Jurnal Akuntansi, Ekonomi dan Manajemen Bisnis
Vol. 10 No. 1, Juli 2022, 61-71
E-ISSN: 2548-9836

Article History
Received May, 2022
Accepted July, 2022

Production Optimization and Product Sensitivity Analysis of "Bawang Goreng Crispy Yuk Riris" by Linear Programming

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Abstrak

Penelitian ini bertujuan mengetahui optimasi produksi menggunakan *linear programming* dengan metode grafik dan simpleks disertai analisis sensitivitas dalam menentukan kombinasi produk optimal dengan keuntungan maksimal untuk produk "Bawang Goreng Crispy Yuk Riris". Data yang digunakan meliputi data penjualan, persediaan, penggunaan bahan baku dan tambahan, biaya operasional, dan harga jual. Teknik analisis data menggunakan *linear programming* metode grafik dan simpleks disertai analisis sensitivitas dengan bantuan *QM for Windows*. Hasil penelitian menunjukkan optimasi produksi menggunakan *linear programming* metode grafik ataupun simpleks diperoleh hasil yang sama dengan solusi optimal memproduksi bawang goreng crispy rasa original sebanyak 713 bungkus dan rasa pedas sebanyak 333 bungkus dengan keuntungan maksimum sebesar Rp 3.304.500. Analisis sensitivitas menunjukkan solusi tetap optimal dengan batas toleransi keuntungan rasa original adalah 0 sampai 3.500 dan rasa pedas antara 3.000 sampai tak terhingga, serta terdapat 5 input produksi yang belum optimal.

Kata kunci: *Linear Programming*, Metode Grafik, Metode Simpleks, dan Analisis Sensitivitas

Abstract

This study aims to optimize production using linear programming with graphical and simplex methods accompanied by sensitivity analysis to determine the optimal product combination with maximum profit for the "Bawang Goreng Crispy Yuk Riris". The data are sales, inventory, use of raw and additional materials, operations, and selling prices. The data analysis technique uses linear programming, graphs and simplex methods, and sensitivity analysis with the help of QM for Windows. The result shows that production optimization using linear programming graphical methods or simple graphs obtains the same results as the optimal solution of producing 713 packs of original crispy fried shallot and 333 packs of spicy fried shallot with a maximum profit of IDR 3.304.500.Sensitivity analysis shows that the solution remains optimal with the tolerance limit for the original taste from 0 to 3.500 and the spicy taste from 3.000 to infinity, and five production inputs are not optimal.

Keywords: Linear Programming, Graphical Method, Simplex Method, and Sensitivity Analysis

1. Introduction

One of important sectors in the regional economy is micro, small, and medium enterprises (MSMEs). Cooperative and MSMEs contributed 57,25 percent to East Java's GRDP in 2020, lower than in 2019 but higher than in 2018 (Satu Data Diskop UKM Prov. Jatim, 2020). It was an effect of Covid-19 pandemic which has changed customer behaviour from offline shopping to online shopping. On the other hand, micro, small and medium enterprises (MSMEs) need to increase digital marketing efforts to promote and sell their products by online due to the industrial revolution 4.0. MSMEs needs to take advantage of social media platforms before entering to a large e-commerce platform to sell their products. This is related to production capacity which is one of the challenges in encouraging MSMEs to join the digital ecosystem. When MSMEs enters to a large platform, it must pay attention to their production capacity because many Indonesia MSME products of various types and varieties have not been supported by proper capacity. In the digital market, it needs speed and accuracy.

Based on Satu Data Diskop UKM Prov. Jatim (2020), it shows that mostly common problem of MSMEs in East Java Province is including 37% of capital, 35% of marketing, and 14% of human resources. As a result of limited capital, MSMEs may not be able to develop their manufacturing capabilities fully. Because of company's limited capital, a large consumer demands may often must be ignored. If this trend is going on, a business will be able to lose sales opportunities, affecting the company's revenue (Nursanti et al., 2015). Therefore, a company or industry requires production optimization planning to maximize profits, minimize production costs, and always fulfill consumer demands.

The optimization term itself refers to process in choosing the optimal option from variously alternative possibilities (Devani & Kartika, 2020). Meanwhile, production optimization is a method of planning or controlling for a company to use labour, working capital, raw materials, and manufacturing facilities to fulfil consumer demand while optimizing the use of currently available raw materials and ensuring the manufacturing process runs smoothly, effective, and efficient (Syafril, 2020). Companies need production optimization to optimize their available resources to ensure that products can be produced with the desired quantity and quality so that the company can reach its goals (Andini & Slamet, 2016).

