

Sensitivity Analysis in Optimizing Coffee Production Profit Using Linear Programming with Simplex Method (Case Study: Komocha Coffee Home Industry)

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Abstract

Bengkulu Province is the third largest coffee producing province in Indonesia, which is mostly dominated by the Robusta coffee type. One of the businesses engaged in the coffee production process is the Komocha coffee home industry. However, the industry has profit constraints that are not yet optimal. One method that can be used in solving optimization problems is linear programming (simplex method). The purpose of this research is to optimize the profit of coffee production and determine the results of sensitivity analysis using linear programming with simplex method. Based on the calculation results, the profit per production is IDR 2,061,836 by producing 101 pcs of bitter melon seed variant coffee, 60 pcs of premium variant and 54 pcs of regular variant. The results of the sensitivity analysis of the Komocha coffee home industry are that it can produce coffee with a minimum raw material usage limit of 28 kg and a maximum of 32 kg. Limits for packaging costs are at least IDR 430,717.9. Then, for minimum labor costs of IDR 239,038.5 per person and for minimum machine working hours of 34 hours and minimum operational costs of IDR 2,482,139 per production.

1. INTRODUCTION

The world knows so many species of coffee plants, but only a few types are popular and can be cultivated in Indonesia, including Robusta, Arabica and Liberica coffee types [1]. One of the provinces with the largest coffee producer in Indonesia is Bengkulu Province. In 2020 Bengkulu Province has produced 80 thousand tons of coffee per year, therefore Bengkulu Province became the third largest coffee producing province in Indonesia and contributed to the total Robusta coffee production in Indonesia by around 70 percent [2]. Businesses engaged in the industrial sector, especially in coffee production, have various kinds of problems including problems regarding the determination of resources and sources of funds such as raw materials, labor, machinery and capital. These resources have a limited amount so that the determination must be done as much as possible, this is because the production process can support the running of a business and can determine the amount of income [3]. One of the businesses engaged in the coffee production process is the Komocha coffee home industry located at Jalan Hibrida XI B, RT 23 RW 08, Bengkulu City. The Komocha coffee home industry was established in early 2019 and was founded by Bengkulu University students. This home industry produces processed robusta coffee typical of Bengkulu with a blend of coffee beans and bitter melon seeds. The coffee variants that have been produced are bitter melon seed coffee, premium robusta coffee and regular robusta coffee.

The three types of coffee variants have different selling prices, making it difficult to generate maximum profits. The problems that occur in the case of Komocha coffee home industry is in the level of profit, production factors and products produced. One method that can be used in solving optimization problems is the linear programming method. There are several ways that can be used to solve linear programming problems, including using the graph method and simplex method. Most linear programming problems have more than two variables which makes solving with the graph method less effective [4]. Therefore, the solution to the Komocha coffee home industry problem on the level of profit, production factors and products produced, can be solved using the simplex method. The simplex method is often carried out with an analysis called sensitivity analysis to observe changes that occur in the objective function coefficients and right-hand side constants of the constraint function, and their impact on optimality.

Problems in linear programs include quite a lot of variables so it is not effective if solved manually, therefore software assistance is needed to be able to find solutions to these problems, one of which is the POM-QM for Windows software [5]. Based on the explanation above, research will be conducted on optimizing the linear program.

2. METHOD

The type of research applied in this research is a case study with the topic of discussion regarding the optimization of Komocha coffee production profits using linear programming, namely the simplex method to find optimal results. Then, the sensitivity analysis stage is carried out to determine changes in the right segment constant in the model. Then, the sensitivity analysis results for production profit optimization using linear programming are solved using POM-QM for Windows software [6]. The time used in the preparation of this thesis was 5 months. The research was conducted at the Komocha coffee production house located at Jalan Hibrida XI B, RT 23 RW 08, Sidomulyo Village, Gading Cempaka District, Bengkulu City. The type of data used is primary data obtained based on the results of direct research through the interview stage to the owner of the Komocha coffee home industry. The data obtained are data on raw materials for making Komocha coffee, labor wages, machine working hours, operational costs, capital and production profits in a one-month period in 2021. The research procedures applied in this study are as follows:

1. Data Collection Techniques

Data collection techniques are carried out through several stages, namely:

- a. Observation is carried out by visiting the research location and observing the process of production activities to find out the production process directly
- b. Interviews were conducted with Komocha coffee home industry business owners with the aim of knowing the problems often faced by Komocha coffee businesses related to the production stages that have been carried out
- c. Documentation is the stage of taking pictures in the research process which aims to strengthen the data of the research results

2. Data Processing

Data processing is carried out to be able to simplify the data into tabular form before calculations are carried out using the simplex method and sensitivity analysis.

