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Optimization of production planning using integer linear programming method at bakpia menik

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ABSTRACT

Bakpia Menik is a Small and Medium Enterprise (SME) that operates in the field of Bakpia production. Bakpia is one of the local cakes which is the main souvenir from Yogyakarta. Thus, there is a potential for increasing production. However, SMEs still have lack of production management planning to optimize resource use. It is difficult to capture this opportunity to maximize profits for SMEs. Seeing these problems, this research designed an integer linear programming mathematical model to optimize profits using existing resources. Integer Linear Programming (ILP) is a mathematical model for maximizing profit and minimizing cost based on a mathematical model involving integer variables represented in a linear relationship. This research produces an integer linear programming model that presents the variables, resources, and constraints of Bakpia Menik. The model output shows that the optimal production amount by maximizing resource use is 31232 units and the maximum profit is IDR 33,431,750. From the model output, it can also show the advantages and disadvantages of Bakpia resources. So that resource availability planning can be carried out that can minimize holding costs.

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1. INTRODUCTION

Indonesia's economic growth is supported by sustainable industrial development from various stakeholder aspects. In this modern industrial era, small industries are also required to follow developments and be ready in various aspects[1]. MSMEs are mostly household business activities that can absorb a lot of labor. Based on data from the Ministry of Cooperatives and SMEs, in 2019, there were 65.4 million MSMEs, which could absorb 123.3 thousand workers. This proves that the impact and contribution of MSMEs is very large in reducing the unemployment rate in Indonesia. Based on data from the Ministry of Cooperatives and SMEs, the contribution of MSMEs to National GDP is 60.5%. It shows that MSMEs in Indonesia have great potential to be developed. Thus, they can contribute even more to the economy. Market competition is increasingly fierce, making it increasingly urgent to foster and develop MSMEs so that they can continue to increase their independence by making improvements, one of which is in the field of production planning[2].

Bakpia Menik is a business engaged in the production and sale of Bakpia which is in Pondok Hamlet, Condongcatur, Depok, Sleman, Yogyakarta. Bakpia, is a typical food or souvenir from the Special Region of Yogyakarta with various flavors such as green beans, Kumbu, and cheese. In the production process, Bakpia Menik carries out production planning to fulfill market desires intuitively based on habits, existing capacity, and simple estimates.

In market competition, Bakpia Menik is required to be able to compete with similar Bakpia producers in the surrounding area. Competition cannot be avoided but requires a competitive strategy that can strengthen the sustainability of Bakpia's business. Production planning carried out so far is based on inaccurate intuition[3]. Therefore, production planning needs to be done as a competitive strategy to find out the optimal production amount, as well as estimate the raw materials and working hours available to get maximum results.

Bakpia sales continue to increase the date, especially during the end year holiday and Eid season. There is an increase of 200% -300% from normal days[4]. The Bakpia industry in Yogyakarta is profitable and worth pursuing[5]. Therefore, proper production planning is needed to get maximum profits. Production planning is a process of determining the overall level of manufacturing output to meet the planned sales level and desired inventory. Even though the company has a certain number of orders per period, planning still needs to be done to determine the company's ability to fulfill all orders for a certain period and to know how much raw material must be prepared. Thus, it does not exceed the company's capacity[6]. Production planning is the prior planning and organization of people, materials, machines, and equipment as well as the capital required to produce goods in a certain period in the future as predicted[7], [8].

The estimates in production planning can use forecasting methods. Forecasting is the art or science of predicting something that has not yet happened based on data that existed in the past which was analyzed using certain methods. Forecasting is intended to minimize the influence of this uncertainty, in other words, it aims to obtain a forecast that can minimize forecasting errors. Forecasting is a very important tool in effective and efficient planning[9], [10].

The use of raw materials, labor, machines, production quantities, and costs managed by the Company can be evaluated and planned using Integer Linear Programming[11]. Integer Linear Programming (ILP) is another form of Linear Programming where the visibility function is weak or missing altogether. This form arises because not all decision variables can be fractional numbers. Integer Linear Programming (ILP) is a mathematical model for maximizing profits and minimizing costs based on a mathematical model involving integer-type variables which are represented in the form of a linear relationship[12].