“Bawang Goreng Crispy Yuk Riris” is one of the products produced by Talitakum Kitchen, an MSME located in Puri Surya Jaya Housing Block C1 No. 19 Gedangan - Sidoarjo. “Bawang Goreng Crispy Yuk Riris” consists of two flavours, namely, original and spicy. Based on the initial interview with the owner, he has explained that in running his business, he was confused about how to make the right product combination to produce crispy fried shallot product with an original taste and with a spicy taste. According to rate of selling, Talitakum Kitchen mostly sells more original flavour. Whereas, there are still many consumers who also want to buy spicy flavours, but due to the unavailability of spicy-tasting products, many of them don't buy its products. The comparison of sales of Bawang Goreng Crispy Yuk Riris during the period from December 2021 to February 2020 can be seen in Table 1 as follows:

TABLE I

SALE DATA OF BAWANG GORENG CRISPY YUK RIRIS THE PERIOD OF DECEMBER 2021 – FEBRUARY 2022

Flavour Variants	**Demand (pack)**		
	Des-2021	**Jan-2022**	**Feb-2022**
Original	805	735	700
Spicy	345	315	300
Total	**1.150**	**1.050**	**1.000**

Source: Talitakum Kitchen (2022)

Based on the Table 1, it can be seen that during the last three months, sale of Bawang Goreng Crispy Yuk Riris have decreased, both the original taste and the spicy taste. This is indicated as the unavailability of spicy-tasting products due to the inaccurate determination of the number of product combinations during the production process. So, we need a calculation technique with the right method to obtain the optimal product combination and get the maximum profit. If the problem is not resolved immediately, Bawang Goreng Crispy Yuk Riris customers may switch to buy other brands.

Linear Programming (LP) is an optimization technique for allocating available resources by using the equation constraint functions and linear inequalities to optimize the objective function (maximizing or minimizing) (Fadhillah, 2022). Linear programming analysis allows a company to find the best way to make optimal production combinations when limited resources are available (Buana & Purnawati, 2021). These limitations are mainly related to resources, including labour, raw materials, time, money, and so on (Ong et al., 2019). According to Asmara et al. (2018) and Nuryana (2019), The linear programming paradigm has three essential components, such as (a) Decision Variables, namely problem variables that will have an impact on the value of the objectives to be obtained; (b) Objective Function, it is a goal to obtain and needs to be made of the form of a linear mathematical function which is then to be maximized or minimized concerning the existing constraints; (c) Functional Constraints/Functional Constraints, they are various obstacles that must be overcome by management to achieve goals.

There are 2 types of solution methods in linear programming consisting of the graphical method and the simplex method (Nurmayanti & Sudrajat, 2021). The graph method is a linear programming technique used to solve problems consisting of two problem variables (Nuryana, 2019). The graph is composed of equations that have been formulated in such a way that the points of the intersection of the lines are obtained as solutions (Asmara et al., 2018). According to Hasni (2015), the presentation of a linear programming model to solve problems using the graphical method aims to identify the relationship between constraints in linear programming. At the same time, the simplex method is a method for solving linear programming problems that it is used as a decision-making strategy in problems involving optimal allocation of resources containing inequalities and large numbers of variables (Asmara et al., 2018). The complete process of finding solutions in this simplex method goes through an iteration path that requires identifying a feasible point from the goal to be achieved by using a table until the optimal solution is obtained (Anti & Sudrajat, 2021).

Several studies applying linear programming to maximizing total profit using the graphical method are researched by Nuraeni & Sari (2022), Palayukan (2021), and Syafril (2020). The simplex method has been researched by Purwanti & Pramestari (2022), Aini et al. (2021), and Warman et al. (2021). Based on the research, it can be concluded that the application of linear programming using either the graphical method or the simplex method can obtain the correct number of product combinations to maximize profits in optimizing production results to increase profits. Most of the research related to linear programming uses only one method, even though a study that only uses two decision variables can be completed using both methods in linear programming, namely graphs and simplex. In addition, the research objectives are also averaged only to find out the optimal solution for achieving maximum profit without any sensitivity analysis. According to Devani & Kartika (2020), sensitivity analysis is a type of analysis used to examine the impact of parameter changes on the optimal solution found. The use of this sensitivity analysis is to interpret the results of the achievements that have been obtained. This shows that the solution that initially had a static nature to solve linear problems turned into a dynamic tool that can be used to analyze changing conditions.

Thus, based on the description above, this study aims to determine the optimization of production using linear programming with the graphical method and the simplex method accompanied by sensitivity analysis to determine the optimal number of product combinations with maximum profit for “Bawang Goreng Crispy Yuk Riris products.”

2. Research Methods

This research was conducted at Talitakum Kitchen, located in Puri Surya Jaya Housing Block C1 No. 19 Gedangan – Sidoarjo. Data collection was carried out in March 2022. Data was collected from interviews with the Bawang Goreng Crispy Yuk Riris owner Yuk and business documents, including sales data, raw materials and additional materials, operational costs, inventory data, and product selling prices. This research uses a quantitative descriptive approach. According to Yusuf (2016), quantitative descriptive research is a conscious and systematic effort to provide answers to the problems to be investigated and seeks to obtain more in-depth and comprehensive information about a phenomenon through the quantitative approach research stages.

