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Application of Branch and Bound Method to Optimize the Profit of Kue Kacang Hijau MD Production of Special Souvenir Sabang City

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Abstract. Kue Kacang Hijau MD is a company that engages in the food business in Sabang City. This company produces more than one flavor of mung bean cakes including original flavor, coffee flavor, durian flavor, pandan flavor and chocolate flavor. For the limitation of available raw materials, this company difficulty to optimize its production profits. The aim of this study is to determine the amount of daily production of mung bean cake so the profit is maximum with the limited raw materials that available. This study uses the Branch and Bound Method, that is a method used to solve Integer Programming. From the analysis with this method, the optimal number of mug bean cake production is 1,060 boxes per day, that is 440 boxes of original flavor, 166 boxes of coffee flavor, 146 boxes of durian flavor, 146 boxes of pandan flavor, and 162 boxes of chocolate flavor with maximum profit is Rp. 4,323,200. By applying this method, daily profit would increase 6.35% or Rp. 258,200 compared to the previous profit.

Keyword: Branch and Bound Method, Production Optimization, Linear Programming, Integer Linier Programming

Abstrak. *Perusahaan kue kacang hijau MD merupakan perusahaan yang bergerak di bidang usaha makanan oleh-oleh khas Kota Sabang. Perusahaan ini memproduksi lebih dari satu jenis kue kacang hijau diantaranya rasa original, rasa kopi, rasa durian, rasa pandan dan rasa coklat. Dengan keterbatasan bahan baku yang tersedia, perusahaan ini kerapkali kesulitan dalam mengoptimalkan keuntungan produksinya. Penelitian ini bertujuan untuk menentukan jumlah produksi harian kue kacang hijau untuk berbagai rasa, sehingga diperoleh keuntungan maksimum dengan keterbatasan bahan baku yang tersedia. Penelitian ini menggunakan Metode Branch and Bound, yakni metode yang digunakan untuk menyelesaikan program bilangan cacah. Dari analisis menggunakan metode ini, diperoleh jumlah produksi kue kacang hijau yang optimal adalah sebanyak 1.060 kotak perhari, yang terdiri dari 440 kotak rasa original, 166 kotak rasa kopi, 146 kotak rasa durian, 146 kotak rasa pandan, dan 162 kotak rasa coklat dengan keuntungan maksimum sebesar Rp.*

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4.323.200. Dengan penerapan metode ini, keuntungan harian meningkat sebesar 6,35% atau sebesar Rp. 258.200 dari keuntungan sebelumnya.

Kata Kunci: *Metode Branch and Bound, Optimisasi Produksi, Program Linier, Program Bilangan Cacah.*

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1. Introduction

Currently, competition in the industrial world is getting tougher, it can be seen from the development of existing factories. Many factories are competing to be the best in their field, one of the ways to improve and develop performance to achieve efficiency and effectiveness in carrying out production into optimizing revenue by utilizing existing sources of power.

In general, every company would want to get the maximum income with the minimum expenses to increase company profits, this is also done by the Kue Kacang Hijau MD company that engages in the food business in Sabang City. From the results of the researchers' initial interviews with the head of the company, this company faced a problem that is the difficulty of determining the optimal amount of production with various constraints, One of them is the limited amount of raw materials available every day that will affect the company's profits. To make the number of mung bean cakes produced to be optimal, then the Linear Programming Method can be used.

However, in solving using Linear Programming, the result obtained may not be in form integer, so the production of mug bean cake is impossible produced in irregular quantities. Therefore, one of the methods that can be used in Linear Program is Integer Linear Programming. Integer Linear Programming is a linear programming model that is used to solve a problem in linear programming where the decision variables in the optimal solution must be an integer [1]. One method in Integer Linear Programming is to use the Branch and Bound Method.

The Branch and Bound method can be used in determining the amount of optimal production. This method is better than other methods because optimal results obtained are usually more than one solution so that the most optimal results can be selected from the results that have been obtained [1].