3. Steps of Mathematical Model Formulation

The steps in formulating a mathematical model with the simplex method are [7]:

- a. Determine the decision variable
- b. Determining the constraint function elements that exist in the Komocha coffee production process
- c. Calculating the optimization of production profits using the simplex method with POM-QM for Windows software
- d. Read the *report* results from POM-QM for Windows Software
- e. Perform sensitivity analysis on changes in the constant parameter of the right-hand side of the constraint function in the linear programming model

4. Inference

Conclusions are drawn from the results of the calculations that have been carried out, namely the results of the optimal solution to production profits and answer the formulation of the problem in the study.

5. Research Flow Chart

Based on the model formulation above, the flow chart of this research is obtained, namely:

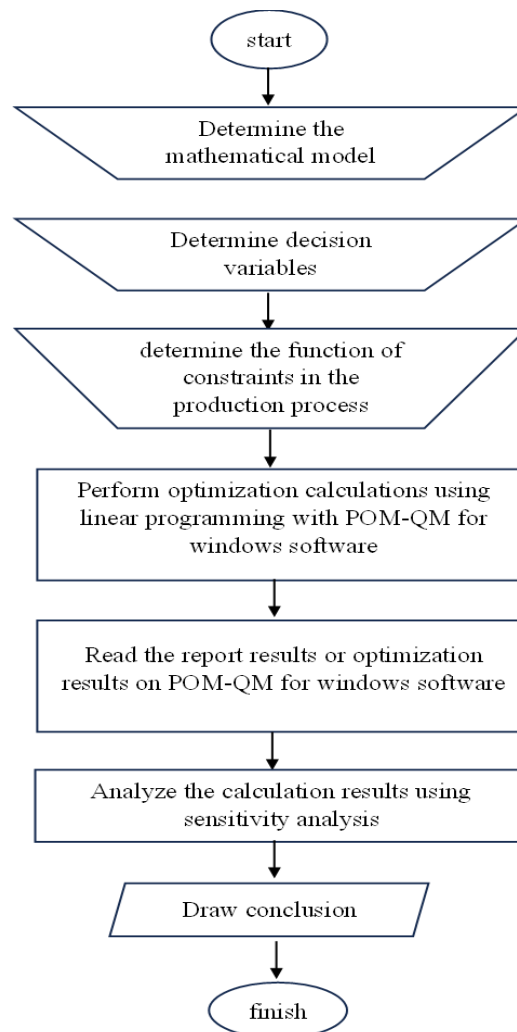


Figure 1. Research Flow Chart

3. RESULTS AND DISCUSSION

Komocha coffee is a ground coffee that produces Bengkulu robusta coffee with a mixture of bitter melon seeds that are good for health and was established in early 2019 by Bengkulu University students. Initially, the owners of the Komocha coffee home industry, Chyntia, started running the business with the proceeds from the scientific paper competition, so the number of products produced each month was still uncertain. At the end of 2020 Chyntia took the initiative to bring Komocha coffee products to the Indonesian Student Entrepreneurship Activity event held by the Indonesian Ministry of Education and Culture and succeeded in bringing a silver medal award and business development capital. In early 2021, the Komocha coffee home industry began to stabilize in producing coffee every month.

There are three variants offered in Komocha coffee, namely bitter melon seed coffee variant, premium and regular. The coffee beans used by the Komocha coffee home industry are robusta coffee from Rejang Lebong Regency, Bengkulu Province and bitter melon seeds from Seluma Regency, Bengkulu Province. The price for premium robusta coffee beans is IDR 40,000 per kg, regular robusta coffee beans are IDR 20,000 per kg and the price for bitter melon seeds is IDR 75,000 per kg. The selling price offered after production for the bitter melon seed variant is IDR 25,000 and the premium robusta coffee variant is IDR 20,000 and for the regular robusta coffee variant is IDR 15,000 with a net weight of 100 grams per variant.

