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The Diet Problem of Food Menu for Starbucks in Malaysia: Linear Programming Problem

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ABSTRACT

Nowadays, fast-food production is in high demand in the food industry. There are many fast-food restaurants in the world, such as Starbucks, McDonald's, Kentucky Fried Chicken (KFC) and others. People would spend their time and money at fast-food restaurants because of their quick serving, convenience, and good taste. Starbucks is also no exception because it has various baked goods and hot breakfast items as part of its cafe menu. This can lead to people overconsuming the food at fast-food restaurants every day. Consequently, they would get health problems such as obesity, heart attack, diabetes and others. In this paper, we determine the most suitable menu from Starbucks for a day to fulfil the daily intake of calories, carbohydrates, protein, and fats for men and women. We will use the linear programming model approach to get the optimal calories, carbohydrates, proteins and fats for men and women. We used the nutritional value chart data from Starbucks' menu, and this diet problem will be solved using an Excel solver. The results obtained fulfilled the required daily intake for men and women for calories, protein, carbohydrates, and fats from the Starbucks menu.

1. Introduction

A linear programming method is well known as one of the mathematical methods to solve optimization problems in real life. This method uses a series of equations as it satisfies all the variables and constraints applied. Linear programming uses graphs to interpret the optimal result in managerial decisions. If the conditions given are complex, the help of computation is needed as well. Research shows that the Excel solver tool gives more precise results than the graph method. This method helps many researchers with the various problem faced, and can saved more cost, with more output for their discoveries. One of the problems that can be solved by using Excel solver is the diet problem. The variables such as calories intake, carbohydrates, protein, and fats consumed is required to satisfy the nutrient requirement for a person for each day. By solving the diet problem, by using Excel solver, we can obtain the optimal solution, hence the person can get the best meal with

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sufficient requirements for daily nutrients. This is because the lack of nutrients or over nutrition can cause many illnesses Dai *et al.,* [8].

Stigler [9] is the one that proposed the diet problem can be solved by using the linear programming. After many decades, nowadays, diet problem can be solved more efficiently and faster by using the latest technology of computers. Besides that, Stigler [9] has opened many of researchers' eyes to find the minimum cost of animal feed problems and fertilizer blending Garille and Gass [10]. Nazmi and Faton found that linear programming method is one of the optimization models that widely used by the managerial decision [1]. The managers use the model to solve the problems based on the resources available for them in the best ways. By using the available resources to solve the problem, the optimal results can be achieved as to maximize the profit or to minimize the cost. Kunwar and Sapkota [2] also state that the linear programming model can be applied in some real-life applications. Linear programming is a branch of mathematics and statistics that researchers used to find out the solutions to the problems of optimization. It is applied to determine the optimal value in various real-life applications.

Linear programming model has been applied for the most problems. For examples, Amol and Sidharth used the linear integer programming for a human diet decision problem [3]. The variables in the problems are from the dietician in health care facility. The range of ages for people in this study are in between 40 to 45 years old. As the result, it gives the opportunity to the health care organization to apply the optimization techniques in problems related to the given resources allocation. It also could be a complimentary tool to economic evaluation models.

Linear programming model can be interpreted in graphical method or Excel built-in solver method. Ruslan and Mohamed show that linear programming model can be used to determine the minimal amount of vitamin A [4]. Balanced diet is needed as it is a requirement for the human in life. Vitamin A is the fat-soluble vitamin, and it is important to get the normal vision, the immune system, reproduction, and the functionality of the organs to work properly. They also state that both methods give the same results, but the Excel solver gives more precise value compared to graphical method because the value generated from it is in decimal values.

Corné *et al.,* [5] aims to find the suitable diets with low price and low climate impact yet fulfilling all nutritional requirements for every citizen. 206 consumed food products for 31 to 51 years old male dan female respectively is used as the objective function for the optimization model. As stated by Nazmi and Faton [1], Corné *et al.,* also agreed that linear programming model can be a promising tool for selecting the best option among the resource's allocation [5]. The study by Corné *et al.,* shows they can identify healthy and affordable diets with minimal environmental impacts on both societal and individual levels [5].

The study made by Jakia *et al.,* [6] determine on what do they need to consume in certain ages. A linear programming model is constructed based on the data given to define the various food types with their corresponding cost and nutrition elements that appropriate to the three distinct age groups. By utilizing these linear programming models, Jakia *et al.,* [6] can determine the cost used and amount of food types to be purchased which have been optimized based on the model and the data given.