2. Literature Review

2.1 Liner Programming

Linear Programming is a technique in operations research that is widely used. Linear Program was introduced by George B. Dantzig. The initial use of the Linear Program was in the military (transport and logistics), then developed in the case of government and business [2]. Beneke and

Winterboer explains that Linear Programming is a way of planning which is used to assist in the selection of decisions to take several existing alternatives. Linear means that all mathematical functions in this model must be are linear functions. Programming is a synonym for the word planning. Thus, the Linear Program can be interpreted as making a plan activities to achieve the stated goals in the most effective way well and in sync with the mathematical model among all possible alternatives [3].

2.2 Linear Program Model

The Linear Programming Model is about choosing values for the decision variables. The general equation in a Linear Program can be formulated as follows [1] :

Maximize/minimize:

$$Z = \sum_{j=1}^{n} C_j x_j$$

Constraints:

$$\sum_{j=1}^{n} a_{ij} x_j \geq b_i$$

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i$$

With $x_j \geq 0$; and i = 1,2,3,. . . ,m; j=1,2,3,. . . ,n. Assuming that a_{ij}, b_i, c_j is the known model coefficient.

where:

Z = The objective function for optimal value (maximum or minimum)

x_j = decision variable j-th

a_{ij} = Resource requirement i-th to produce each unit of activity j-th

b_i = Amount of available resource i-th

c_j = Cost per unit of activity j-th

m = Number of available resources

n = Number of activities

2.3 Linear Programming Solution

a) Graph method

The graphical method is one method that can be used in solving problems in linear programming. In its decision making, this method uses a graphical approach where all constraint functions are made in one part picture then to determine the value of the optimum decision variable is taken from the graph. This method is limited only for two decision variables, if the problem is more than two decision variables then this method cannot be used [3].

b) Simplex Method

The Simplex method was introduced by George B. Dantzig in 1947. This method is used to solve linear programming problems with many variables. The simplex method is an algebraic procedure that goes through a series of operations that over and over again [4]. This method can solve the linear programming problem that consists of two or more variables.

In general, the standard form of the simplex method function is:

Maximize:

$$Z - c_1x_1 - c_2x_2 - \ldots - c_nx_n - 0s_1 - 0s_2 - \ldots - 0s_n = 0$$

Constraint function:

$$a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n + s_1 + 0s_2 + \ldots + 0s_n = b_1$$
$$a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n + 0s_1 + s_2 + \ldots + 0s_n = b_2$$
$$\vdots$$
$$a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n + 0s_1 + 0s_2 + \ldots + s_n = b_m$$

2.4 Integer Linear Programming

According to [1], Integer Linear Programming is a linear programming model that is specifically used to solve a linear programming problem. where the value of the decision variables in optimizing the solution must be integer. Integer Linear problem-solving method begins with a solution using the simplex method. The optimal result obtained by this method may not be in the form of a integer number. Therefore, this non-integer solution is optimized by using the method Integer Linear Programming, one of which is the Branch and Bound Method and Cutting Planes Method.

2.5 Branch and Bound Method

The Branch and Bound method was introduced by A.H.Land and A.G.Doig in 1960, then further developed by Little and other researchers. This method has become the standard computer code for Linear Integer Programming, and its practical applications suggest the use of this method because it is more efficient than the Gomory approach [5]. The Branch and Bound method is a "branching and bounding" strategy. This method not only for integer problem, but it is also an approach solution that can be applied to a wide variety of different problems.

2.6 Branch and Bound Method Procedure

According to [1], procedure to maximizes Integer Linear Programming problem with the Branch and Bound Method are as follows:

1. Finding optimal solution using Linear Program Method

   The problem is first solved by Linear Programming (graph or simplex) until the optimum result is obtained.
2. Checking Optimal Solution

In the first steps, the optimal solution that have been obtained are checked first whether the decision variable is in the form of an integer or not. If the value of the decision variable turns out to be in the form of an positive integer, then the optimal problem solving has been completed. If not, then process iteration continues.

3. Determinae the subproblems (branching)

   If the optimal problem solving has not been successful, then the problem is included in two sub-problems by changing the old constraints with constraints new ones into each of these sub-problems.

4. Determine the limit value (bounding)

   Optimal results obtained using the Linear Programming method are the upper bound value for each sub-problem. Meanwhile, the optimal result value by solving the Integer Linear Programming problem is the lower bound value for each sub-problem. If in solving the problem of Integer Linear Programming get a value that is equal to or better than the upper limit value of each problem, then the solution the integer optimal problem has been reached. If not, then the sub-problem that has the best upper limit value will be selected and then become a sub-problem the new one. The iteration process is repeated in step (b), and so on until optimal solution.