This research aims to obtain optimal production quantities of the Bakpia variants produced by optimizing the use of resources to obtain maximum profits using the Integer Linear Programming model.

2. RESEARCH METHOD

The stages in data processing and analysis are as follows:

1) Understand the general description of the process by observing the production process site and interviews with production actors.
2) Make sales forecasts to determine sales volume target limits, production costs, and profit targets[13]
3) Create an Integer Linear Programming formulation looking for optimal solutions. This model is a rounding of the results of the linear programming model. The results of the decision must be made in the form of whole numbers. One way to approach is by solving the model as continuous Linear Programming and then rounding off the optimal problem-solving to the nearest feasible integer value [14].
4) Analyze the processing output and analyze its sensitivity. The value of the right side of the integer linear programming model constraint is measured between increases and decreases. If a resource is a limiting resource, then the resource has an increase and decrease in value of a certain value. If the resource is a constraint, not a limiter, then the resource will have an infinite increase value (infinity) and a decrease value equal to the slack/surplus value[15].
5) Provide optimal suggestions

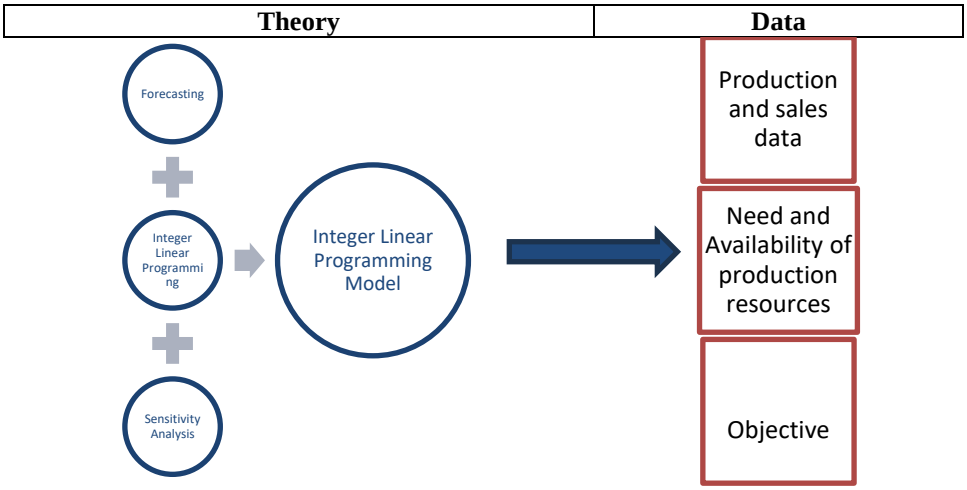

Figure 1. Decision and Analysis Model

3. RESULTS AND ANALYSIS

The results of data collection, data processing and sensitivity analysis are based on the output of the winQSB software.

3.1. Forecasting

Historical sales data for the period May 2022 – April 2023 is initial data that will be processed to predict sales plans for the following month.