Other than food diet and cost optimization, linear programing model also can be applied in other problems. For example, Maria *et al.,* [7] is interested in understanding how the cognitive process in a virtual classroom was. To solve this optimization problem, a linear programming model with three objective functions and 56 binary variables was used. The data is collected by using virtual reality tools and software to create variations of virtual classrooms for a sample of 112 students. It is optimally solved to obtain 13 efficient solutions to the multi-objective problem, allowing the decision maker to analyze all the information given [7]. Maria *et al.,* [7] founds that best cognitive processing performance can be achieved by using different classroom configuration. This shows that the linear programming model can be utilized and used to solve the real-life problems in various aspects such as in product consumerization, production, and minimization of task assessment.

Since mathematical modelling has been used widely in the world for solving real life problems, there are many methods in solving the mathematical modelling. The research done by Mohd Saifizi Saidon *et al.,* [12,13] shows how to employ ARX (and ARMAX) models to create a dynamic model of a cooling system connected with TEC. In mathematical modelling, the finite element method is frequently used to approximate and resolve complicated physical phenomena by breaking them up into smaller, more manageable pieces. Researchers like Mohamad *et al.,* [14], Mohd *et al.,* [15], and Law Ruen *et al.,* [16] have employed this approach in various studies to examine a variety of issues, including structural analysis, fluid dynamics, heat transfer, and electromagnetic simulations. The Lagrange approach, on the other hand, is frequently used in mathematical modelling to optimize systems by posing and resolving restricted optimisation issues. This approach was used in two studies, one by Touaibi *et al.,* [17] to reduce the thermal energy consumption of an absorption cooling machine and the other by K. Gulnaz and Refail [18] to address the issue of aviation maintenance routing.

2. Methodology

An integer linear programming problem is used to optimize a problem with minimizing or maximizing objective function subject to the linear constraints. In this section, we proposed the model formulation of the daily diet problem for Starbucks' food sets menu in Malaysia for women and men.

3. Model Formulation

The integer linear programming includes the objective function, a set of constraints, a set of decision variables and the parameters. The objective function that minimizes or maximizes must be determine first to solve the integer linear programming while satisfy the set of the constraints of the model. In this paper, the objective function is to maximize the intake of calories for the given diet, while the minimum requirement of calories intake in a day for men and women is restricted. When the nutritional requirement by a person is satisfied, we determine the menu that will be chosen by solving the mathematical modelling. The formulation of the mathematical model of the diet problem of Starbucks' food sets menu in Malaysia is showed in this section. In Table 1, the notations used in the model are determined.

Table 1
The notations in the diet problem of Starbucks' sets menu in Malaysia

Notation	Explanation
x_i	Sets menu for food in Starbucks' Malaysia
c_i	Calories for the set x_i
p_i	Carbohydrates for the set menu x_i
q_i	Protein for the set menu x_i
r_i	Fats for the set menu x_i

The integer linear programming for the diet problem of Starbucks' food sets menu in Malaysia is shown as follows:

$$\text{Max } c_1x_1 + c_2x_2 + c_3x_3 + \cdots + c_{57}x_{57} \tag{1}$$

subject to

$$c_1x_1 + c_2x_2 + \cdots + c_{57}x_{57} \leq 2500\ /2200 \tag{2}$$

$$p_1x_1 + p_2x_2 + \cdots + p_{57}x_{57} \leq 375 \tag{3}$$

$$q_1x_1 + q_2x_2 + \cdots + q_{57}x_{57} \leq 63 \tag{4}$$

$$r_1x_1 + r_2x_2 + \cdots + r_{57}x_{57} \leq 80 \tag{5}$$

$$x_1,\ x_2, x_3, \dots, x_{57} \geq 0 \tag{6}$$

The objective function, Eq. (1), aims to get the maximum calories intake that can be consumed by a person. Eq. (2) restricts the calorie intake by a person for man which is 2500 kcal and woman is 2200 kcal. Eq. (3) restricts the carbohydrates need to be consumed by a person at most 375 grams. Eq. (4) guarantees that the protein taken by a person is at most as 63 grams. Eq. (5) makes sure that the fats intake by a person is 80 grams. Eq. (6) is to make sure that variables obtained is an integer number. Table 2 shows the nutrients for each Starbucks' food sets menu in Malaysia [11].