The total availability of coffee bean raw materials owned by the Komocha coffee home industry is approximately 29 kg and the availability of bitter melon seeds is 3 kg. The raw materials used for the bitter melon seed coffee variant are 11.6 kg of coffee beans and 1.1 kg of bitter melon seeds with a minimum production limit of 82 pcs, then 8.5 kg of coffee beans for the premium robusta coffee variant with a minimum production limit of 60 pcs and 7.6 kg

of coffee beans for the regular robusta variant with a minimum production limit of 54 pcs in a period per one month. The packaging used to package coffee powder is a type of standing pouch packaging with a price of IDR 2,000 per package and requires around 196 packages, so the cost required is approximately IDR 450,000.

Komocha coffee home industry also employs two workers who are given a production wage per pcs of IDR 1,500 for the bitter melon seed coffee variant, then IDR 1,000 for the premium robusta coffee variant and IDR 500 for the regular robusta coffee variant, so the cost required for the wages of two workers is around IDR 400,000 for one production process in a period of one month. The profit obtained in one production for the bitter melon seed coffee variant is approximately IDR 11,800 and the premium robusta coffee variant is IDR 8,400 and the regular robusta coffee variant is IDR 6,700 per pcs. Komocha coffee home industry has operational costs for production of approximately IDR 2,500,000 with capital per pcs for the bitter melon seed variant of IDR 13,200 and premium robusta coffee of IDR 11,600 and IDR 8,300 for regular robusta coffee. Factors that affect production results include raw materials, operating costs, labor and machine hours. Table 1 describes the operational costs used in the production process, for example:

x_1 : bitter melon seed coffee

x_2 : premium robusta coffee

x_3 : regular robusta coffee

Table 1. Operating Cost

No	Product (variant)	Raw material cost/pcs	Labor costs/pcs	Other costs/pcs	Total cost/pcs	Selling price/pcs	Profit/pcs
1.	x_1	9.700	1.500	2.000	13.200	25.000	11.800
2.	x_2	8.600	1.000	2.000	11.600	20.000	8.400
3.	x_3	5.800	500	2.000	8.300	15.000	6.700

Another factor in the production of Komocha coffee is machine hours. Therefore, the machine working hours used in each production per one month are calculated by means of the total capacity of the machine used divided by the production limit per variant, thus obtaining the following machine working hours:

Table 2. Machine Working Hours

Machine	Capacity used/month (hours)	Machine working Hours/pcs		
		x_1	x_2	x_3
Roasting	15	0,07	0,07	0,07
Milling	20	0,09	0,09	0,09
Total	35	0,16	0,16	0,16

The Komocha coffee home industry also has availability that affects production factors in a one-month period. The amount of availability required can be seen in the following table.

Table 3. Availability of Production Factors

No	Production Factors	Availability	Unit
1.	Raw Materials		
	a) Coffee beans	29	Kg
	b) Bitter melon seeds	3	Kg
2.	Packaging cost/pieces	2.000	IDR
3.	Labor	2	People
4.	Machine working hours		
	a) Roasting	15	Hours
	b) Milling	20	Hours
5.	Operational costs	2.500.000	IDR

No	Production Factors	Availability	Unit
6.	Production limits		
	a) Bitter melon seeds (x_1)	82	Pcs
	b) premium robusta coffee (x_2)	60	Pcs
	c) regular robusta coffee (x_3)	54	Pcs

Therefore, it can be calculated how many Komocha coffee products can be produced in order to get maximum profit with a minimum production limit of 82 pcs for the bitter melon seed variant, 60 pcs for the regular robusta coffee variant and 54 pcs for the premium robusta coffee variant in a monthly period. The problem can be solved using the simplex method. The stages of solving using the simplex method with the POM-QM for Windows software tool are:

1. Determine the decision variables as follows:

x_1 = bitter melon seed coffee

x_2 = premium robusta coffee

x_3 = regular robusta coffee

2. Determining the objective function, the following is obtained:

$$\text{Maximize } z = 11.800x_1 + 8.400x_2 + 6.700x_3 \quad (1)$$

3. Determine the constraint function that exists in the Komocha coffee production process per pcs by converting kilogram units into grams and hour units into seconds to simplify calculations. Based on the conversion results of the above constraints, the constraint function elements are assumed to be in the form of mathematical symbols with the aim of simplifying the calculation [8]. The symbols used are as follows:

Raw material (b_1):

$$156x_1 + 142x_2 + 142x_3 \leq 32.000 \quad (2)$$

Packaging (b_2):

$$2.000x_1 + 2.000x_2 + 2.000x_3 \leq 450.000 \quad (3)$$

Labor wages (b_3):

$$1.500x_1 + 1.000x_2 + 500x_3 \leq 400.000 \quad (4)$$

Machine working hours (b_4):

$$576x_1 + 576x_2 + 576x_3 \leq 126.000 \quad (5)$$

Operating costs (b_5):

$$13.200x_1 + 11.600x_2 + 8.300x_3 \leq 2.500.000 \quad (6)$$

Production limit of bitter melon seed coffee variant (b_6):

$$x_1 \geq 82 \quad (7)$$

Production limit of premium robusta coffee variant (b_7):

$$x_2 \geq 60 \quad (8)$$

Production limit of regular robusta coffee variant (b_8):

$$x_3 \geq 54 \quad (9)$$

Thus, the mathematical model formulation for the constraint function is as follows:

s.t

$$\begin{array}{rclclcl}
 156x_1 & + & 142x_2 & + & 142x_3 & \leq & 32.000 \\
 2.000x_1 & + & 2.000x_2 & + & 2.000x_3 & \leq & 450.000 \\
 1.500x_1 & + & 1.000x_2 & + & 500x_3 & \leq & 400.000 \\
 576x_1 & + & 576x_2 & + & 576x_3 & \leq & 126.000 \\
 13.200x_1 & + & 11.600x_2 & + & 8.300x_3 & \leq & 2.500.000 \\
 x_1 & & & & & \geq & 82 \\
 & & x_2 & & & \geq & 60 \\
 & & & & x_3 & \geq & 54
 \end{array} \quad (10)$$

4. Calculating production profit optimization using software POM-QM for Windows

	x_1	x_2	x_3		RHS	Dual
Maximize	11.800	8.400	6.700			
Raw material	156	142	142	$\leq$	32.000	75,64
Packaging	2.000	2.000	2.000	$\leq$	450.000	0
Labor	1.500	1.000	500	$\leq$	400.000	0
Machine working hours	576	576	576	$\leq$	126.000	0
Operational costs	13.200	11.600	8.300	$\leq$	2.500.000	0
Production limits (x_1)	1	0	0	$\geq$	82	0
Production limits (x_2)	0	1	0	$\geq$	60	-2341,03
Production limits (x_3)	0	0	1	$\geq$	54	-4041,03
Solution	101,36	60	54		2.061.836,0	

Table 4. Output Value Simplex Method Using Software POM-QM for Windows

5. Perform sensitivity analysis when there is a change in parameters in the model linear programming

Variable	Value	Reduced Cost	Original Value	Lower Bound	Upper Bound
x_1	101, 36	0	11.800	9.228,17	Infinity
x_2	60	0	8.400	-infinity	10.741,03
x_3	54	0	6.700	-infinity	10.741,03
	Dual Value	Slack/Surplus	Original Value	Lower Bound	Upper Bound
Raw material	75,64	0	32.000	28.980	32.211,09
Packaging	0	19.282,05	450.000	430.717,9	Infinity
Labor	0	16.0961,5	400.000	239.038,5	Infinity
Machine working hours	0	1.953,23	126.000	124.046,8	Infinity
Operational costs	0	17.861,54	2.500.000	2.482.139,0	Infinity
Production limits (x_1)	0	19,36	82	-Infinity	101,36
Production limits (x_2)	-2341,03	0	60	17	81,27
Production limits (x_3)	-4041,03	0	54	49,19	75,27

Table 5. Sensitivity Analysis Results Using POM-QM for Windows

The results of the calculation using the simplex method with the POM-QM for Windows software tool version 5.3, namely the Komocha coffee home industry will get optimal profit if it produces coffee for the bitter melon seed variant as much as 101 pcs, then for the production of premium robusta coffee as much as 60 pcs and for the regular robusta coffee variant as much as 54 pcs with a profit of approximately IDR 2,061,836 and based on the availability of raw materials provided by the Komocha coffee home industry, the results show that the remaining raw materials available can be used to produce 19 pcs of bitter melon seed variant coffee so that optimal production profits can be achieved.

