JMSCOWA 5 (2) (2024) Pages:. 66-72

Journal homepage: https://pcijournal.org/index.php/jmscowa

Journal of Mathematics and Scientific Computing with Applications

Published: Pena Cendekia Insani

IMPLEMENTATION OF THE CUTTING PLANE METHOD TO OPTIMIZE THE PRODUCTION PROFIT OF PAK SUNAR'S TEMPE FACTORY

Sofiah Aini[1]

[1]Department of Mathematics, Universitas Mulawarman, Samarinda, Indonesia

Article Info

Article history:

Received 02 29, 2024
Revised 03 30, 2024
Accepted 05 10, 2024

Keywords:

Tempe, Profit, Optimal, Cutting Plane, POM-QM

ABSTRACT

Tempe is a traditional Indonesian food rich in protein, made from soybeans fermented with the Rhizopus mold. The tempeh production process often faces challenges in managing efficiency and costs to achieve optimal profits. This research aims to optimize tempeh production using the cutting plane method, which is a mathematical optimization technique for solving problems with integer constraints and complex decision variables. This method adds new constraints that narrow the solution space, allowing for the discovery of the best production combination. The optimization process is carried out with the help of POM-QM software to improve efficiency and accuracy in determining the optimal solution. The optimization results show that the optimal production is 37 large-sized plastic tempeh and 50 large-sized leaf tempeh, with daily profits increasing compared to the previous production, which only yielded per day. The application of the cutting plane method has proven effective in increasing production efficiency, reducing raw material waste, and maximizing profits in the tempeh factory.

Corresponding Author:

Sofiah Aini,
Department Of Mathematic,
Universitas Mulawarman
Email: sofiahaini@gmail.com

1. INTRODUCTION

Indonesia is the largest tempeh producer in the world and the largest soybean market in Asia. About 50% of the soybeans consumed in Indonesia are processed into tempeh, 40% into tofu, and 10% are used for other products such as tauco, soy sauce, and so on. The average tempeh consumption per person in Indonesia is estimated to reach around 6.45 kg per year [1]. Tempe is a traditional Indonesian food rich in protein, made from soybeans that are boiled and fermented using the Rhizopus mold. This mold plays an important role in the fermentation process of tempeh, which produces various nutrients such as carbohydrates, proteins, fats, vitamins, and minerals needed by the body [2].

Tempe, as one of the environmentally friendly sources of plant-based protein, is becoming increasingly popular among health-conscious and sustainability-minded consumers. In recent years, tempeh has gained global attention as a healthy food alternative, driving innovation in product variations and presentation methods [3]. With strong cultural roots and vast market potential, tempe not only symbolizes the richness of Indonesian cuisine but also contributes to public health and the local economy.

With the increasing interest of the public in healthy and plant-based foods, the tempe industry is growing rapidly. Tempeh factories play an important role in meeting market demands, both local and international. Variations in operations, ranging from home-based businesses to large industries with advanced technology [4]. Although many tempeh factories have developed processes and improved product quality, most still rely on traditional methods. This poses a unique challenge, especially for entrepreneurs in the home industry, in competing with more modern industries. In this context, the main challenge is to achieve optimal profit. Profit is the difference between the amount of capital expended and the revenue received. Business actors can determine what they desire. However, the chosen profit will carry potential risks that will be faced [5]. Therefore, profits must be managed well for the sustainability of the business in the future.

Pak Sunar's tempe factory is a home-based industrial business that has been established since 1995, and until now, it has been operating for approximately 29 years. This factory produces various types of tempeh, such as plastic tempeh and leaf tempeh. Pak Sunar's Tempe Factory still uses traditional or manual production planning methods, making it difficult to predict and optimize profits effectively. Poorly managed production planning can result in losses, even to the point of bankruptcy risk [6]. With that, Pak Sunar's Tempe Factory requires a more efficient production planning approach to optimize profits.