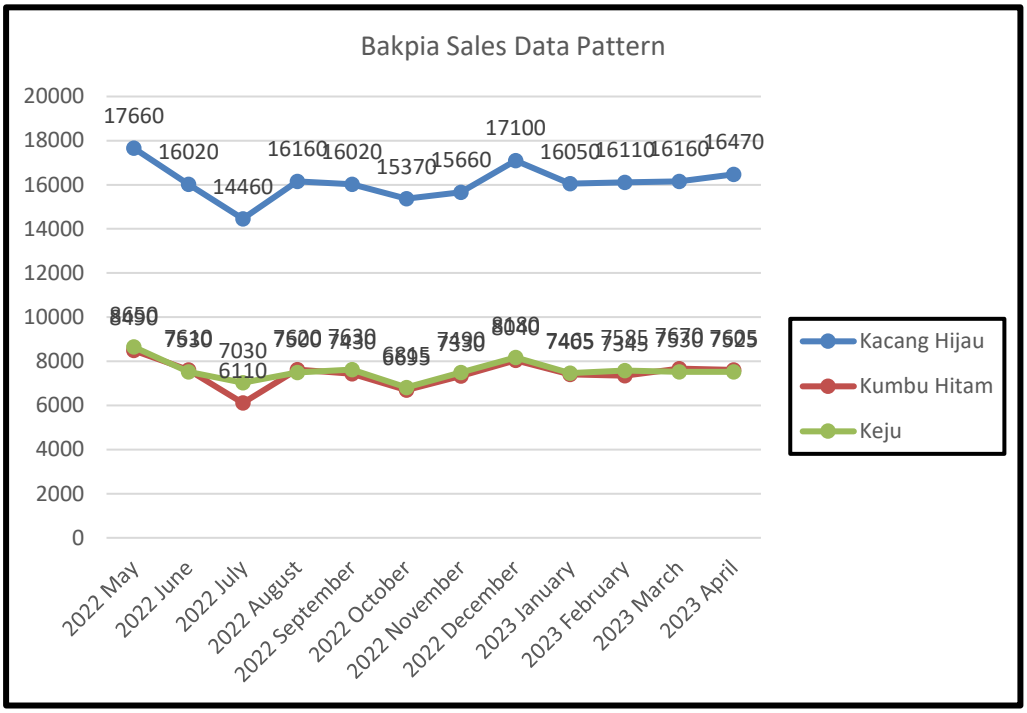

Figure 2. Bakpia Sales Data Pattern

The pattern of Bakpia sales data shows that the data is random and does not contain trend elements. Thus, the time series forecasting method is suitable for use based on fluctuating and random demand data. Suitable methods are the moving average and exponential smoothing methods.

Table 1. MAD forecasting method

No	Forecasting Method	Green Beans	Black Pepper	Cheese
1	*Moving Average n = 2*	756	644	433.5
2	*Moving Average n = 3*	351.11	262.59	277.77
3	***Moving Average n = 4***	**258.43**	**233.28**	**274.84**
4	*Exponential Smoothing a = 0,1*	1069.67	705.07	739.01
5	*Exponential Smoothing a = 0,5*	675.40	540.71	424.35
6	*Exponential Smoothing a = 0,9*	776-04	632.99	473.60

Calculations and determination of forecasting methods are based on the smallest mean absolute deviation value. From Table 1, the smallest MAD is the moving average n = 4. It means that the forecasting method that will be used to determine sales estimates for the next month is using the moving average method n = 4. The results of processing historical sales data show that the next month's sales forecast for green beans is 16198 pcs, as big as black pepper 7507 pcs, and as big as cheese 7527 pcs.

3.2. Production Cost

Production costs are costs used during the production process. The costs in question are raw material costs, direct labor costs, and packaging costs. The following are the costs incurred for the production process. Under normal production conditions, Bakpia Menik can produce 1200 pcs/day operating for 26 days each month, which is done by 4 employees with wages worth IDR 750,000/month.
Daily labor costs use the following formula:

a. Daily labor costs = $\frac{Total\ Salary/Month}{Work\ Day} = \frac{Rp.3.000.000}{26} = IDR\ 115.384/Day$

b. Labor Cost/product = $\frac{Labor\ Cost/day}{Production\ quantity/day} = \frac{IDR\ 115.384}{1200} = IDR\ 96,-/pcs$

c. Packing cost = $\frac{Packing\ price}{Packing\ Volume} = \frac{Rp.1500}{20\ pcs} = IDR\ 75/pcs$

Table 2. Raw Material Cost/pcs

Raw Material	Cost/pcs (IDR)	Raw material cost
Wheat flour	53	Green beans = IDR 247/pcs Red beans = IDR 248/pcs Cheese = IDR 294/pcs
Sugar	12	
Margarine	7	
Salt	2	
Vegetable oil	13	
Green bean	160	
Red bean	120	
Food coloring	1	
Cheese	87	

Table 2 shows the use of raw materials per piece of Bakpia. Raw material costs per product show the margin cost contribution of each raw material component used.

