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Applications of Linear Programming for Profit Maximization in Food Industry

Nurul Syafika Abdul Rizal[1], Siti Noor Asyikin Mohd Razali[2*]

[1] Tiong Nam Logistics Solution Kulim,
Lot 3176, Jalan Perusahaan, Bandar Kulim,
09000 Kulim, Kedah, MALAYSIA

[2] Department of Mathematics and Statistics,
Faculty of Applied Sciences and Technology,
Universiti Tun Hussein Onn Malaysia (Pagoh Campus),
84600 Pagoh, Muar, Johor, MALAYSIA.

*Corresponding Author Designation

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Abstract: Food has become a pivotal part of our daily lives. The linear programming method is commonly used in the food industry, such as developing linear programming model for food products. The purpose of this study is to create a mathematical linear programming model for two datasets of food types. Second objective is to determine the optimal profit for each food type in order to maximize profit for the food industry. Last objective is to analyse the flexibility of the linear programming model using sensitivity analysis and visualize the result using descriptive analysis. Two data sets involve are ABC Fruit Stall located at Sungai Kob (case study 1) and the Bakery Shop at Kulim (case study 2). The result of Linear Programming model shows that the ABC company (case study 1) will gain profit RM 276.77 per day. While, for the Bakery Shop (case study 2), the result shows that the optimal profit is RM 370.50 per week. For sensitivity analysis, case study 1 shows that if the quantity supply of wafers and flavour is increased, it will contribute increment profit of about 14.68% and 10.00% respectively to the ABC Stall. While the sensitivity analysis for case study 2 shows that increasing supply of sugar contributes approximately 14.78% increase in profit to the bakery shop. For future study, it is recommended to obtain large datasets from related authorities and others food industries.

Keywords: Linear Programming, Profit Maximization, Food Industry

1.0 Introduction

Food has become a pivotal part in our daily life. All living things in world need food to stay alive and healthy. Food industry is the basic and play a vital role to every nation [1]. International trade includes both export and import activities where country have foreign export goods and services

**Corresponding author: asyikinr@uthm.edu.my*

conclude that food industry is one of industry that helps in economic growth [2]. Food product categorization is a system for classifying different food names into groups based on their commonalities or similarities [3].

In food industry, it divided food types in five food groups which are cereals and grains, fruits, vegetables, poultry products and dairy products. In addition, food industry is an important aspect in satisfying consumer's requirements through raw and processed supply [4]. It is because customers prefer high-quality products. [5]. The contribution of this research is application on new dataset for Malaysian case study of food industry which are ABC Fruit Shop and Bakery Shop. ABC desert product dataset is consisting of 3 types of ABC which are ABC Chocolate Strawberry, ABC Strawberry and ABC Milo. Bread product dataset is consisting of 5 types of bread which are chicken floss, spicy floss, sausage bun, curry chicken bun and donut.

The problem statement in this study for grains and sweets industry is struggled to determine the amount of raw materials it should supply and the number of production units each product should produce. Secondly, both of food industries only have little knowledge on statistics and prediction further. Finally, most sweet industries rely on trial and error to maximize profit that will leads to inaccurate results and affected financial company.

Operational research techniques are mathematics tools that useful in a wide range of industries [6]. Paint manufacturing company located at Nigeria determine an ideal product combination for five items and optimum profit using OR technique [7]. Human resources have also been used in operational research to determine management decision such as creating nursing schedule and determining the optimal number of staff departments to minimize cost, along with optimal recruitment of staff and training [8].

In operation research, there are four optimization techniques which are Linear Programming (LP), Integer Programming (IP), Mixed Integer Programming (MIP) and Goal Programming (GP) which commonly used to find optimal solution [9]. (LP) was applied for the determining the most efficient use of a company's limited resources to achieve a specific goal [10]. LP is also being used by a huge number of businesses to tackle a variety of real challenges [11]. To solve linear programming problem, we can use graphical method and simplex method [12]. One of research study that using linear programming technique to find the best production procedure is Coca Cola. The result showed that they need to make 462,547 and 415,593 bottles of Fanta and Coke, respectively, in order to make a profit of $263,497283 [13].