Optimization is the process of finding the best outcome, both in terms of maximizing profits and reducing costs, according to conditions that have been mathematically established. In production, optimization is necessary so that resource utilization can be carried out as efficiently as possible, ensuring that the number of products produced meets the targets and business objectives can be achieved [7]. One of the approaches that can be used to achieve that efficiency is linear programming. Linear programming involves structuring a real-world problem into a mathematical model consisting of an objective function and several linear constraints [8]. Integer linear programming is a linear programming model specifically designed to solve problems. Where the value of the decision variable in the optimal solution must be an integer. This is important because in some cases, the value of the decision variable cannot be in fractional form [9].

The main methods for solving integer linear programming problems are the rounding method, branch and bound, and cutting plane. The branch and bound method seeks an optimal solution by creating upper and lower branches on each variable that is not yet in integer form, so that each branch generates new branches until an integer solution is achieved [10]. Meanwhile, the cutting plane method narrows the solution space by adding additional constraints known as Gomory cuts, leaving only integer solutions without the need for branching [11].

Research on problem-solving using integer programming methods has been conducted by [12], which concluded that the branch and bound method and the cutting plane method both yield equally effective results in profit optimization. However, in the process of solving, the branch and bound method requires many iterations and more time compared to the Gomory cutting plane method. Research [13] produced optimal production regarding the optimization of electronic manufacturing, with two constraint limits and two decision variables, whereas in the chili plant research, the cutting plane method resulted in maximum production with minimum cost [14].

Based on the description above, the researcher is interested in applying the cutting plane method in an effort to optimize tempe production profits. This research aims to maximize profits by considering various production factors, such as raw materials and production capacity. By using the cutting plane method and with the help of the POM-QM (Production and Operations Management-Quality Control) for Windows software, which is designed to assist in mathematical calculations, especially in linear programming problems [15], this research can achieve its goal of finding the most efficient and profitable production combination for Pak Sunar's tempe factory. Through this research, it is hoped that there will be a contribution to the development of more optimal and effective production strategies, thereby supporting the growth of the tempeh industry in Indonesia.

2. RESEARCH METHODE

The type of research is quantitative research. The data collection method used in this research is primary data obtained through direct interviews and surveys at Pak Sunar's tempeh factory located in Tj. Mulia Hilir, Kec. Medan Deli, Kota Medan, North Sumatra 20241. The products that are the focus of this research include various types of tempeh, namely small-sized tempeh, large-sized plastic tempeh, and large-sized leaf tempeh. Additionally, this research also involves data on production factors and sales profits. The research process uses the cutting plane method detailed through systematic stages, explained in detail in the following steps:

a. Formulation of integer linear programming problems

Formulate the optimization problem into the form of integer linear programming that includes decision variables, objective function, and constraints.

b. Linear Programming
Solve the linear programming problem using the simplex method assisted by the POM-QM software to obtain the optimal solution while ignoring integer constraints.

c. Solution Evalution
Check if the optimal solution obtained from the simplex method is an integer. If the solution is already an integer, then the solution is optimal. If the solution is not an integer, the next step will be to use the cutting plane method.

d. Addition of Constraints (cutting plane)
The approach used in the cutting plane method is to add additional constraint boundaries to the linear programming model to eliminate non-integer solutions. The additional constraint that corresponds to the following equation:

$$Sg_i - \sum_{j=1}^{n} \binom{n}{k} f_{ij} x_j = -f_i$$

Explanation:

Sg_i : Gomory's cutting plane method ke i

f_{ij} : fraction in a_{ij}

f_i : fraction in b_i

3. RESULT AND ANALYSIS

a. Data Collection
The data obtained from the interview at Mr. Sunar's tempeh factory, which includes daily sales profit data and production factor data, will be presented in the following table:

Table 1. Selling Price and Profit of Pak Sunar's Tempe Factory

No.	Type of Tempe	Selling Price	Profit
1.	Small Plastic Container	$Rp. 800$	$Rp. 500$
2.	Large Plastic Container	$Rp. 2500$	$Rp. 1800$
3.	Large Leaf Tempeh	$Rp. 2000$	$Rp. 1600$