The results of the sensitivity analysis found that any addition that will occur to the number of constraint function limiting values on packaging, labor, machine hours, operational costs and production limits of bitter melon seed variants (x_1) obtained dual value results that are worth 0, meaning that the use of these variables is optimal [9].

Table 4. Sensitivity Analysis of Komocha Coffee Production

Constraint element	Availability	Optimal		Unit
		Minimum	Maximum	
b_1	32.000	28.980	32.211,09	Gr
b_2	450.000	430.717,9	Infinity	IDR
b_3	400.000	239.038,5	Infinity	IDR
b_4	126.000	124.046,8	Infinity	Sec
Constraint element	Availability	Optimal		Unit
		Minimum	Maximum	
b_5	2.500.000	2.482.139	Infinity	IDR
b_6	82	-Infinity	101, 36	Pcs
b_7	60	17	81, 27	Pcs
b_8	54	49,19	75, 27	Pcs

The results of the first sensitivity analysis have restrictions on raw materials, namely $b_1 = [28,980; 32,211.09]$ which means that the profit from the production of Komocha coffee will be optimal. $b_2 = [430,717.9; \text{infinity}]$. Furthermore, there is a production cost limitation on the packaging used, namely $b_2 = [430,717.9; \text{infinity}]$ which means that the komocha coffee home industry can produce coffee with a minimum packaging cost of IDR 430,717.9 with no maximum limit. Then, the labor cost limitation is $b_3 = [239,038.5; \text{infinity}]$ which means that the Komocha coffee home industry will still get optimal profit by giving a minimum labor wage of IDR 239,038.5 per person in one production without a maximum limit. Parameter changes that occur in the constants of the right segment of the constraint function are also found in the working hours of the machine, namely $b_4 = [124,046.8; \text{infinity}]$ which means that the working hours of the machine can be operated for a minimum of 124,046.8 seconds or approximately 34 hours per production. and the maximum there is no limit, which means that if the Komocha coffee production industry wants to produce coffee using a machine, it must be adjusted to machine capacity and the amount of raw materials used.

Based on the results of the sensitivity analysis, there is a maximum limit of raw materials, namely 29 kg of coffee beans and 3 kg of bitter melon seeds, so that machine working hours can be adjusted to the capacity of these raw materials. Furthermore, changes in operational costs, namely $b_5 = [2,482,139; \text{infinity}]$ with a minimum operational cost limit of IDR 2,482,139 and no maximum limit, will be adjusted accordingly. obtained optimal production profit in the Komocha coffee home industry. Furthermore, in the production limitation of the bitter melon seed coffee variant (x_1) there is a limitation $b_6 = (-\text{infinity}; 101,36]$ with a maximum production of 101 pcs, then for the regular robusta coffee variant (x_2) there is a limitation $b_7 = [17; 81,27]$ with a minimum production of 17 pcs and a maximum of 81 pcs. Then, for the regular robusta coffee variant (x_3) there is a limitation $b_8 = [49,19; 75.27]$ with a minimum production of 49 pcs and a maximum of 75 pcs. If there is a decrease in the number of constraint values in the constraint function, the number of constraint values must be adjusted to the predetermined minimum limit so as not to affect the optimal solution and for additional production is also limited to the specified limit.

4. CONCLUSION

Based on the research that has been done, it is concluded that the profit obtained by the Komocha coffee home industry with the simplex method will be optimal if it produces coffee with 101 pcs of bitter melon seed variants, 60 pcs of premium robusta coffee variants and 54 pcs of regular robusta coffee variants with a profit of IDR 2,061,836. then, the results of sensitivity analysis in optimizing Komocha coffee production profits with the simplex method assisted by POM-QM for Windows software, namely the Komocha coffee home industry can produce coffee with a minimum raw material usage limit of 28 kg and a maximum of 32 kg. Limits for packaging costs are at least IDR 430,717.9 without a maximum limit. Then, the minimum labor cost is IDR 239,038.5 and there is no maximum limit. Furthermore, for minimum machine working hours of 34 hours and minimum operational costs of IDR 2,482,139 with no maximum limit. Furthermore, the results of sensitivity analysis on production limits so that the profit

obtained remains optimal, namely for the bitter melon seed coffee variant, the maximum production is 101 pcs, then the original premium robusta coffee variant is at least 17 pcs and a maximum of 81 pcs and the original regular coffee variant is at least 49 pcs and a maximum of 75 pcs.

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