3.3. Machine Working Hours

The use of machine working hours during one production.
Milling Machine; the process of grinding the green beans to make them soft takes 8 minutes, in one production run they are only used once $X_1, X_2, X_3 = 8\ Minutes\ /1200\ pcs = 0{,}4\ second/pcs$
Furnace; In the production process, the stove is used twice, namely when steaming green beans and baking Bakpia. Calculation based on furnace capacity:
Steaming green beans using 2 stoves with a steaming time of 30 minutes, then the daily production amount is divided into two:

$$X_1, X_2, X_3 = 30\ Minute\ /1200\ pcs = 1.5\ second/pcs$$

Baking bakpia takes 10 minutes using 6 stoves with a capacity of 36 pcs or 216 pcs bakpia, each stove works 5-6 times per day so the daily production amount is:

$$X_1, X_2, X_3 = 10\ Minute\ /216\ pcs = 2.77\ second/pcs$$

The working hours of the furnace through two processes to make one bakpia are 4.27 seconds.

Table 3. Production Cost

No	Types of product	Main raw material cost (IDR)	Varian raw material cost (IDR)	Cost Labot (IDR)	Packing cost (IDR)	Total production cost (IDR)	Price Bakpia per pcs (IDR)	Contribution Margin (IDR)
1	X_1	87	160	96	75	418	1,500	1,082
2	X_2	87	161	96	75	419	1,500	1,081
3	X_3	87	207	96	75	465	1,500	1,035

3.4. Linear Programming Model

Table 4. Linear Programming Model Formulation

Objective Function	Profit maximization : Y = 1,082 X_1 + 1,081 X_2 + 1,035 X_3	
Boundary	$5x_1 + 5x_2 + 5x_3 \leq 175000$	Wheat flour
	$5{,}33x_1 + 5{,}33x_2 + 4x_3 \leq 180000$	Green bean
	$0{,}625x_1 + 0{,}625x_2 + 0{,}625x_3 \leq 20000$	Vegetable oil
	$0.1x_1 + 0{,}1x_2 + 0{,}1x_3 \leq 4000$	Salt
	$0{,}833x_1 + 0{,}833x_2 + 0{,}833x_3 \leq 30000$	Sugar
	$0{,}166x_1 + 0{,}166x_2 + 0{,}166x_3 \leq 8000$	Margarine
	$0x_1 + 0{,}0016x_2 + 0x_3 \leq 150$	Food coloring
	$0x_1 + 0x_2 + 1{,}33x_3 \leq 13000$	Cheese
	$0{,}4x_1 + 0{,}4x_2 + 0{,}4x_3 \leq 468000$	Grinder Machine Working Hours
	$4{,}27x_1 + 4{,}27x_2 + 4{,}27x_3 \leq 468000$	Furnace Machine Working Hours
	$X_1 \leq 16198,\ X_2 \leq 7507, \& X_3 \leq 7527$	Production target
	$X_1 \geq 0,\ X_2 \geq 0, \& X_3 \geq 0$	Non Negative Boundary
Information	X_1 = Green Bean Bakpia, X_2 = Red Bean Bakpia X_3 = Cheese Bakpia	

3.5. Results Of Integer Linear Programming Processing

Table 5. Results Of Integer Linear Programming Processing

No	Variable	Margin Contribution (IDR)	Production Cost (IDR)	Solution Value	Total Profit (IDR)	Total Production Cost
1	X_1	1,082	418	16198 pcs	17,526,240	6,770.764
2	X_2	1,081	419	7507 pcs	8,115,067	3,145.433
3	X_3	1,035	465	7527 pcs	7,790,445	3,500,055
	Total			31.232 *pcs*	33,431,750	13,416,252

Based on data processing with problem formulation and research objectives, it was obtained from the results of data processing that had been carried out previously that the research objectives had been achieved. The obtained results for the following month with total production costs of Rp. 13,416,252 produces 31,232 pcs of Bakpia with an optimal profit value of Rp. 33,431,750. Solution value is directly proportional to the results of production forecasting for the following month.