Table 2. Production Factors

Production Factor	1	2	3	Supplies	Unit
Soybean	76	125	111	80000	Gram
Ragi Tempe	1	2	2	500	Gram
Plastic	120	266		10000	Centimeter
Daun			180	9000	Centimeter
Production Limitations	1	1	1	40	Batang

b. Formulating Linear Integer Problems
Formulating Decision Variables

The decision variables are obtained from the types of tempeh produced at Mr. Sunar's tempeh factory, which includes 3 types of tempeh as follows:

x_1 : Small Plastic Container

x_2 : Large Plastic Container

x_3 : Large Leaf Tempeh

Formulating the Objective Function

The objective of this research is to maximize profit, so the objective function is obtained from Table 1, which shows the profit per type of tempe over a one-day period, as follows:

$$Z_{max} = 500x_1 + 1800x_2 + 1600x_3$$

Formulating the Constraint Function

The constraint function or limitation is obtained from the production factors in the form of raw materials and production constraints formulated into the following mathematical model:

$76x_1 + 125x_2 + 111x_3 \leq 80000$
$1x_1 + 2x_2 + 2x_3 \leq 500$
$120x_1 + 266x_2 + 0x_3 \leq 10000$
$0x_1 + 0x_2 + 180x_3 \leq 9000$
$x_1 + x_2 + x_3 \geq 40$

c. Evaluating Solutions Using the Simplex Method

The simplex method is a process that applies a systematic procedure repeatedly (iteration) until the desired result is achieved [16]. To produce an optimal solution, the simplex method will be used with the help of the POM-QM software. There are steps to the solution, namely first transforming the linear programming form into the standard form of the simplex method, which consists of the objective function and constraint functions as follows:

$Z_{max} = 500x_1 + 1800x_2 + 1600x_3 + 0S_1 + 0S_2 + 0S_3 + 0S_4 + 0S_5$
$76x_1 + 125x_2 + 111x_3 + S_1 + 0S_2 + 0S_3 + 0S_4 + 0S_5 = 80000$
$1x_1 + 2x_2 + 2x_3 + 0S_1 + S_2 + 0S_3 + 0S_4 + 0S_5 = 500$
$120x_1 + 266x_2 + 0x_3 + 0S_1 + 0S_2 + S_3 + 0S_4 + 0S_5 = 10000$
$0x_1 + 0x_2 + 180x_3 + 0S_1 + 0S_2 + 0S_3 + S_4 + 0S_5 = 9000$
$x_1 + x_2 + x_3 + 0S_1 + 0S_2 + 0S_3 + 0S_4 + S_5 = 40$

Second, enter the standard form of the objective function and the constraint function into the initial simplex table as shown in the table below.

Table 3. Initial Simplex Table

Cj	VB	Quantity	500	1800	1600	0	0	0	0	0
			X1	X2	X3	S1	S2	S3	S4	S5
0	S1	80.000	76	125	111	1	0	0	0	0
0	S2	500	1	2	2	0	1	0	0	0
0	S3	10.000	120	266	0	0	0	1	0	0
0	S4	9.000	0	0	180	0	0	0	1	0
0	S5	40	1	1	1	0	0	0	0	1
	zj	0	0	0	0	0	0	0	0	0
	cj-zj		500	1.800	1.600	0	0	0	0	0

Thirdly, the data processing can be calculated using the POM-QM software to obtain optimal results. Here are the calculation results using the POM-QM software:

Table 4. Simplex Table Using POM-QM Software

Cj	VB	Quantity	500	1800	1600	0	0	0	0	0
Iterasi 1			X1	X2	X3	S1	S2	S3	S4	S5
0	S1	80.000	76	125	111	1	0	0	0	0
0	S2	500	1	2	2	0	1	0	0	0
0	S3	10.000	120	266	0	0	0	1	0	0
0	S4	9.000	0	0	180	0	0	0	1	0
0	S5	40	1	1	1	0	0	0	0	1
	zj	0	0	0	0	0	0	0	0	0
	cj-zj		500	1.800	1.600	0	0	0	0	0
Iterasi 2										
0	S1	75.300,75	19,609	0	111	1	0	-0,4699	0	0