Some variable operational definitions used in this study are as follows:

1. Linear programming is an optimization technique used to determine the number of optimal combinations of crispy fried shallot products by a linear objective function with certain conditions.
2. Decision variable is related to determine the number of crispy fried shallots produced.
3. The constraint function is a function of the limited resources available to produce each crispy fried shallot product.
4. The objective function is a function of the decision variables used to maximize profits in each variant of the crispy fried shallot flavour produced.
5. Sensitivity analysis is an analysis used to determine the impact of adjustments on profits and consumption of raw materials for each flavour variant.

This study's production optimization data analysis technique uses linear programming with the graphical method and the simplex method accompanied by a sensitivity analysis using the *QM for Windows Version 2.2* software. According to Purwanti & Pramestari (2022), *QM for Windows* can be used to quickly identify solutions to various business problems because multiple modules can be used for decision-making in a company. *POM QM* software has a series of steps on how to use it, which are listed below (Nuraeni & Sari, 2022):

1. Open the *POM* software on the computer to get started.
2. Open the *Module* menu and select *Linear Programming*.
3. Click the *New File* menu, then fill in the title of the problem you want to process with *POM* software in the *Title* column, and write down the resource constraints in the *Number of Constraints* section, as well as the number of decision variables that will be used in the *Number of Variables* section, then determine the purpose of the problem to be solved, namely maximize or minimize the *Objective* area, finally fill in the constraint naming options in the *Row Name Options*.
4. Select *“OK”* until the display appears for filling in the problem function model that has been defined mathematically.
5. Select the *“Solve”* option after filling all problem function models. *POM* will present the most optimal computational results. Then select the *Window* menu to display a list of results for linear programming solutions, graphs, iterations, and more.

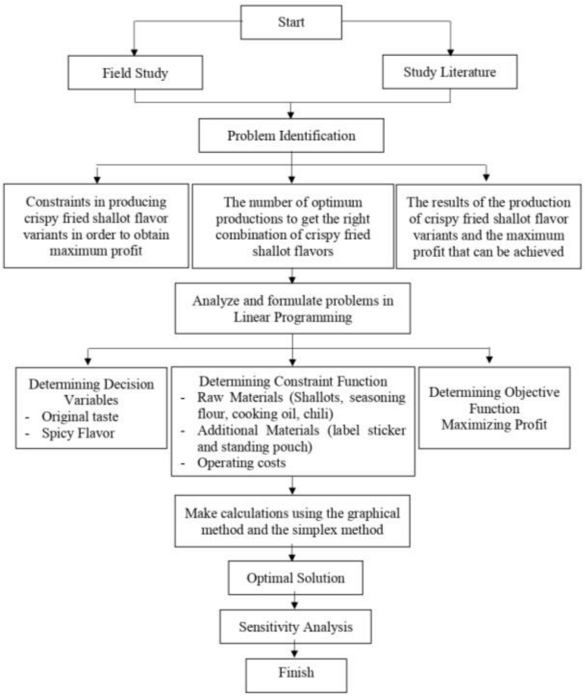

Figure 1: Research Flowchart

3. Results and Discussion

Decision Variable

Decision variables are variables that fully describe the decisions to be made (Kawulusan et al., 2020). In this study, the decision variables related to determine the number of Bawang Goreng Crispy Yuk Riris products to be produced are:

X1 = The number of original flavoured crispy fried shallots produced

X2 = The number of spicy flavoured crispy fried shallots produced

Constraint Function

The constraint function is a limitation for a company and the price of decision variable cannot be determined in a balanced way (Buana & Purnawati, 2021). The constraint function in this study broadly consists of raw materials, additional materials, and operational costs. In one month, the raw materials for crispy fried shallot products are available at 300.000 grams of shallots, 45.000 grams of seasoned flour, 32.400 ml of cooking oil, and 2.000 grams of chilli. Meanwhile, the additional ingredients for crispy fried shallot products are available 1.200 sheets of label stickers and 1.250 pcs of standing pouches. As well as operating costs per month are IDR 250.000. Talitakum Kitchen produces two crispy fried shallot products, namely the original taste and the spicy taste. Every pack of crispy fried shallot product with original taste requires 143 grams of shallots, 43 grams of seasoned flour, 26 ml of cooking oil, 1 sheet of label sticker, 1 pcs of the standing pouch and an operational cost of IDR 200. In the meantime, 1 pack of spicy crispy fried shallots requires 143 grams of shallots, 43 grams of seasoned flour, 39 ml of cooking oil, 6 grams of chilli, 1 sheet of label sticker, 1 pcs of the standing pouch, and an operational cost of IDR 250.