3. Result and Discussion

The production process is a way, method, or technique in creating or increase the usefulness of an item into a finished item. The path depends on the existing production system in the company so the control of the production process determines whether the production system is good or bad in a company. In this study, the data obtained from Kue Kacang Hijau MD company are as follows:

Table 1. Raw Material for Mug Bean Cakes

No	Raw Material Used	Flour				
		Original	Coffee	Durian	Pandan	Chocolate
1	Flour	0,084	0,084	0,084	0,084	0,084
2	Mung beans	0,084	0,084	0,084	0,084	0,084
3	Sugar	0,056	0,056	0,056	0,056	0,056
4	Oil	0,011	0,011	0,011	0,011	0,011
5	Butter	0,011	0,011	0,011	0,011	0,011
6	Banana Flavor	0,001	0	0	0	0
7	Coffee Flavor	0	0,006	0	0	0
8	Pandan Flavor	0	0	0,003	0	0
9	Durian Flavor	0	0	0	0.003	0
10	Chocolate Flavor	0	0	0	0	0,008

Table 2. Inventory of Raw Materials Mung Bean Cake (Kg)

No	Raw Materials Used	Inventory of Raw Materials
1	Flour	150
2	Mung beans	150
3	Sugar	100
4	Oil	20
5	Butter	20
6	Banana Flavor	0,44
7	Coffee Flavor	1
8	Pandan Flavor	0,44
9	Durian Flavor	0,44
10	Chocolate Flavor	1,3

Table 3. Production Costs and Profits of Mung Bean Cake (Rp)

No	Flavor	Production cost Per Box	Selling Fee Per Box	Profit Per Box
1	Original	8.800	13.000	4.200
2	Coffee	9.000	13.000	4.000
3	Durian	8.850	13.000	4.150
4	Pandan	8.850	13.000	4.150
5	Chocolate	9.300	13.000	3.700

Table 4. Daily Production of Mung Bean Cake

No	Flavor	Production Quantity (Box)	Profit (Rp)
1	Original	400	1.680.000
2	Coffee	160	640.000
3	Durian	130	539.500
4	Pandan	130	539.500
5	Chocolate	180	666.000

3.1 Mathematical Model Formation

The mathematical model in this study is a positive integer linear programming model. In this model, there are objective functions, constraint functions, and constraints positive integer.

Maximize profit:

$$Z = 4.200\, x_1 + 4.000\, x_2 + 4.150\, x_3 + 4.150\, x_4 + 3.700\, x_5 \qquad (1)$$

Constrains:

Flour

$$0{,}084\, x_1 + 0{,}084\, x_2 + 0{,}084\, x_3 + 0{,}084\, x_4 + 0{,}084\, x_5 \leq 150$$

Mung beans

$$0{,}084\, x_1 + 0{,}084\, x_2 + 0{,}084\, x_3 + 0{,}084\, x_4 + 0{,}084\, x_5 \leq 150$$

Sugar

$$0{,}056\, x_1 + 0{,}056\, x_2 + 0{,}056\, x_3 + 0{,}056\, x_4 + 0{,}056\, x_5 \leq 100$$

Oil

$$0{,}011\, x_1 + 0{,}011\, x_2 + 0{,}011\, x_3 + 0{,}011\, x_4 + 0{,}011\, x_5 \leq 20$$

Butter

$$0{,}011\, x_1 + 0{,}011\, x_2 + 0{,}011\, x_3 + 0{,}011\, x_4 + 0{,}011\, x_5 \leq 20$$

Banana flavor

$0{,}001\,x_1 \leq 0{,}44$

Coffee flavor

$0{,}006\,x_2 \leq 1$

Pandan flavor

$0{,}003\,x_3 \leq 0{,}44$

Durian flavor

$0{,}003\,x_4 \leq 0{,}44$

Chocolate flavor

$0{,}008\,x_5 \leq 1{,}3$

Decision variable

$$x_j \in \{B^+\} \quad \text{for } j = 1,2,3,4,5. \tag{2}$$

Where:

x_1 = Number of original flavored mung bean cakes (box)

x_2 = Number of coffee-flavored mung bean cakes (box)

x_3 = Number of durian-flavored mung bean cakes (box)

x_4 = Number of pandan flavored mung bean cakes (box)

x_5 = Number of chocolate-flavored mung bean cakes (box)