0	S2	424,812	0,0977	0	2	0	1	-0,0075	0	0
1800	x2	37,594	0,4511	1	0	0	0	0,0038	0	0
0	S4	9.000	0	0	180	0	0	0	1	0
0	S5	362,406	0,5489	0	1	0	0	-0,0038	0	1
	zj	67.669,17	812,03	1800	0	0	0	6,77	0	0
	cj-zj		-312,03	0	1.600	0	0	-6,7669	0	0
Iterasi 3										
0	S1	69.750,75	19,61	0	0	1	0	-0,47	-0,6167	0
0	S2	324,812	0,098	0	0	0	1	-0,01	-0,0111	0
1800	X2	37,594	0,451	1	0	0	0	0,004	0	0
1600	X3	50	0	0	1	0	0	0	0,0056	0
0	S5	312,406	0,549	0	0	0	0	-0	-0,0056	1
	zj	147.669,17	812	1800	1600	0	0	6,77	8,89	0
	cj-zj		-312	0	0	0	0	-6,77	-8,8889	0

From the results in the table above, the optimal results obtained are 0, 37, 594, and 50 tempe, with a profit of Rp. 147,669.17. However, since there are fractional numbers (non-integer), this solution will be continued to obtain integer numbers using the cutting plane method to produce optimal values in the form of whole numbers.

d. Method Cutting Plane

Based on the optimization table using the simplex method through the POM QM software, the Z row no longer contains negative values, indicating that the solution obtained is optimal, namely 0, 37.594, and 50 tempe, with Rp. 147,669.17. However, this result does not yet meet the criteria for integer values, as there are still variables in the optimal solution that are fractional, namely . Therefore, this problem will be continued by adding new constraints or using the cutting plane method as follows:

$$x_2 + 0{,}4511x_1 + 0{,}0038S_3 = 37{,}594$$
$$x_2 + 0{,}4511x_1 + 0{,}0038S_3 = 37 + 0{,}594$$
$$x_2 - 37 = -0{,}4511x_1 - 0{,}0038S_3 + 0{,}594$$

So, the Gomory constraint is:

$$W_1 - 0{,}4511x_1 - 0{,}0038S_3 = -0{,}594$$

Based on the optimal table from the simplex method using the POM QM software, new constraints have been identified that need to be considered. In addition, the first Gomory constraint that has been determined is also added to improve the solution and ensure that all basic variables meet the requirement of being integers.

$$19{,}609x_1 + 0x_2 + 0x_3 + 1S_1 + 0S_2 - 0{,}4699S_3 - 0{,}6167S_4 + 0S_5 + 0W_1 = 69.750{,}75$$
$$0{,}0977x_1 + 0x_2 + 0x_3 + 0S_1 + 1S_2 - 0.0075S_3 - 0{,}0111S_4 + 0S_5 + 0W_1 = 324.812$$
$$0{,}4511x_1 + x_2 + 0x_3 + 0S_1 + 0S_2 + 0{,}0038S_3 + 0S_4 + 0S_5 + 0W_1 = 37{,}594$$
$$0x_1 + 0x_2 + x_3 + 0S_1 + 0S_2 + 0S_3 + 0{,}0056S_4 + 0S_5 + 0W_1 = 50$$
$$0{,}5489x_1 + 0x_2 + 0x_3 + 0S_1 + 0S_2 - 0{,}0038S_3 - 0{,}0056S_4 + S_5 + 0W_1 = 312{,}406$$
$$-0{,}4511x_1 + 0x_2 + 0x_3 + 0S_1 + 0S_2 - 0{,}0038S_3 + 0S_4 + 0S_5 + 1W_1 = -0{,}594$$

After the Gomory constraints are known, the next step is to insert the first Gomory constraint into the table that has already reached the optimal condition as follows:

Table 5. Gomory Cutting Plane Table

Cj	VB	Quantity	500	1800	1600	0	0	0	0	0	0
			X1	X2	X3	S1	S2	S3	S4	S5	W1
0	S1	69.750,75	19,609	0	0	1	0	-0,4699	-0,6167	0	0
0	S2	324,812	0,0977	0	0	0	1	-0,0075	-0,0111	0	0
1800	X2	37,594	0,4511	1	0	0	0	0,0038	0	0	0
1600	X3	50	0	0	1	0	0	0	0,0056	0	0
0	S5	312,406	0,5489	0	0	0	0	-0,0038	-0,0056	1	0
0	W1	-0,594	-0,4511	0	0	0	0	-0,0038	0	0	1

	zj	147.669,17	812,03	1800	1600	0	0	6,77	8,89	0	0
	cj-zj		-312,03	0	0	0	0	-6,7669	-8,8889	0	0

Table 6. Gomory Cutting Plane Results Table

cj	VB	Quantity	500	1800	1600	0	0	0	0	0	0
			X1	X2	X3	S1	S2	S3	S4	S5	W1
0	S1	69824,205	75,3911	0	0	1	0	-0,47	-0,6	0	0
0	S2	325,98437	0,98803	0	0	0	1	-0,01	-0	0	0
1800	X2	37	0	1	0	0	0	0,004	0	0	0
1600	X3	50	0	0	1	0	0	0	0,01	0	0
0	S5	313	1	0	0	0	0	-0	-0	1	0
0	S3	156,31579	118,711	0	0	0	0	1	0	0	-263,16
	zj	146610,91	8,35974	8,89+F667	1600	0	0	6,77	8,89	0	0
	cj-zj		491,64	0	0	0	0	-3,77	-4,9	0	0

e. Discussion

From the calculation results using the simplex method with the POM-QM software, the integer results have not yet been obtained, which are 0, 37.594, and 50 tempe, with a profit of Rp. 147,669.17. Continuing with the cutting plane method, an optimal result was obtained, with the final calculation results indicating that there are no non-integer numbers left, so the solution is now integer. This means that Pak Sunar's tempeh factory can produce small-sized plastic tempeh (x_1 0 units), large-sized plastic tempeh (x_2 37 units), and large-sized leaf tempeh (x_3 50 units), achieving a maximum profit of $Rp. 146.610,91$.

4. CONCLUSION

The conclusion obtained from the results and discussion above can be outlined, to achieve profit at Pak Sunar's tempeh factory by applying the cutting plane method to determine the production quantity that provides maximum profit in one day. Pak Sunar's tempe factory needs to produce 0 small-sized plastic tempe, 37 large-sized plastic tempe, and 50 large-sized leaf tempe, resulting in a maximum profit per day ofThis profit has increased from the previous profit, which was per day.

5. REFERENCES

[1] Y. Asbur and Khairunnisyah, “Tempe Sebagai Sumber Antioksidan : Sebuah Telaah Pustaka Tempe as a Source Of Antioxidants : A Review,” *Agril. J. Ilmu Pertan.*, vol. 9, no. 3, pp. 183–192, 2021.

[2] A. P. Lamuka, F. R. Walangadi, F. Y. Djafar, P. N. pratiwi Abas, and D. Y. Polamolo, “Fermentasi Sorgum (Sorghum bicolor) menggunakan (Rhizopus oligosporus) sebagai Sumber Alternatif Karbohidrat,” *Mitita J. Penelit.*, vol. 1, no. 3, pp. 11–16, 2023.

[3] R. Puspitorini, “Pengaruh kualitas produk, harga, dan promosi terhadap keputusan pembelian tempekita pada konsumen rumah tempe Indonesia Kota Bogor,” *Uinjkt*, p. 97, 2022.

[4] B. Andri Mongan, L. Ricky Rengkung, and E. Olly Harryani Laoh, “Analysis Of The Benefits Of The Tofu And Tempe Making Business In UD. Bringer Of Blessings In South Tomohon City,” vol. 5, pp. 513–524, 2024.