TABLE II

DATA OF PRODUCTION FACTORS OF BAWANG GORENG CRISPY YUK RIRIS

Factors of Production	Product		Availability
	Original Flavor (X1)	Spicy Flavor (X2)	
Raw Material			
Shallot (gr)	143	143	300.000
Seasoned Flour (gr)	43	43	45.000
Cooking Oil (ml)	26	39	32.400
Chilli (gr)	0	6	2.000
Additional Material			
Label Sticker (sheet)	1	1	1.200
Standing Pouch (pcs)	1	1	1.250
Operational Cost (IDR)	200	250	250.000

Source: Talitakum Kitchen (2022)

Based on Table 2 above, it can be described that the limited resources of Talitakum Kitchen can be formulated as follows:

1. The raw materials for making Bawang Goreng Crispy Yuk Riris consist of 4 kinds, namely shallots, seasoned flour, cooking oil, and chillies.
- The raw materials for shallots are 143 grams to produce 1 pack of crispy fried shallot products with original flavour (X1) and 143 grams to produce 1 pack of spicy crispy fried shallots products (X2) with the available capacity in the company per month is 300.000 gr.
- The raw material for seasoned flour is 43 grams to produce 1 pack of crispy fried shallot products with original flavour (X1) and 43 grams to produce 1 pack of spicy crispy fried shallot products (X2) with the available capacity in the company per month is 45.000 grams.
- The raw material for cooking oil is 26 ml to produce 1 pack of crispy fried shallot product with original taste (X1) and 39 ml to produce 1 pack of spicy crispy fried shallot product (X2) with the available capacity in the company per month is 32.400 ml.
- The raw material for chilli is 6 grams to produce 1 pack of spicy crispy fried shallot products (X2), with the available capacity in the company per month being 2.000 grams.

2. The additional materials for making Bawang Goreng Crispy Yuk Riris consist of 2 labels and a standing pouch.
- - The additional material for the label sticker is 1 sheet to produce 1 pack of crispy fried shallot product with original taste (X1) and 1 sheet to produce 1 pack of spicy crispy fried shallot product (X2) with the company's available capacity per month is 1.200 sheet.
- The additional material for the standing pouch is 1 pcs to produce 1 pack of crispy fried shallot product with original taste (X1) and 1 pcs to produce 1 pack of spicy crispy fried shallot product (X2) with the company's available capacity per month is 1.250 pcs.

3. The operational costs are IDR 200 to produce 1 pack of crispy fried shallot products with original taste (X1) and IDR 250 to produce 1 pack of spicy fried shallot products (X2) with a maximum operational cost of IDR 250,000.

From the information of table 2 above, it can be formulated a mathematical model formulation for the constraint function as follows:

1. Shallot : 143X1 + 143X2 ⩽ 300.000 ……….... (1)
2. Seasoned Flour : 43X1 + 43X2 ⩽ 45.000 …….. (2)
3. Cooking Oil : 26X1 + 39X2 ⩽ 32.400 ……..... (3)
4. Chilli : 6X2 ⩽ 2.000 ………...……………..… (4)
5. Label Sticker : X1 + X2 ⩽ 1.200 ……..……… (5)
6. Standing Pouch : X1 + X2 ⩽ 1.250 …………... (6)
7. Operational Cost : 200X1 + 250X2 ⩽ 250.000 . (7)
8. Non-Zero Variable : X1, X2 ⩾ 0 …………..… (8)

Objective Function

The objective function is the equation of the decision variables that need to be maximized (in terms of income or profit) or minimized (for costs) (Kawulusan et al., 2020). The objective function of this study is to maximize the profit obtained by Talitakum Kitchen for the Bawang Goreng Crispy Yuk Riris product which can be calculated from the total profit value per pack product multiplied by the decision variable. The profit data for each flavour variant of the Bawang Goreng Crispy Yuk Riris product can be seen in the table below:

TABLE III

PROFIT DATA FOR EACH VARIETY OF FLAVOR OF BAWANG GORENG CRISPY YUK RIRIS PRODUCTS

Flavor Variants	Selling Price/pack	Production Cost/pack	Profit/pack
Original (X1)	IDR 10.000	IDR 7.000	IDR 3.000
Spicy (X2)	IDR 12.000	IDR 8.500	IDR 3.500

Source: Talitakum Kitchen (2022)

The profit that can be obtained from every sale of 1 pack of crispy fried shallot, original flavour (X1) is IDR 3,000 and IDR 3,500 for every sale of 1 pack of spicy crispy fried shallot (X2). Therefore, from the explanation and Table 3 above, the formulation of the objective function of a linear program can be formulated as follows:

Maximizing Profit:

Zmax = 3.000X1 + 3.500X2 ……………………..... (9)

Optimization Model Formulation

With the equations (1) – (9) that have been compiled, the objective function and the constraint function of the linear programming optimization model are obtained as follows:

Maximizing Profit: Zmax = 3.000X1 + 3.500X2

Constraints:

- 143X1 + 143X2 ⩽ 300.000
- 43X1 + 43X2 ⩽ 45.000
- 26X1 + 39X2 ⩽ 32.400
- 6X2 ⩽ 2.000
- X1 + X2 ⩽ 1.200
- X1 + X2 ⩽ 1.250
- 200X1 + 250X2 ⩽ 250.000
- X1, X2 ⩾ 0

Optimal Solution Using Graphical Method

In this study, to determine the optimal solution, you can use linear programming with the graphical method. There were only two decision variables in this study, namely the original crispy fried shallot product (X1) and the spicy crispy fried shallot (X2). This is in harmony with Susdarwono's (2020) statement if the solution uses a very simple graph method in the form of a two-dimensional graph but it can only be applied to two problem variables, if the graph exceeds two dimensions (variables), then the challenge faced is in determining the solution point that optimal. The steps for solving linear programming graphical methods with the help of *QM for Windows* software are:

1. Still starting with formulating a model that includes decision variables, constraint functions, and objective functions.
2. Enter the constant value of the equation into the *QM for Windows* software. When it's finished, you

can select *Solve* at the top.