Z = Total profit of all flavors mung bean cake (Rp)

3.2 Solution Using the Simplex Method

Table 5. Simplex Table 1

VB	Z	x_1	x_2	x_3	x_4	x_5	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	NK
Z	1	-4.200	-4.000	-4.150	-4.150	-3.700	0	0	0	0	0	0	0	0	0	0	0
S_1	0	0,084	0,084	0,084	0,084	0,084	1	0	0	0	0	0	0	0	0	0	150
S_2	0	0,084	0,084	0,084	0,084	0,084	0	1	0	0	0	0	0	0	0	0	150
S_3	0	0,056	0,056	0,056	0,056	0,056	0	0	1	0	0	0	0	0	0	0	100
S_4	0	0,011	0,011	0,011	0,011	0,011	0	0	0	1	0	0	0	0	0	0	20
S_5	0	0,011	0,011	0,011	0,011	0,011	0	0	0	0	1	0	0	0	0	0	20
S_6	0	0,001	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0,44
S_7	0	0	0,006	0	0	0	0	0	0	0	0	0	1	0	0	0	1
S_8	0	0	0	0,003	0	0	0	0	0	0	0	0	0	1	0	0	0,44
S_9	0	0	0	0	0,003	0	0	0	0	0	0	0	0	0	1	0	0,44
S_{10}	0	0	0	0	0	0,008	0	0	0	0	0	0	0	0	0	1	1,3

Table 6. Simplex Table Iteration 1

VB	Z	x_1	x_2	x_3	x_4	x_5	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	NK
Z	1	0	-4.000	-4.150	-4.150	-3.700	0	0	0	0	0	4.200.000	0	0	0	0	1.848.000
S_1	0	0	0,084	0,084	0,084	0,084	1	0	0	0	0	-84	0	0	0	0	113,04
S_2	0	0	0,084	0,084	0,084	0,084	0	1	0	0	0	-84	0	0	0	0	113,04
S_3	0	0	0,056	0,056	0,056	0,056	0	0	1	0	0	-56	0	0	0	0	75,36
S_4	0	0	0,011	0,011	0,011	0,011	0	0	0	1	0	-11	0	0	0	0	15,16
S_5	0	0	0,011	0,011	0,011	0,011	0	0	0	0	1	-11	0	0	0	0	15,16
x_1	0	1	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	440
S_7	0	0	0,006	0	0	0	0	0	0	0	0	0	1	0	0	0	1
S_8	0	0	0	0,003	0	0	0	0	0	0	0	0	0	1	0	0	0,44
S_9	0	0	0	0	0,003	0	0	0	0	0	0	0	0	0	1	0	0,44
S_{10}	0	0	0	0	0	0,008	0	0	0	0	0	0	0	0	0	1	1,3

Table 7. Simplex Table Iteration 2

VB	Z	x_1	x_2	x_3	x_4	x_5	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	NK
Z	1	0	-4.000	0	-4.150	-3.700	0	0	0	0	0	4.200.000	0	1.383.333,33	0	0	2.456.639
S_1	0	0	0,084	0	0,084	0,084	1	0	0	0	0	-84	0	-27,99	0	0	100,72
S_2	0	0	0,084	0	0,084	0,084	0	1	0	0	0	-84	0	-27,99	0	0	100,72
S_3	0	0	0,056	0	0,056	0,056	0	0	1	0	0	-56	0	-18,66	0	0	67,14
S_4	0	0	0,011	0	0,011	0,011	0	0	0	1	0	-11	0	-3,66	0	0	13,54
S_5	0	0	0,011	0	0,011	0,011	0	0	0	0	1	-11	0	-3,66	0	0	13,54
x_1	0	1	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	440
S_7	0	0	0,006	0	0	0	0	0	0	0	0	0	1	0	0	0	1
x_3	0	0	0	1	0	0	0	0	0	0	0	0	0	333,33	0	0	146,66
S_9	0	0	0	0	0,003	0	0	0	0	0	0	0	0	0	1	0	0,44
S_{10}	0	0	0	0	0	0,008	0	0	0	0	0	0	0	0	0	1	1,3