Integer Programming technique is frequently used in engineering technology, corporate management, and a variety of other fields to describe choice issues using effective resources [14]. In many operations research applications such as scheduling, task assignment and transportation problem can be model as integer problem [15]. In university departments, the scheduling problem typically arises when assigning students to course subjects and their choice of section course. In university departments, the scheduling problem typically arises when assigning students to course subjects and their choice of section course. To solve this problem, the department used integer programming. For example, a list of courses, course sections and number of instructors as constraints [16]. The implementation of a Truck Appointment System is one of the transportation problems to arrange the disorderly arrival of trucks (TAS). In order to reduce the turnaround time represented by the entire delay of the vehicle arriving at the terminal to pick up delivery products, an integer programming model is developed [17].

Mixed Integer Programming technique is presented to solve any problems in term of scheduling such as flexible job shop scheduling problem [18]. The mixed integer programming technique is presented to solve any problems in terms of scheduling, such as the flexible job shop scheduling problem [18]. Scheduling problems focus on timing several activities, one of which is task [19]. For example, it is used to determine the weights for total delay time and total completion time specified in

manufacturing company [20]. To sum up, it can also minimize the total processing cost by determine optimal job to machine assignments [21].

Meanwhile, Goal Programming usually used to build an optimal solution, mainly in multi criteria and linear problem [22]. In health-care organization, goal programming helps with planning and allocation of scarce human resources. The case's purpose was to assign a cost while keeping the patient happy. Hospital bed allocation model often applied goal programming approach [23]. Besides that, Goal programming techniques were used in the frozen food industry to maximize profit, minimise overtime and staff, and maximise machine utility [24]. Simultaneously, Goal programming make an improvement in the model and analysis of a real-life situation [25].

The objectives in this research study are to create a mathematical linear programming model for two datasets of food types. Second objectives are to determine the optimal profit for each food type in order to maximize profit for the food industry. Last objectives is to analyse the flexibility of the linear programming model using sensitivity analysis and visualize the result using descriptive analysis.

2.0 Materials and Methods

In this study, there are two types of food categories data that which are ABC desert product and bread product. There are three decision variables for ABC production which are $\boldsymbol{x_1}$ (ABC Chocolate Strawberry), $\boldsymbol{x_2}$ (ABC Strawberry) and $\boldsymbol{x_3}$ (ABC Milo).

The objective function for ABC dessert production is shown in equation 1.

Maximize profit, Z= $3.27x_1 + 2.37\ x_2 + 3.25\ x_3$ *Eq.1*

There are 9 constraints consist of ice shave, strawberry, ice cream, wafer, chocolate syrup and flavour which are assigned as raw materials in producing ABC and minimum production of ABC Chocolate Strawberry, ABC Strawberry and ABC Milo. The total available for all constraints is shown in equation 2 until 10.

$200x_1 + 200x_2 + 200x_3$	(Gram)	≤ 20000	(Ice Shave)	*Eq.2*
$4x_1 + 6x_2 + 0x_3$	(Pieces)	≤ 200	(Strawberry)	*Eq.3*
$1x_1 + 1x_2 + 1x_3$	(Scoops)	≤ 100	(Ice Cream)	*Eq.4*
$2x_1 + 1x_2 + 1x_3$	(Pieces)	≤ 100	(Wafer)	*Eq.5*
$50x_1 + 50x_2 + 50x_3$	(Ml)	≤ 5000	(Chocolate Syrup)	*Eq.6*
$10x_1 + 10x_2 + 10x_3$	(Ml)	≤ 1500	(Flavour)	*Eq.7*
x_1	(Units)	≥ 5	(ABC Chocolate Strawberry)	*Eq.8*
x_2	(Units)	≥ 5	(ABC Strawberry)	*Eq.9*
x_3	(Units)	≥ 5	(ABC Milo)	*Eq.10*

For case study 2, there are five of decision variables for bread production which are x_1 (Chicken Floss), x_2 (Spicy Floss), x_3 (Sausage Floss), x_4 (Curry Chicken Bun) and x_5 (Donut)

The objective function is shown in equation 11.

