ltr	14000 ltr
6	Oil	0	0	1 ltr	3000 ltr
7	Board	1	1	0	4325
8	Basket	0	0	1	6534

Table 2. Production costs, selling prices and tofu profits (per board/basket)

No	Type of Tofu	Production Cost (Rp)	Selling Price (Rp)	Profit (Rp)
1	White Tofu	111.500	126.000	14.500
2	Yellow Tofu	102.000	120.000	18.000
3	Pong Tofu	96.000	111.000	15.000

Table 3. The daily tofu production amount

No.	Type of Tofu	Production Quantity (Board/basket)	Profit (Rp)
1	White Tofu	33	478.500
2	Yellow Tofu	45	810.000
3	Pong Tofu	40	600.000
	Total	118	1.888.500

In this research, mathematical model formulation is used to achieve optimal results by applying the integer linear programming approach. The method used in this analysis is branch and bound, which is an

effective technique for finding optimal solutions in problems involving integer variables. The model used in this research is a linear programming model with positive integer variables, which has a structure that includes a clear objective function, constraints that must be satisfied, and relevant limitations that affect production decisions.
Objective function
$Z = 14.500x_1 + 18.000x_2 + 15.000x_3$
Constraint function
$12x_1 + 9{,}5x_2 + 9x_3 \leq 3100$
$15x_1 + 25x_2 + 20x_3 \leq 2900$
$39x_1 + 25x_2 + 30x_3 \leq 4400$
$38x_2 \leq 1953$
$50x_1 + 40x_2 + 55x_3 \leq 14000$
$x_3 \leq 3000$
$x_1 + x_2 \leq 4325$
$x_3 \leq 6534$

To achieve an optimal solution in linear programming problems, the simplex method is used, which involves steps to transform the problem into a clear mathematical model. In this process, the researcher formulates the objective function and constraint functions in standard or implicit format. The purpose function is to optimize the profits of Mas Ponimin's Tofu Factory:
$Z_{maks} = 14.500x_1 + 18.000x_2 + 15.000x_3 + 0S_1 + 0S_2 + 0S_3 + 0S_4 + 0S_5 + 0S_6 + 0S_7 + 0S_8$
With constraints/restrictions:
$12x_1 + 9{,}5x_2 + 9x_3 + S_1 = 3100$
$15x_1 + 25x_2 + 20x_3 + S_2 = 2900$
$39x_1 + 25x_2 + 30x_3 + S_3 = 4400$
$38x_2 + S_4 = 1953$
$50x_1 + 40x_2 + 55x_3 + S_5 = 14000$
$x_3 + S_6 = 3000$
$x_1 + x_2 + S_7 = 4325$
$x_3 + S_8 = 6534$

The next step is to perform iterative calculations using the simplex method, presented in tabular form. All the necessary values will be placed into the simplex table. The initial table for the simplex method is as follows.

Table 4. Initial simplex method table

	x_1	x_2	x_3	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	rhs
Z	14500	18000	15000	0	0	0	0	0	0	0	0	0
S_1	12	9,5	9	1	0	0	0	0	0	0	0	3100
S_2	15	25	20	0	1	0	0	0	0	0	0	2900
S_3	39	25	30	0	0	1	0	0	0	0	0	4400
S_4	0	38	0	0	0	0	1	0	0	0	0	1953
S_5	50	40	55	0	0	0	0	1	0	0	0	14000
S_6	0	0	1	0	0	0	0	0	1	0	0	3000
S_7	1	1	0	0	0	0	0	0	0	1	0	4325
S_8	0	0	1	0	0	0	0	0	0	0	1	6534

The next step is to continue the iteration process using the simplex method to find the best (optimal) value of the objective function. In each iteration, what needs to be done is to update the simplex table, which means adding new values to the table. This process will continue to be repeated until we find the optimal result, which is when the value can no longer be improved.

Table 5. Iteration 4 (Optimal table of the simplex method)

	x_1	x_2	x_3	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	rhs
Z	14500	18000	15000	0	454,55	196,9697	45,06	0	0	0	0	2.272.842,50
S_1	12	9,5	9	1	0	0	0	0	0	0	0	1.664,62
x_3	15	25	20	0	1	0	0	0	0	0	0	49,2823
x_1	39	25	30	0	0	1	0	0	0	0	0	41,9657
x_2	0	38	0	0	0	0	1	0	0	0	0	51,3947
S_5	50	40	55	0	0	0	0	1	0	0	0	7.135,40
S_6	0	0	1	0	0	0	0	0	1	0	0	2.950,72
S_7	1	1	0	0	0	0	0	0	0	1	0	4.231,64
S_8	0	0	1	0	0	0	0	0	0	0	1	6.484,72