Table 6. Use and Availability of Raw Materials

No	Constrain	Left Hand Side	Right Hand Side	Surplus	Usage Percentage
1	Wheat Flour	156.160	175.000	18.840	89
2	Green Bean	156.455,70	180.000	23.544,35	87
3	Vegetable Oil	19520	20.000	480	98
4	Salt	3.123,20	4.000	876,80	78
5	Sugar	26.016,25	30.000	3983,74	87
6	Margarine	5.184,51	8.000	2815,49	65
7	Food coloring	12,01	150	137,99	8
8	Cheese	10.010,91	13.000	2989,09	77
9	Grinder Working Hours	12.492,80	468.000	455.507,2	3
10	Furnace Working Hours	133.360,60	468.000	334.639,4	3

From the table 6, it shows that raw materials and machine hours are in excess, meaning that the use of raw materials and machine hours is still below their availability capacity. The only raw material that is used up is vegetable oil, while the remaining raw materials are wheat flour, nuts, salt, sugar, margarine, food colouring and cheese. Reducing raw materials is only carried out on raw materials that have surplus or excess

conditions to reduce storage costs and minimize losses due to long storage and attacks by lice and fungi. Planning the optimal period for purchasing raw materials again to reduce the costs incurred[16].

Reducing the stock of raw materials for green beans by 23 kg from previously 180 kg to 157 kg, sugar by 3 kg from 30 kg to 27 kg, margarine by 2 kg from 8 kg to 6 kg, cheese by 2 kg from 13 kg to 11 kg. It is known that the raw materials for salt, oil and food colouring are not affected by the reduction because the remaining raw materials are no more than 1 kg, while the remaining 18.84 kg of wheat flour is not affected by the reduction because the capacity of one sack is 25 kg or the remaining flour is no more than 1 sack. Consumers' decisions to modify, delay, or defer purchasing decisions are strongly influenced by budget risk[17].

Table 7. Comparative Sensitivity Analysis

No	Variable	Preliminary Results	Sensitivity Analysis Results
1	Profit	IDR 33,431,750.00-	IDR 33,431,750.00-
2	Total Production	31.232 pcs	31.232 pcs
3	Leftover Flour	18.840 gr	18.840 gr
4	Leftover Nuts	23.544,35 gr	544,35 gr
5	Residual Oil	480 ml	480 ml
6	Residual Salt	876,80 gr	876,80 gr
7	Residual Sugar	3983,74 gr	983,74 gr
8	Leftover Margarine	2815,49 gr	815,49 gr
9	The rest of Food Colouring	137,99 gr	137,99 gr
10	Leftover Cheese	2989,09 gr	989,09 gr

From the table above, the results of reducing raw materials do not affect the amount of production so that the total profit does not change. Reducing raw materials can save raw material costs of IDR 42,000 from granulated sugar, IDR 76,000 from margarine, IDR 130,000 from cheese, so in one month of production the company can save at least IDR 938,000.00 with relatively small amounts of remaining raw materials to minimize losses due to long storage and attacks by lice and fungus. The output of the integer linear programming model shows that several raw materials and working hours are in excess condition. This shows the need for strategies for reducing and adding raw materials and labor to achieve maximum profits.

CONCLUSION

Integer linear programming model of the Bakpia Menik produced a product combination of 16198 pcs Green Bean Bakpia, 7507 pcs Red Bean Bakpia, and 7527 pcs Cheese Bakpia with a total production cost of Rp. 13,416,252 and the optimal profit value is Rp. 33,431,750. The excess resources are 18 kg of wheat flour, 23 kg of green beans, 3 kg of granulated sugar, 2 kg of margarine and 2 kg of cheese. Sensitivity analysis of raw material availability can minimize the remaining raw materials in a production period, saving costs as much as Rp. 938,000.00-.

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