Table 2
The nutrients for each Starbucks' food set menu in Malaysia, x_i

Menu	Calories (kcal)	Carbohydrate (g)	Protein (g)	Fats (g)
x1	383.9	69.10	7.0	8.8
x2	399.0	55.00	37.0	16.8
x3	583.8	57.90	6.3	36.4
x4	465.0	57.90	5.5	23.5
x5	249.9	25.70	5.1	14.0
x6	352.0	40.60	6.1	18.3
x7	235.5	18.30	5.2	15.8
x8	612.5	56.50	12.3	37.5
x9	523.1	35.20	30.5	28.9
x10	329.6	35.80	7.0	17.5
x11	345.5	40.20	7.7	17.1
x12	291.9	30.80	10.3	14.2
x13	300.0	24.70	11.2	17.4
x14	289.7	29.70	6.9	15.8
x15	335.5	27.00	13.5	19.3
x16	302.6	37.20	8.1	13.5
x17	588.0	81.60	46.2	8.4
x18	474.5	62.40	18.3	16.8
x19	214.2	20.30	17.6	7.0
x20	489.6	47.80	19.9	24.3

Menu	Calories (kcal)	Carbohydrate (g)	Protein (g)	Fats (g)
x21	160.0	4.00	12.4	10.5
x22	378.1	32.30	19.2	19.2
x23	412.5	47.30	17.3	17.1
x24	444.7	18.40	11.8	35.9
x25	441.0	38.40	13.4	26.0
x26	291.6	34.80	9.9	12.4
x27	403.7	39.60	22.5	17.2
x28	214.2	29.70	11.4	5.5
x29	344.4	41.30	16.9	12.3
x30	364.8	70.30	12.5	3.8
x31	518.7	47.90	46.0	16.0
x32	514.0	63.40	27.8	16.6
x33	311.7	51.40	16.5	4.5
x34	518.7	54.30	11.4	28.5
x35	414.2	49.20	24.5	13.3
x36	506.0	60.20	18.8	21.0
x37	244.0	27.90	12.2	15.4
x38	354.0	26.80	24.6	21.7
x39	253.0	19.50	16.4	16.7
x40	82.0	11.40	3.2	8.9
x41	81.0	12.10	2.8	8.7
x42	81.0	10.80	3.5	4.1
x43	359.1	35.40	4.5	22.2
x44	477.4	54.56	5.4	26.4
x45	223.3	7.00	9.5	17.5
x46	304.3	25.50	5.8	19.8
x47	445.0	30.20	7.1	32.9
x48	468.0	35.30	4.4	34.3
x49	524.0	44.20	7.0	35.5
x50	455.0	61.70	7.2	20.0
x51	532.0	36.30	8.5	39.2
x52	512.0	44.50	8.1	33.5
x53	388.0	35.40	5.7	24.8
x54	438.1	34.90	8.3	29.3
x55	433.8	33.80	7.2	30.0
x56	346.5	39.60	2.8	19.6
x57	334.1	42.50	3.9	16.5

Table 3 shows the recommended daily nutrients for a diet of 2500 Kcal per day for men and 2200 Kcal per day for women from the Recommended Nutrient Intakes for Malaysia (2017).

Table 3
Recommended daily values of carbohydrates, protein, and fats

Number of nutrients	Nutrients	Recommended for	Quantity of calories	
			2500 Kcal	2200 Kcal
1.	Carbohydrates	Less than	375	375
2.	Protein	Less than	63	63
3.	Fats	Less than	80	80

Based on Table 3, the quantity of calories is divided into two parts. The first one is 2500 Kcal, which is for men. In contrast, the second one is 2200 Kcal for women. The mathematical model for this diet problem is determined as an integer linear programming. The maximum food uptake which satisfies the daily requirements for Starbucks' food set menu for a day is the objective function as follows:

$$\begin{aligned} f(x_1, \dots, x_{57}) = {} & 383x_1 + 399x_2 + 583.8x_3 + 465x_4 + 249x_5 + 352x_6 + 235.5x_7 + 612.5x_8 \\ & + 523.1x_9 + 329.6x_{10} + 345.5x_{11} + 291.9x_{12} + 300x_{13} + 289.7x_{14} + 335.5x_{15} \\ & + 302.6x_{16} + 588x_{17} + 474.5x_{18} + 214.2x_{19} + 489.6x_{20} + 160x_{21} + 378.1x_{22} \\ & + 412.5x_{23} + 444.7x_{24} + 441x_{25} + 291.6x_{26} + 403.2x_{27} + 214.2x_{28} + 344.4x_{29} \\ & + 364.8x_{30} + 518.7x_{31} + 514x_{32} + 311.7x_{33} + 518.7x_{34} + 414.2x_{35} + 506x_{36} \\ & + 244x_{37} + 354x_{38} + 253x_{39} + 82x_{40} + 81x_{41} + 81x_{42} + 359.1x_{43} + 477.4x_{44} \\ & + 223.3x_{45} + 304.3x_{46} + 445x_{47} + 468x_{48} + 524x_{49} + 455x_{50} + 532x_{51} \\ & + 512x_{52} + 388x_{53} + 438x_{54} + 433.8x_{55} + 346.5x_{56} + 334.1x_{57}. \end{aligned}$$

For this diet problem, there are several constraints that need to be satisfied, which are:

Calories (Kcal):
$383x_1 + 399x_2 + 583.8x_3 + 465x_4 + 249x_5 + 352x_6 + 235.5x_7 + 612.5x_8 + 523.1x_9 + 329.6x_{10} + 345.5x_{11} + 291.9x_{12} + 300x_{13} + 289.7x_{14} + 335.5x_{15} + 302.6x_{16} + 588x_{17} + 474.5x_{18} + 214.2x_{19} + 489.6x_{20} + 160x_{21} + 378.1x_{22} + 412.5x_{23} + 444.7x_{24} + 441x_{25} + 291.6x_{26} + 403.2x_{27} + 214.2x_{28} + 344.4x_{29} + 364.8x_{30} + 518.7x_{31} + 514x_{32} + 311.7x_{33} + 518.7x_{34} + 414.2x_{35} + 506x_{36} + 244x_{37} + 354x_{38} + 253x_{39} + 82x_{40} + 81x_{41} + 81x_{42} + 359.1x_{43} + 477.4x_{44} + 223.3x_{45} + 304.3x_{46} + 445x_{47} + 468x_{48} + 524x_{49} + 455x_{50} + 532x_{51} + 512x_{52} + 388x_{53} + 438x_{54} + 433.8x_{55} + 346.5x_{56} + 334.1x_{57} \leq 2500/2200.$

Carbohydrates (g):
$69.1x_1 + 55x_2 + 57.9x_3 + 57.9x_4 + 25.7x_5 + 406.x_6 + 18.3x_7 + 56.5x_8 + 35.2x_9 + 35.8x_{10} + 40.2x_{11} + 30.8x_{12} + 24.7x_{13} + 29.7x_{14} + 27x_{15} + 37.2x_{16} + 81.6x_{17} + 62.4x_{18} + 20.3x_{19} + 47.8x_{20} + 4.0x_{21} + 32.3x_{22} + 47.3x_{23} + 18.4x_{24} + 38.4x_{25} + 34.8x_{26} + 39.6x_{27} + 2.97x_{28} + 41.3x_{29} + 70.3x_{30} + 47.9x_{31} + 63.4x_{32} + 51.4x_{33} + 54.3x_{34} + 49.2x_{35} + 60.2x_{36} + 27.9x_{37} + 26.8x_{38} + 19.5x_{39} + 11.4x_{40} + 12.1x_{41} + 10.8x_{42} + 35.4x_{43} + 54.56x_{44} + 7x_{45} + 25.5x_{46} + 30.2x_{47} + 35.3x_{48} + 44.2x_{49} + 61.7x_{50} + 36.3x_{51} + 44.5x_{52} + 35.4x_{53} + 34.9x_{54} + 33.8x_{55} + 39.6x_{56} + 42.5x_{57} \leq 375.$

Protein (g) :
$7x_1 + 37x_2 + 6.3x_3 + 5.5x_4 + 5.1x_5 + 6.1x_6 + 5.2x_7 + 12.3x_8 + 30.5x_9 + 7.0x_{10} + 7.7x_{11} + 10.3x_{12} + 11.2x_{13} + 6.9x_{14} + 14.5x_{15} + 8.1x_{16} + 46.2x_{17} + 18.3x_{18} + 17.6x_{19} + 19.9x_{20} + 12.4x_{21} + 19.2x_{22} + 17.3x_{23} + 11.8x_{24} + 13.4x_{25} + 9.9x_{26} + 22.5x_{27} + 11.4x_{28} + 16.9x_{29} + 12.5x_{30} + 46x_{31} + 27.8x_{32} + 16.5x_{33} + 11.4x_{34} + 24.5x_{35} + 18.8x_{36} + 12.2x_{37} + 24.6x_{38} + 16.4x_{39} + 3.2x_{40} + 2.8x_{41} + 3.5x_{42} + 4.47x_{43} + 5.39x_{44} + 9.5x_{45} + 5.78x_{46} + 7.1x_{47} +$