Maximize profit, Z = $0.80x_1 + 0.80x_2 + 0.50x_3 + 0.60x_4 + 0.40x_5$ *Eq.11*

For grain food type, 12 constraints involved which are flour, yeast, water, egg, milk, butter and sugar assigned as raw materials in producing breads and minimum production of chicken floss, spicy floss, sausage bun, curry chicken bun and donut.

$300x_1 + 300x_2 + 270x_3 + 380x_4 + 320x_5$	(Gram)	≤ 188500	(Flour)	(*Eq.12*)
$10x_1 + 10x_2 + 9 + 15x_4 + 9x_5$	(Gram)	≤ 6500	(Yeast)	(*Eq.13*)
$15x_1 + 15x_2 + 45x_3 + 25x_4 + 15x_5$	(Ml)	≤ 14000	(Water)	(*Eq.14*)
$50x_1 + 50x_2 + 100x_3 + 50x_4 + 54x_5$	(Gram)	≤ 36500	(Egg)	(*Eq.15*)
$200x_1 + 200x_2 + 120x_3 + 200x_4 + 240x_5$	(Gram)	≤ 115500	(Milk)	(*Eq.16*)
$30x_1 + 30x_2 + 28x_3 + 40x_4 + 56x_5$	(Gram)	≤ 22500	(Butter)	(*Eq.17*)
$60x_1 + 60x_2 + 38x_3 + 40x_4 + 30x_5$	(Gram)	≤ 27500	(Sugar)	(*Eq.18*)
x_1	(Units)	≥ 300	(Chicken Floss)	(*Eq.19*)
x_2	(Units)	≥ 60	(Spicy Floss)	(*Eq.20*)
x_3	(Units)	≥ 50	(Sausage Bun)	(*Eq.21*)
x_4	(Units)	≥ 55	(Curry Chicken Bun)	(*Eq.22*)
x_5	(Units)	≥ 50	(Donut)	(Eq.23)

3.0 Results and Discussion

Result and discussion divided into four section which are section 3.1 explained about optimal result in this case study 1 and section 3.2 explained about optimal result of case study 2. While, sensitivity analysis in case study 1 and case study 2 is divided in section 3.3 and 3.4 respectively.

3.1 Optimal Result for case study 1

The company provides three types of ABC which are ABC Chocolate Strawberry, ABC Strawberry and ABC Milo. The company is suggested to produce more production of ABC Milo as the profit of ABC Milo is high which is recommended by using linear programming technique. The company could obtain optimum profit of RM 276.77 per days as stated in Table 1.

Table 1: Optimal profit for case study 1

Types of ABC	ABC Chocolate Strawberry	ABC Strawberry	ABC Milo	Total
Optimal Production	7.14	28.57	57.14	**92.85**
Recommended Optimal Production (Integer)	7	28	57	**92**
The Optimum of Profit (RM)	23.35	67.71	185.71	**276.77**

The company is suggested to produce optimum production for each type of ABC are 7 units of ABC Chocolate indicates profit (RM 23.35), 28 units of ABC Strawberry indicates profit (RM 67.71) and 92 units of ABC Milo indicates profit (RM 185.71).

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
NUMBER TO MAKE ABC CHOC STRAWBERRY	7.142857143	0	3.27	0.59	1.148333333
NUMBER TO MAKE ABC STRAWBERRY	28.57142857	0	2.37	1.7225	0.196666667
NUMBER TO MAKE ABC MILO	57.14285714	0	3.25	0.59	1.9825

nts

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
Ice Shave USED	18571.42857	0	20000	1E+30	1428.571429
Strawberry USED	200	0.042142857	200	100	133.3333333
Ice cream USED	92.85714286	0	100	1E+30	7.142857143
Wafer USED	100	0.984285714	100	50	8.333333333
Chocolate Syrup USED	4642.857143	0	5000	1E+30	357.1428571
Flavour USED	1500	0.113285714	1500	166.6666667	1000

Figure 1: Analysis results for case study 1

Based on Figure 1 and Table 1, it concluded that the differences of 0.14 in number production ABC Chocolate Strawberry will not change any optimum profit because in the range of the allowable decrease and allowable increase. Therefore, differences of 0.57 in number production for ABC Strawberry will no affected on optimum profit because it is in the range of allowable decrease and allowable increase. The same situation for ABC Milo production where the difference value between the recommended for production and the linear programming model suggestion is acceptable as it is in that range of allowable limit. The company will obtain the same optimum profit which is RM 276.77 per days.