Based on Table 6, the iteration calculations ended at the 4th iteration, because all values in the objective function are already positive. Thus, Table 6 shows the optimal solution obtained through the simplex method. The decision variables generated for each type of tofu are as follows:

$Z = 2.272.842,5$
$x_1 = 41.9657$
$x_2 = 51,3947$
$x_3 = 49,2823$

Based on the calculations performed using the POM QM software, it can be seen in the image below:

	White Tofu	Yellow Tofu	Pong Tofu		RHS	Dual
Maximize	14500	18000	15000			
Soybean	12	9,5	9	<=	3100	0
Salt	15	25	20	<=	2900	454,55
Water	39	25	30	<=	4400	196,97
Turmenic	0	38	0	<=	1953	45,06
Vinegar	50	40	55	<=	14000	0
Oil	0	0	1	<=	3000	0
Board	1	1	0	<=	4325	0
Basket	0	0	1	<=	6534	0
Solution->	41,97	51,39	49,28		2272843,0	

Figure 1. The POM QM software uses the simplex method

The optimal solution produced through this simplex method is not the true optimal solution. This is because the production output of tofu must be in the form of integers. Therefore, the search for the optimal solution continues with the branch and bound method, so that the remaining raw materials can be minimized and the solution still meets the constraint limits. Based on the optimal table of the simplex method, the optimal value produced is $x_1 = 41.9657$, $x_2 = 51,3947$ and $x_3 = 49,2823$ with a profit of Rp2.272,843. Because the desired value of the decision variable must be in integer form, the process is continued with integer linear programming using the branch and bound method. The steps of the calculation are as follows:

1. Choosing the decision variable with the largest fractional value, which is $\mathrm{x}_1 = 41.9657$ to create branches. The variable will be divided into two sub-problems, namely sub-problem 1 and 2.
2. For sub-problem 1, add constraints $x_1 \leq 41$ and sub-problem 2, which is $x_1 \geq 42$.
3. Then, find the solution for each sub-problem using the simplex method to determine the optimal value. Each branch that has a feasible solution will continue to be processed until it reaches the optimal iteration.

Based on the calculations performed with the POM QM software, the final result of the calculations shows that the optimal solution is as follows:

Variable	Type	Value
White Tofu	Integer	39
Yellow Tofu	Integer	51
Pong Tofu	Integer	52
Solution value		2263500

Figure 2. Calculation of the branch and bound method using POM QM software

According to the final results obtained using the branch and bound method, the daily production of each type of tofu is 39 boards of white tofu, 51 boards of yellow tofu, and 52 baskets of pong tofu. The profit generated from that production is Rp.2,263500. The comparison between the actual factory data and the data obtained through the branch and bound method, including profit calculations and production quantities, can be seen in the table below.

Table 6. Comparison of factory data and branch and bound method calculations

No.	Types of Tofu	Real Factory Data		Branch and Bound Method	
		Production Quantity (Board/Basket)	Advantage	Production Quantity (Board/Basket)	Advantage
1	White Tofu	33	478.500	39	565.500
2	Yellow Tofu	45	810.000	51	918.000
3	Pong Tofu	40	600.000	52	780.000
	Total	118	1.888.500	142	2.263.500

According to Table 7, which shows the comparison between factory data and the branch and bound method, it can be seen that the initial daily production of the factory was 118 boards/baskets, consisting of white tofu, yellow tofu, and pong tofu, with a profit of Rp1,888,500 per day. After processing using the branch and bound method, the production quantity increased to 142 with a profit reaching Rp2,263,500 per day. From the data, it can be seen that several types of tofu experienced an increase in production compared to the initial figures, which include each type of tofu as follows:

1. White tofu experienced an increase in production by 6 boards.
2. Yellow tofu experienced an increase in production by 6 boards.
3. Tahu pong experienced an increase in production by 12 baskets.

Based on the analysis that has been conducted, the profit from the sale of each type of tofu by the Tofu Factory Sumedang Mas Ponimin increased by Rp375,000 compared to the profit based on the factory's real data.

4. CONCLUSION

This research successfully demonstrated that the application of the Integer Linear Programming method using the simplex and branch and bound approaches can effectively improve production efficiency and profits at the Tahu Sumedang Mas Ponimin Factory. The application of this method resulted in an increase in daily production from 118 boards/baskets to 142 boards/baskets and an increase in daily profit from Rp1,888,500 to Rp2,263,500. The results of this study emphasize the importance of using mathematical methods in decision-making in the food production sector. The implications of this research indicate that factories can continue to use this optimization model to support more effective planning. As a suggestion, the factory should conduct periodic evaluations of this model to ensure its relevance to the dynamic production conditions.

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