$4.4x_{48} + 7.0x_{49} + 7.2x_{50} + 8.5x_{51} + 8.1x_{52} + 5.7x_{53} + 8.3x_{54} + 7.2x_{55} + 2.79x_{56} + 3.9x_{57} \leq 63.$

Fats (g):
$8.8x_1 + 16.8x_2 + 36.4x_3 + 23.5x_4 + 14.0x_5 + 18.3x_6 + 15.8x_7 + 37.5x_8 + 28.9x_9 + 17.5x_{10} + 17.1x_{11} + 14.2x_{12} + 17.4x_{13} + 15.8x_{14} + 19.3x_{15} + 13.5x_{16} + 8.4x_{17} + 16.8x_{18} + 7.0x_{19} + 24.3x_{20} + 10.5x_{21} + 19.2x_{22} + 17.1x_{23} + 35.9x_{24} + 26.0x_{25} + 12.4x_{26} + 17.2x_{27} + 5.5x_{28} + 12.3x_{29} + 3.8x_{30} + 16x_{31} + 16.6x_{32} + 4.5x_{33} + 28.5x_{34} + 13.3x_{35} + 21x_{36} + 15.4x_{37} + 21.7x_{38} + 16.7x_{39} + 8.9x_{40} + 8.7x_{41} + 4.1x_{42} + 22.2x_{43} + 26.4x_{44} + 17.5x_{45} + 19.8x_{46} + 32.9x_{47} + 34.3x_{48} + 35.65x_{49} + 20.0x_{50} + 39.2x_{51} + 33.5x_{52} + 24.8x_{53} + 29.3x_{54} + 30x_{55} + 19.6x_{56} + 16.5x_{57} \leq 80.$

4. Result and Discussion

A mathematical model for the diet problem of Starbucks' food sets menu in Malaysia is formulated in this research. The objective function of the model is to reach the maximum calories from the food menu sets of Starbucks consumed by a person per day while satisfying all the nutrient requirements needed. By solving this mathematical model, all daily food sets menus fulfilled the requirements needed by a person, which are the total amounts of calories, carbohydrates, protein, and fats. Furthermore, an integer linear based on this diet problem was built in an Excel workbook using the Excel Solver method and is being solved.

By using the Solver tool in Microsoft Excel, the number of calories obtained is maximal while satisfying all the nutrients requirement, which means that the solution obtained is optimal.

4.1 Suggested Menu for Men

The solution obtained for the type of diet for men (2500 Kcal) is 2456.4 Kcal. This means that men consumed the maximum number of calories which is 2456.4 Kcal, while satisfying all the required nutrients with the suggested menu:

i. three sets of Cranberry Scones,
ii. a set of Thai Basil Chicken Danish,
iii. a piece of Cranberry Chicken Sandwich,
iv. a piece of Baked Ciabatta Mushroom Melt, and
v. a stick of Stick Walnut Bar.

4.2 Suggested Menu for Women

The solution obtained for the type of diet for women (2200 Kcal) is 2193.4 Kcal. This means that women consumed the maximum number of calories which is 2193.4 Kcal, while satisfying all the required nutrients with the suggested menu:

i. two sets of Cranberry Scones,
ii. a bowl of Baked Mac & Cheese,
iii. two pieces of Macaron strawberry flavoured,
iv. a slice of Choco-Choco Brownie, an
v. a slice of Lemon Slice.

5. Conclusions

A linear programming model helps to find the optimal solution for many problems. It also could be considered a helpful tool to support decision-making processes in various situations. In this situation, consumers can make wiser choices while selecting menus in restaurants. They can also get a sufficient number of calories and nutrients for their body. Consequently, it helps them to keep their health in good condition. For future research, the proposed mathematical model in this research can be solved by using the heuristic approach and then we can compare the results from both methods.

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