3. Select the main menu *Window* and *Graph.*

The display of the results of linear programming data processing with the graphical method with the help of *QM for Windows* software is as follows:

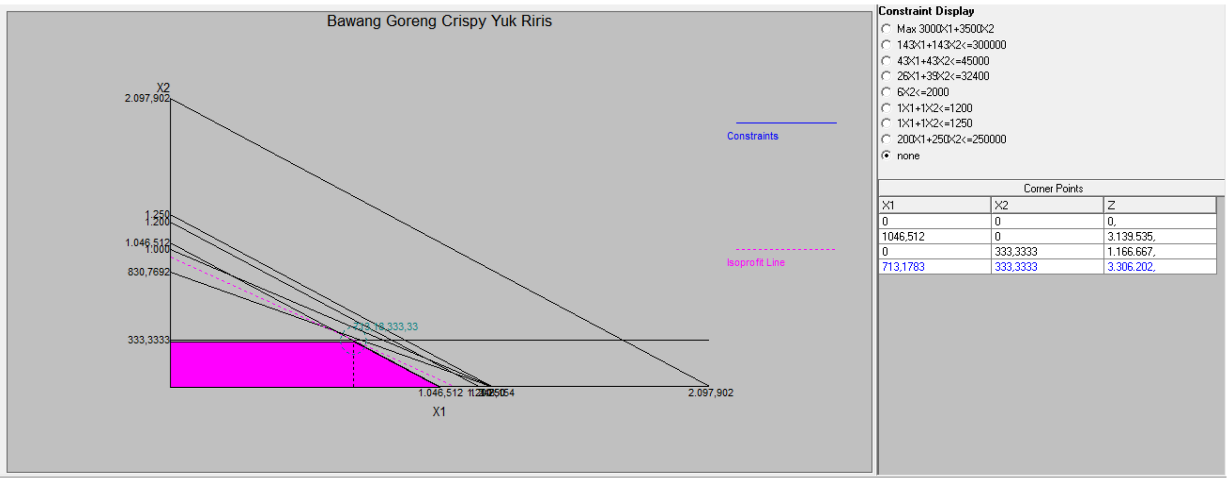

Figure 2: Output of *QM for Windows* Graphical Method

Based on the results of linear programming data processing with the graphical method with the help of *QM for Windows* contained in Figure 2, it can be seen that the area that simultaneously satisfies the seven constraints is shown by the purple/shaded image area on the graph. This area is called the feasible area because it has fulfilled the solution from all existing barriers. A feasible area is a potential area limitation to allocate available production resources following the specified time (Ayu et al., 2020). The coordinate points can be known, namely the point (0;0), point (1.046,512;0), point (0;333,333), and point (713,1783;333,3333). The point (713,1783;333,3333) can be obtained based on the point of intersection of two tangent lines, namely by substitution or elimination. So, the coordinates (713,1783;333,3333) are obtained by substituting the constraint 6X2 = 2.000 with the constraint 43X1 + 43X2 = 45.000.

Next, examine the overall coordinates of the feasible area obtained from the objective function equation. It produces several alternatives, which are then selected the results with the largest Z value because, in this study, the maximization problem is maximizing profit.

- Point (0;0)
  Zmax = 3.000 (0) + 3.500 (0)
  = 0
- Point (1.046,512;0)
  Zmax = 3.000 (1.046,512) + 3.500 (0)
  = 3.139.535
- Point (0;333,333)
  Zmax = 3.000 (0) + 3.500 (333,333)
  = 1.166.667
- Point (713,1783;333,3333)
  Zmax = 3.000 (713,1783) + 3.500 (333,333)
  = 3.306.202 (Optimal)

Based on testing the feasible area, the optimum value is obtained at the point (713,1783; 333,3333). Similar to Render's statement et al. (2018), the optimal solution is a point located in a feasible area that produces the highest profit. Thus, the number of original flavoured crispy fried shallot (X1) produced is 713,1783, and spicy crispy fried shallot (X2) that must be produced is 333,3333 for optimal production with a profit of IDR 3.306.202.

The results of this study are in line with the research of Nur'safara et al. (2015), which explains that with the application of the graphical method, companies can obtain optimal profits because the products produced can be sold out precisely with the estimated number that has been previously determined to avoid losses due to excess product inventory, in addition to the percentage of profits obtained also increased by 6.5% from before using the graphical method.