From the value of shadow price of ice shave, the company does not suggest to increase one gram of ice shaves as the company will not gain any profit. On the other hand, based on shadow price for Strawberry the company could get increment RM 0.04 of profit for each extra pieces of strawberry. The company does not recommend adding an extra scoop of ice cream because doing so would prevent it from making any increment of profit. Then, the company can gain about RM 0.98 of profit increment for one pieces of wafer. On other hand, the company did not recommend increasing one ml of chocolate syrup because it was not profitable.

Compared to how much ice shavings (1428.57 gram), ice cream (7.14 scoops), and chocolate syrup (357.14 ml) were utilized, the quantity of strawberry, wafer, and flavour had totally been consumed. According to the value indicated by the LP model, the corporation should only carry ice shavings (about 18571.43 gram), ice cream (about 93 scoops), and chocolate syrup (about 4642.856 ml).

3.2 Optimal Result for Case Study 2

The company provides five types of breads which are chicken floss, spicy floss, sausage bun, curry chicken bun and donut. The bakery should increase the production of chicken floss because of high profit. The recommended optimum profit suggested by linear programming model is RM 370.50 per week.

Table 2: Optimal profit for case study 2

Types of Bread	Chicken Floss	Spicy Floss	Sausage Bun	Curry Chicken Bun	Donut	Total
The Optimal Production	300	60	50	62.5	50	**522.50**
Recommended Optimal Production (Integer)	300	60	50	62	50	**522**
The Optimum Profit (RM)	240	48	25	37.50	20	**370.50**

The 300 units of Chicken Floss indicates profit (RM 240.00), 60 units of Spicy Floss indicates profit (RM 48.00), 50 units of Sausage Bun indicates profit (RM25.00), 62 units of Curry Chicken Bun indicates profit (RM 37.50), and 50 units of Donut indicate profit are the recommended maximum value of production for all types of bread (RM 20.00).

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
Number Should Produce Chicken Floss	300	-0.1	0.8	0.1	1E+30
Number Should Produce Spicy Floss	60	-0.1	0.8	0.1	1E+30
Number Should Produce Sausage Bun	50	-0.07	0.5	0.07	1E+30
Number Should Produce Curry Chicken Bun	62.5	0	0.6	1E+30	0.066666667
Number Should Produce Donut	50	-0.05	0.4	0.05	1E+30

ts

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
Flour Used	161250	0	188500	1E+30	27250
Yeast Used	5437.5	0	6500	1E+30	1062.5
Water Used	9962.5	0	14000	1E+30	4037.5
Egg Used	28825	0	36500	1E+30	7675
Milk Used	102500	0	115500	1E+30	13000
Butter Used	17500	0	22500	1E+30	5000
Sugar Used	27500	0.015	27500	2600	300

Figure 2: Analysis results for case study 2

Based on Figure 2, it shows that variations of 0.5 in curry chicken bun bread number production would not affect the optimum profit due to in the range of the allowable decrease and allowable increase in that range. The company will obtain the same optimum profit, which is RM 370.50 per weeks. Based on the value of the shadow price, it is not recommended for company to increase the quantity of flour, yeast, water, eggs, milk, and butter, as this would result in not gaining profit. On the other hand, the company can gain about RM 0.015 profit increment one gram of sugar. The following ingredients have been used completely which are flour (27250 grams), yeast (1062.5 grams), water (4037.5 grams), egg (7675 grams), milk (13000 grams), and butter (5000 grams). According to the model, the company should prepare enough quantity flour to 161250 grams, yeast to 5437.5 grams, water to 9962.5 grams, eggs to 28825 grams, milk to 102500 grams, and butter to 17500 grams.

3.3 Sensitivity Analysis for Case Study 1

In some situations, the optimum profit was affected by changing quantity of raw materials. There are six situations were used for sensitivity analysis of case study 1 (ABC Fruit Stall). These six situations involved six raw materials that been used in case study are ice shave, strawberry, ice cream, wafer, chocolate syrup and flavour.