[5] N. N. Faraiddin and M. Fathurrahman, “Pengukuran Tingkat Keuntungan Dan Faktor Yang Mempengaruhinya Pada Umkm Donatawa,” *J. Ilm. Manajemen, Bisnis dan Kewirausahaan*, vol. 3, no. 2, pp. 233–239, 2023, doi: 10.55606/jurimbik.v3i2.484.

[6] Z. A. Zahra, A. Yudistira, and N. F. Alvan, “Literature Review: Peran Tujuan Perusahaan, Struktur Organisasi Perusahaan, Dan Hukum Bisnis Dalam Aktivitas Perusahaan Sebagai Organisasi Bisnis,” *J. Pijar*, vol. 1, no. 2, pp. 266–274, 2023.

[7] A. Tantri, A. Siregar, and S. Sitepu, “Leibniz: Jurnal Matematika,” vol. 4, 2024.

[8] Ayu Khoerun Nisa, Suci Putri Lestari, and Barin Barlian, “Analisis Pemanfaatan Program Linear Untuk Alokasi Bahan Baku Dalam Rangka Memaksimalisasi Keuntungan,” *J. Rimba Ris. Ilmu Manaj. Bisnis dan Akuntansi*, vol. 1, no. 4, pp. 57–71, 2023, doi: 10.61132/rimba.v1i4.281.

[9] K. Kambu and P. Linear, “Jurnal Matematika , Komputasi dan Statistika PENERAPAN PROGRAM LINEAR BILANGAN BULAT MENGGUNAKAN Program Studi Matematika , Jurusan Matematika Fakultas Matematika dan Ilmu Pengetahuan Alam , Universitas Halu Oleo , Indonesia Email : irta2401@gmail.com Pro,” vol. 4, no. April, pp. 603–614, 2024.

[10] D. S. Anggraini, S. Syaripuddin, and Q. Q. A, “Optimasi Penjadwalan Menggunakan Pemrograman Linier Integer pada Masalah Penjadwalan Perawat UPT Dinas Kesehatan Puskesmas Jonggon Jaya,” *J. Ilm. Mat.*, vol. 3, no. 1, pp. 54–60, 2024.

[11] M. Sarisa and D. Murni, “Metode Cutting Plane dan Analisis Sensitivitas pada Optimasi Keuntungan Penjualan Usaha Kue Putu Asli M*R,” *J. Math. UNP*, vol. 7, no. 3, p. 52, 2022, doi: 10.24036/unpjomath.v7i3.13016.

[12] N. Putri, M. S. Syahrul, and R. Ramayanti, “Integer Linear Programming In Production Profit Optimization Problems Using Branch And Bound Methods & Gomory Cutting Plane,” *J. Mat. Stat. dan Komputasi*, vol. 20, no. 3, pp. 552–567, 2024, doi: 10.20956/j.v20i3.32888.

[13] H. L. Sapitri, “Metode Cutting Plane dalam Optimasi Jumlah Produksi Pada Perusahaan Manufaktur Elektronik The Flash,” *J. Pendidik. Tambusai*, vol. 5, no. 3, pp. 114570–114575, 2021.

[14] E. Safitri, S. Basriati, and W. Ulya, “Penerapan Metode Cutting Plane untuk Optimasi Biaya Pemupukan pada Tanaman Cabai (Studi Kasus: Kelompok Wanita Tani Sentosa Santul),” *J. Sains Mat. dan Stat.*, vol. 6, no. 1, p. 79, 2020, doi: 10.24014/jsms.v6i1.9256.

[15] I. M. Bernard, Alimuddin, Sahid, “Modeling Dan Penyelesaian Masalah Program Linear Dengan Pom-Qm for Windows,” *Ininnawa J. Pengabdi. Masy.*, vol. 01, no. 01, pp. 107–115, 2023.

[16] P. E. P. Utomo, U. Khaira, C. Ramdan, and G. A. Wandira, “Optimalisasi Keuntungan Roti Panggang Menggunakan Pemrograman Linear Metode Simpleks,” *Juisik*, vol. 1, no. 2, p. 62, 2023.