Optimal Solution Using Simplex Method

This study also uses linear programming with the simplex method. According to Asmara et al. (2018), when comparing the graph method and the simplex method, the simplex method has the advantage that it can solve two or more decision variables than the graph method, which can only apply two decision variables. The steps for solving linear programming using the simplex method with the help of *QM for Windows* software are the same as those using the graphical method. The differences are that select the main menu *Window* and *Iterations* in the third stage. The display of the result of linear programming data processing using the simplex method with the help of *QM for Windows* software is as follows:

Cj	Basic Variables	3000 X1	3500 X2	0 slack 1	0 slack 2	0 slack 3	0 slack 4	0 slack 5	0 slack 6	0 slack 7	Quantity
Iteration 1											
0	slack 1	143,	143,	1,	0,	0,	0,	0,	0,	0,	300.000,
0	slack 2	43,	43,	0,	1,	0,	0,	0,	0,	0,	45.000,
0	slack 3	26,	39,	0,	0,	1,	0,	0,	0,	0,	32.400,
0	slack 4	0,	6,	0,	0,	0,	1,	0,	0,	0,	2.000,
0	slack 5	1,	1,	0,	0,	0,	0,	1,	0,	0,	1.200,
0	slack 6	1,	1,	0,	0,	0,	0,	0,	1,	0,	1.250,
0	slack 7	200,	250,	0,	0,	0,	0,	0,	0,	1,	250.000,
	zj	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,
	cj-zj	3.000,	3.500,	0,	0,	0,	0,	0,	0,	0,	
Iteration 2											
0	slack 1	143,	0,	1,	0,	0,	-23,8333	0,	0,	0,	252.333,3333
0	slack 2	43,	0,	0,	1,	0,	-7,1667	0,	0,	0,	30.666,6667
0	slack 3	26,	0,	0,	0,	1,	-6,5	0,	0,	0,	19.400,
3.500	X2	0,	1,	0,	0,	0,	0,1667	0,	0,	0,	333,3333
0	slack 5	1,	0,	0,	0,	0,	-0,1667	1,	0,	0,	866,6667
0	slack 6	1,	0,	0,	0,	0,	-0,1667	0,	1,	0,	916,6667
0	slack 7	200,	0,	0,	0,	0,	-41,6667	0,	0,	1,	166.666,6667
	zj	0,	3.500,	0,	0,	0,	583,3333	0,	0,	0,	1.166.666,6667
	cj-zj	3.000,	0,	0,	0,	0,	-583,3333	0,	0,	0,	
Iteration 3											
0	slack 1	0,	0,	1,	-3,3256	0,	0,	0,	0,	0,	150.348,8372
3.000	X1	1,	0,	0,	0,0233	0,	-0,1667	0,	0,	0,	713,1783
0	slack 3	0,	0,	0,	-0,6047	1,	-2,1667	0,	0,	0,	857,3643
3.500	X2	0,	1,	0,	0,	0,	0,1667	0,	0,	0,	333,3333
0	slack 5	0,	0,	0,	-0,0233	0,	0,	1,	0,	0,	153,4884
0	slack 6	0,	0,	0,	-0,0233	0,	0,	0,	1,	0,	203,4884
0	slack 7	0,	0,	0,	-4,6512	0,	-8,3333	0,	0,	1,	24.031,0078
	zj	3.000,	3.500,	0,	69,7674	0,	83,3333	0,	0,	0,	3.306.201,5504
	cj-zj	0,	0,	0,	-69,7674	0,	-83,3333	0,	0,	0,	

Figure 3: Output of *QM for Windows* Simplex Method

Based on the results of linear programming data using the simplex method with the help of *QM for Windows* software shown in Figure 3, it can be explained that in the zj line, there is no longer a negative value because, according to Asmara et al. (2018) if Z is negative, then recalculation is needed to obtain a positive Z. In addition, it can also be seen that cj-zj is worth 0 for the original flavoured crispy fried shallots (X1) and spicy fried shallots (X2), so it can be said that the solution obtained is optimal. The optimal solution for the objective function and constraint function in the Bawang Goreng Crispy Yuk Riris business was obtained in the 3rd iteration. These calculations mean that if Bawang Goreng Crispy Yuk Riris wants the optimal combination of products with maximum profit, the company must produce 713,1783 packs of original crispy fried shallots (X1) and 333,3333 packs of spicy crispy fried shallots (X2) with the maximum profit to be achieved IDR 3.306.201,5504.

The results of this study follow the research conducted by Suryanto et al. (2019), which explains that by optimizing production by utilizing linear programming using the simplex method, we get the optimal combination of production and the allocation of production factors are used effectively and efficiently to optimize profit. In addition, research from Ghaliyah et al. (2021), who conducted research at MSME Aini Nabani, showed that from the results of the linear program analysis of the simplex method with the help of *QM for Windows V5* software, the optimal profit calculation was obtained to produce 200 tuna chilies and 300 squid sauces with a profit of 5.000.000 so that it can increase profits by 42.85% from the profits obtained previously.