Table 8. Simplex Table Iteration 3

VB	Z	x_1	x_2	x_3	x_4	x_5	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	NK
Z	1	0	-4.000	0	0	-3.700	0	0	0	0	0	4.200.000	0	1.383.333,33	1.383.333,33	0	3.065.278
S_1	0	0	0,084	0	0	0,084	1	0	0	0	0	-84	0	-27,99	27,99	0	88,4
S_2	0	0	0,084	0	0	0,084	0	1	0	0	0	-84	0	-27,99	27,99	0	88,4
S_3	0	0	0,056	0	0	0,056	0	0	1	0	0	-56	0	-18,66	-18,66	0	58,93
S_4	0	0	0,011	0	0	0,011	0	0	0	1	0	-11	0	-3,66	-3,66	0	11,93
S_5	0	0	0,011	0	0	0,011	0	0	0	0	1	-11	0	-3,66	-3,66	0	11,93
x_1	0	1	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	440
S_7	0	0	0,006	0	0	0	0	0	0	0	0	0	1	0	0	0	1
x_3	0	0	0	1	0	0	0	0	0	0	0	0	0	333,33	0	0	146,66
x_4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	333,33	0	146,66
S_{10}	0	0	0	0	0	0,008	0	0	0	0	0	0	0	0	0	1	1,3

Table 9. Simplex Table Iteration 4

VB	Z	x_1	x_2	x_3	x_4	x_5	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	NK
Z	1	0	0	0	0	-3.700	0	0	0	0	0	4.200.000	666.666,7	1.383.333,33	1.383.333,33	0	3.731.918
S_1	0	0	0	0	0	0,084	1	0	0	0	0	-84	-13,99	-27,99	-27,99	0	74,4
S_2	0	0	0	0	0	0,084	0	1	0	0	0	-84	-13,99	-27,99	-27,99	0	74,4
S_3	0	0	0	0	0	0,056	0	0	1	0	0	-56	-9,33	-18,66	-18,66	0	49,59
S_4	0	0	0	0	0	0,011	0	0	0	1	0	-11	-1,83	-3,66	-3,66	0	10,1
S_5	0	0	0	0	0	0,011	0	0	0	0	1	-11	-1,83	-3,66	-3,66	0	10,1
x_1	0	1	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	440
x_2	0	0	1	0	0	0	0	0	0	0	0	0	166,66	0	0	0	166,66
x_3	0	0	0	1	0	0	0	0	0	0	0	0	0	333,33	0	0	146,66
x_4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	333,33	0	146,66
S_{10}	0	0	0	0	0	0,008	0	0	0	0	0	0	0	0	0	1	1,3

Table 10. Simplex Table Iteration 5

VB	Z	x_1	x_2	x_3	x_4	x_5	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	NK
Z	1	0	0	0	0	0	0	0	0	0	0	4.200.000	666.666,7	1.383.333,33	1.383.333,33	462.500	4.333.168
S_1	0	0	0	0	0	0	1	0	0	0	0	-84	-13,99	-27,99	-27,99	-10,5	60,75
S_2	0	0	0	0	0	0	0	1	0	0	0	-84	-13,99	-27,99	-27,99	-10,5	60,75
S_3	0	0	0	0	0	0	0	0	1	0	0	-56	-9,33	-18,66	-18,66	-7	40,49
S_4	0	0	0	0	0	0	0	0	0	1	0	-11	-1,83	-3,66	-3,66	-1,375	8,31
S_5	0	0	0	0	0	0	0	0	0	0	1	-11	-1,83	-3,66	-3,66	-1,375	8,31
x_1	0	1	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	440
x_2	0	0	1	0	0	0	0	0	0	0	0	0	166,66	0	0	0	166,66
x_3	0	0	0	1	0	0	0	0	0	0	0	0	0	333,33	0	0	146,66
x_4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	333,33	0	146,66
x_5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	125	162,5

The values obtained for each decision variable are as follows:

$$x_1 = 440$$

$$x_2 = 166,66$$

$$x_3 = 146,66$$

$$x_4 = 146,66$$

$$x_5 = 162,5$$

3.3 Solution Using the Branch and Bound Method

Iteration 1

Upper bound = Rp. 4.333.250, where x_1 = 440, x_2 = 166,66, x_3 = 146,66, x_4 = 146,66, and x_5 = 162,5.