Linear Programming Analysis

Linear programming analysis is used to optimize the number of product combinations produced to obtain maximum profit for the Bawang Goreng Crispy Yuk Riris business by analyzing the secondary data that has been obtained. This linear programming calculation uses the help of *QM for Windows* software. Before doing the calculations, the objective function equations and 7 constraint functions that limit production have been made. The steps for solving linear programming in general with the help of *QM for Windows* software the process is the same as the graphical method or the simplex method, the difference is that in the third stage you can directly select the main *Window* menu and *Linear Programming Result*. The result of the calculation of solutions in linear programming analysis can be seen in the image below:

	X1	X2		RHS	Dual
Maximize	3.000,	3.500,			
Shallot	143,	143,	<=	300.000,	0,
Seasoned Flour	43,	43,	<=	45.000,	69,7674
Cooking Oil	26,	39,	<=	32.400,	0,
Chilli	0,	6,	<=	2.000,	83,3333
Label Sticker	1,	1,	<=	1.200,	0,
Standing Pouch	1,	1,	<=	1.250,	0,
Operational Cost	200,	250,	<=	250.000,	0,
Solution->	713,1783	333,3333		$3.306.201,55	

Figure 4: Output of *QM for Windows* Linear Programming

Results

Based on the results of data processing under the objective function that has been set, namely maximizing profit, then the combination is obtained by producing:

1. Original flavour crispy fried shallots (X1) as many as 713,1783 $\approx$ 713 packs.
2. Spicy flavour crispy fried shallots (X2) as many as 333,333 $\approx$ 333 packs.

So based on the objective function obtained:

- Calculation Without Rounding

  Zmax = 3.000X1 + 3.500X2
  = 3.000 (713,1783) + 3.500 (333,3333)
  = 3.306.201,55

- Calculation After Rounding

  Zmax = 3.000X1 + 3.500X2
  = 3.000 (713) + 3.500 (333)
  = 2.139.000 + 1.165.000
  = 3.304.500

From the results of the three data processing from the menu *graph* (graphic method), *iterations* (simplex method), and *linear programming results* (linear programming analysis) using the *QM for Windows* software, the optimal combination of products with the same results is obtained for crispy fried shallots original flavour (X1) as many as 713,1783 packs so that it can be rounded up to 713 packs. As for the spicy crispy fried shallot product (X2), as many as 333,333 packs, it is rounded to 333 packs.

However, there is a slight difference between the results of the value of the profit or its Z value, where if using a *graph* (graphic method), the profit is IDR 3.306.202. In contrast, *iterations* (simplex method) is IDR 3.306.201,5504 and *linear programming results* (linear programming analysis) of IDR 3.306.201,55. The difference in this value results is not problematic because it is only caused by the influence of the number behind the comma (,) where the value of the graph method is immediately rounded up, and the simplex method is written 4 (four) numbers behind the comma. The linear programming results are only written 2 (two) numbers behind the comma. So in calculating this profit, it is calculated manually according to the objective function by using the value of the product combination that has been rounded up, with a profit of IDR 3.304.500.

The results of this study are in line with Susdarwono's (2020) research which shows that solving problems related to the defence economy using linear programming using the graphical method and the simplex method will produce a Z value with the same optimal point so that there is a match between the results of the solution using the graphical method and the simplex method.

The following compares the amount of production and the profits obtained between the actual and optimal conditions:

TABLE IV

TOTAL PRODUCTION AND PROFIT OF EACH VARIETY OF FLAVOR IN ACTUAL CONDITIONS AND OPTIMAL CONDITIONS FOR THE PERIOD OF FEBRUARY 2022

Flavour Variants	**Production Quantity**		**Profit**	
	Actual (pack)	**Optimal (pack)**	**Actual (IDR)**	**Optimal (IDR)**
Original (X1)	700	713	2.100.000	2.139.000
Spicy (X2)	300	333	1.050.000	1.165.500
Total	**1.000**	**1.046**	**3.150.000**	**3.304.500**

Source: Data Processing Results (2022)

Based on Table 4 above, it can be explained that if Bawang Goreng Crispy Yuk Riris wants to get the optimal product combination, then Bawang Goreng Crispy Yuk Riris must produce 713 packs of original crispy fried shallot (X1) and spicy crispy fried shallot (X2) as many as 333 packs so that the profit that can be obtained in optimal conditions is IDR 3.304.500. At the same time, the profit in actual conditions is IDR 3.150.000, and the increase in profits obtained is Rp. 154,500. From the results of calculations using linear programming with actual conditions, it seems that it is close to optimal profit, but the amount of production is different. So to get the maximum profit, the Bawang Goreng Crispy Yuk Riris must produce according to optimal conditions.