Lower bound = Rp. 4.323.200, where x_1 = 440, x_2 = 166, x_3 = 146, x_4 = 146, and x_5 = 162.

1. Sub Problem 1

   Maximize : Equation 1

   Constraint : Equation 2

   $x_2 \geq 167$

2. Sub Problem 2

   Maximize : Equation 1

   Constraint : Equation 2

   $x_2 \leq 166$

By using the simplex method, the solution for each sub problem is:

Solution to sub problem 1 : There is no feasible solution

Solution to sub problem 2 : x_1 = 440, x_2 = 166, x_3 = 146,66, x_4 = 146,66, x_5 = 162,5 and Z = 4.330.583.

Iteration 2

Upper bound = Rp. 4.330.583, where x_1 = 440, x_2 = 166, x_3 = 146,66, x_4 = 146,66, and x_5 = 162,5

Lower bound = Rp. 4.323.200, where x_1 = 440, x_2 = 166, x_3 = 146, x_4 = 146, and x_5 = 162

1. Sub Problem 3

   Maximize : Equation 1

   Constraint : Equation 2

   $x_2 \geq 167$

   $x_5 \geq 163$

2. Sub Problem 4

   Maximize : Equation 1

   Constraint : Equation 2

   $x_2 \leq 166$

   $x_5 \leq 162$

By using the simplex method, the solution for each sub problem is:

Solution to sub problem 3 : There is no feasible solution

Solution to sub problem 4 : x_1 = 440, x_2 = 166, x_3 = 146,66, x_4 = 146,66, x_5 = 162 and Z = 4,328,733

Iteration 3

Upper bound = Rp. 4.328.733, with $x_1 = 440$, $x_2 = 166$, $x_3 = 146,66$, $x_4 = 146,66$, $x_5 = 162$ Lower bound = Rp. 4.323.200, where $x_1 = 440$, $x_2 = 166$, $x_3 = 146$, $x_4 = 146$, and $x_5 = 162$

1. Sub Problem 5

   Maximize : Equation 1

   Constraint : Equation 2

   $x_2 \geq 167$

   $x_5 \geq 163$

   $x_3 \geq 147$

2. Sub Problem 6

   Maximize : Equation 1

   Constraint : Equation 2

   $x_2 \leq 166$

   $x_5 \leq 162$

   $x_3 \leq 146$

By using the simplex method, the solution for each sub problem is:

Solution to sub problem 5 : There is no feasible solution

Solution to sub problem 6 : $x_1 = 440$, $x2 = 166$, $x_3 = 146$, $x_4 = 146,66$, $x_5 = 162$ and Z = 4.325.967.

Iteration 4

Upper bound = Rp. 4.325.967, where $x_1 = 440$, $x_2 = 166$, $x_3 = 146$, $x_4 = 146.66$, and $x_5 = 162$

Lower bound = Rp. 4.323.200, where $x_1 = 440$, $x_2 = 166$, $x_3 = 146$, $x_4 = 146$, and $x_5 = 162$

1. Sub Problem 7

   Maximize : Equation 1

   Constraint : Equation 2

   $x_2 \geq 167$

   $x_5 \geq 163$

   $x_3 \geq 147$

   $x_4 \geq 147$

2. Sub Problem 8

   Maximize : Equation 1

   Constraint : Equation 2

   $x_2 \leq 166$

   $x_5 \leq 162$

   $x_3 \leq 146$

   $x_4 \leq 146$

By using the simplex method, the solution for each sub problem is:

Solution to sub problem 7 : There is no feasible solution

Solution of sub problem 8 : x_1 = 440, x_2 = 166, x_3 = 146, x_4 = 146, x_5 = 162 and Z = 4.323.200

The solution above can be described in a branching tree Method Branch and Bound which can be seen in Figure 1 as follows:

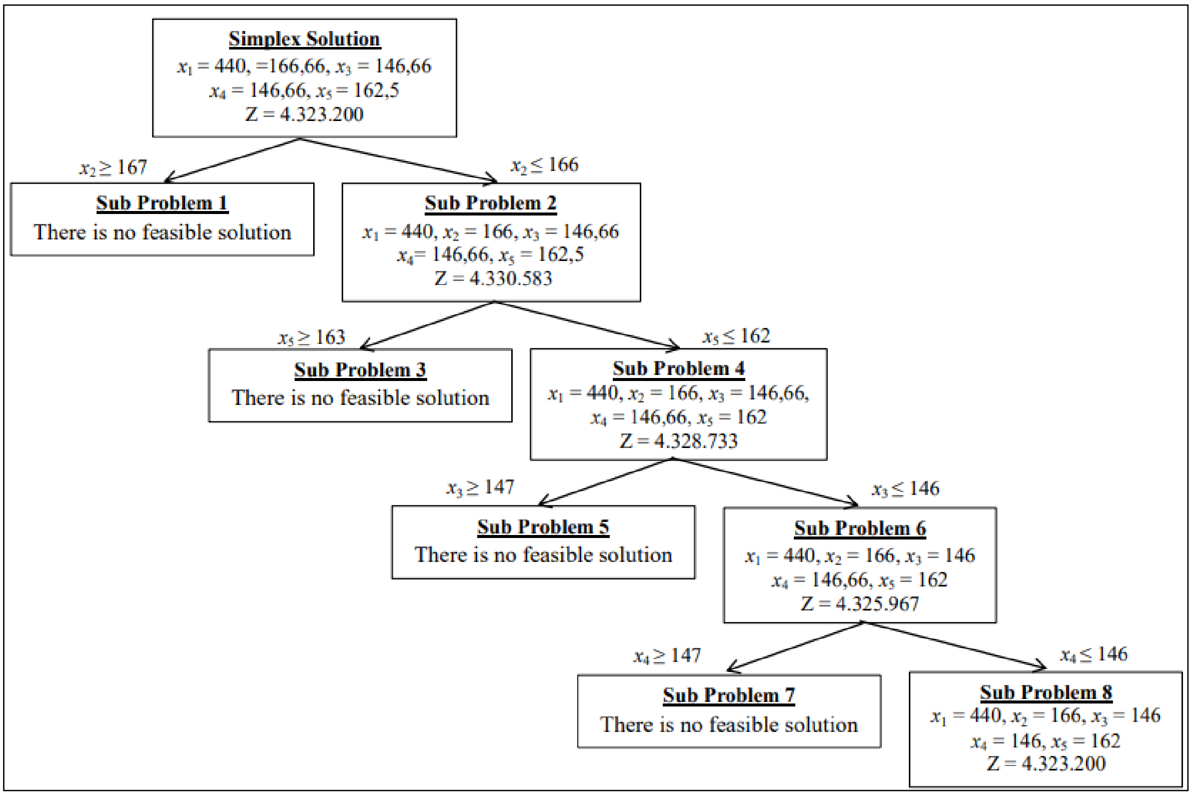

Figure 1. Branching Tree Branch and Bound Method

3.4 Profit Comparison

The comparison of the company's production profits with the calculation of profits using the Branch and Bound Method is as follows:

Table 11. Comparison of Company Profits and the Branch and Method Bound

No	Flavor	Company Production		Branch and Bound Method	
		Total Production (Box)	Profit (Rp)	Total Production (Box)	Profit (Rp)
1	Original	400	1.680.000	440	1.848.00
2	Coffee	160	640.000	166	664.000
3	Durian	130	539.500	146	605.900
4	Pandan	130	539.500	146	605.900
5	Chocolate	180	666.000	162	599.400
	Quantity	1.000	4.065.000	1.060	4.323.200

4. Conclusions

From the description and calculations, it can be concluded that:

1. From the calculations and analysis using the Branch and Bound Method, the optimal quantity of mung bean cake production is 1.060 boxes per day with 440 boxes of original flavored, 166 boxes of coffee flavored, 146 boxes of durian flavored, 146 boxes of pandan flavored and 162 boxes of Chocolate flavored with the maximum profit obtained is of Rp. 4.323.200.
2. Using the Branch and Bound Method, profits increased by 6,35% or Rp. 258.200 of the company's profit per day.

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