Sensitivity Analysis

Sensitivity analysis can be used to deal with errors in estimating input parameters to linear programming models and management experiments with possible future changes in the firm that could affect profits (Render et al., 2018). When a solution has been found in the *QM for Windows* software, the sensitivity analysis can be viewed by selecting the *Window* and *Ranging* menus. The following is the display result of the sensitivity analysis using *QM for Windows*:

Variable	Value	Reduced Cost	Original Val	Lower Bound	Upper Bound
X1	713,18	0,	3.000,	0,	3.500,
X2	333,33	0,	3.500,	3.000,	Infinity
Constraint	Dual Value	Slack/Surplus	Original Val	Lower Bound	Upper Bound
Shallot	0,	150.348,8	300.000,	149.651,2	Infinity
Seasoned Flour	6.976.744,	0,	45.000,	14.333,33	46.417,95
Cooking Oil	0,	857,3652	32.400,	31.542,63	Infinity
Chilli	8.333.334,	0,	2.000,	0,	2.395,71
Label Sticker	0,	153,4884	1.200,	1.046,51	Infinity
Standing Pouch	0,	203,4884	1.250,	1.046,51	Infinity
Operational Cost	0,	24.031,02	250.000,	225.969,	Infinity

Figure 5: Output of *QM for Windows* Ranging

Figure 5 provides ranging outputs related to sensitivity analysis, where the *reduced cost* value for each variable, namely the original crispy fried shallot product (X1) and spicy crispy fried shallot product (X2), is 0 (no reduced cost). This means the value of the *reduced cost* is 0, which indicates that the use of these two variables is optimal and the crispy fried shallot product is profitable to produce.

The profit of the original crispy fried shallot product (X1) is IDR 3.000, while the spicy crispy fried shallot product (X2) is IDR 3.500, which is shown as the *original value* at the output. The *lower bound* and *upper bound* values are used to perform sensitivity analysis. The objective function coefficient for the original flavoured crispy fried shallot product (X1) has a *lower bound* value of 0 and an *upper bound* value of 3.500. This means that the solution at this point remains optimal as long as the profit on the original crispy fried shallot product (X1) does not exceed IDR 3.500. Meanwhile, the spicy crispy fried shallot product variable (X2) has a *lower bound* value of 3.000 and an *upper bound* of infinity. So that the coefficient value can be changed according to the recommended lower and upper bound values because, in the range of coefficient values, this objective function will not change the optimal value.

The sensitivity analysis is shown from the output *ranging* from *QM for Windows* also indicates that the original values for each limit (shallots, seasoned flour, cooking oil, chilli, label stickers, standing pouches, and operational costs are 300.000; 45.000; 32.400; 2.000; 1.200; 1.250; 250.000). Using these inputs, the optimal use of seasoned flour and chilli is marked by the *slack* value, which reaches 0 (zero). The *dual value* for the spice flour limit is 69,76744, and the *lower bound* is 14.333,33, while the *upper bound* is 46.417,95. This means that every additional gram of seasoned flour, up to 46.417,95 grams, will increase the maximum profit by IDR 69,76744. Likewise, if the available seasoned flour is reduced, the maximum possible profit will be reduced by IDR 69,76744 per gram until the amount available is reduced to a *lower bound* of 14.333,33. Meanwhile, the *duel value* for the chilli limit is 83,33334, the *lower bound* is 0, and the *upper bound* is 2.395,71. This means that every additional gram of chilli, up to 2.395,71 grams, will increase the maximum profit by IDR 83,33334. Similarly, if the available chilli is reduced, the maximum possible profit will decrease by IDR 83,33334 until the available quantity is reduced to a *lower bound* of 0.

Dual value for the limits of shallots, cooking oil, label stickers, standing pouches, and operational costs are 0, and the slack value of shallots is 150.248,8; cooking oil is 857,3652; label sticker is 153,4884; standing pouch is 203,4884; and operating costs are 24.031,02. So this is a non-binding constraint, which means that there are leftovers on those five inputs that are not being used even though they are currently available. If these five additional inputs are available, it will still not increase profits but it will only increase the amount of *slack*. This *dual value* is relevant as long as it is not below the *lower bound*, namely for shallots of 149.651,2; cooking oil of 31.542,63; label sticker of 1.046,51; standing pouch of 1.046,51; and operating costs of 225.969. Meanwhile, the *upper bound* of the five inputs is infinity, which indicates that adding more inputs will only increase the amount of remaining unused.

4. Conclusions

Based on the analysis of the calculation results of the optimization of the production of Bawang Goreng Crispy Yuk Riris products using linear programming with the graphical method and the simplex method with the help of *QM for Windows software*, the optimal product combination with the same result is obtained by producing 713 packs of original crispy fried shallots and crispy fried shallot products with a spicy taste of 333 packs with the maximum profit that will be accepted by the Bawang Goreng Crispy Yuk Riris, which is IDR 3.304.500. Sensitivity analysis shows that the solution will remain optimal. The profit tolerance limit for the original flavoured crispy fried shallot product is between IDR 0 to IDR 3.500. In contrast, the profit tolerance limit for the spicy fried shallot product is between IDR 3.000 and infinity. The use of inputs for seasoned flour and chilli production is optimal because it has a slack value that reaches 0 (zero). In contrast, the use of shallots, cooking oil, label stickers, standing pouches, and operational costs is still not optimal because they have a slack value that is not 0 (zero). It shows that there are still many production inputs whose use is not optimal.

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