Table 3: Six situations that will effect on optimum profit of case study 1

Situation	Detail of situation
Situation 1	The quantity of ice shave increases to 40000 gram
Situation 2	The quantity of strawberry increase to 400 pieces
Situation 3	The quantity of ice cream increase to 600 scoops
Situation 4	The quantity of wafer increases to 600 pieces
Situation 5	The quantity of chocolate syrup increases to 10000 ml
Situation 6	The quantity of flavour increases to 5000 ml

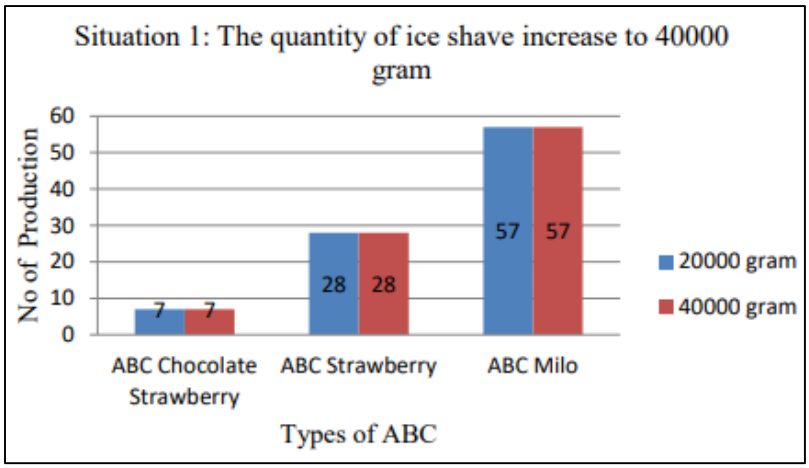

Figure 3: Situation 1

By using the linear programming method, changing the quantity of ice shave from 20,000 to 40,000 grams will not have any effect on maximising profit. It is because the optimum profit remains the same, which is RM 276.77 per day. The production value of the three types of ABC is still the same which are 7 units for ABC Chocolate Strawberry, 28 units for ABC Strawberry, and 57 units for ABC Milo. It is reasonable to conclude that the company do not suggest increase the quantity of ice shave because the company not gain extra profit. The same goes to situation 2, 3 and 5 also not contribute any profit when increased the quantity of raw materials.

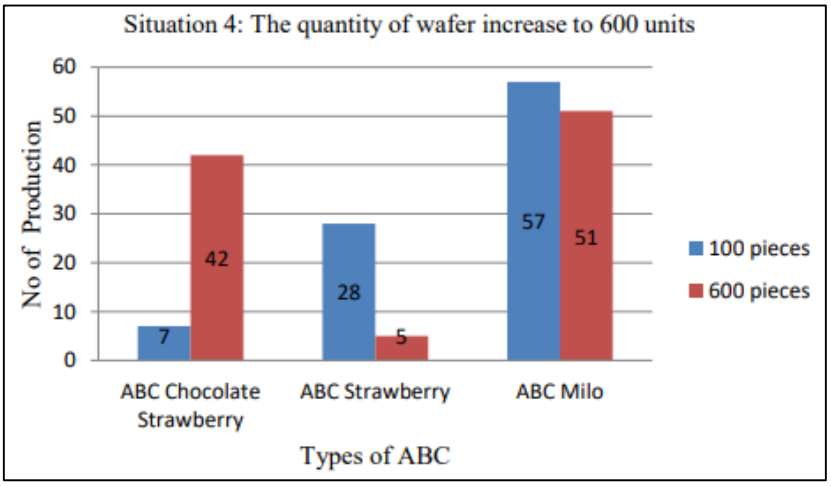

Figure 4: Situation 4

The change in quantity of wafers from 100 to 600 pieces will have an effect on optimum profit as it increases optimum profit to RM 317.39 per days. While, the production value of three types of ABC varieties changes: ABC Chocolate Strawberry (42 units), ABC Strawberry (5 units) and ABC Milo (51 units). It can be concluded that if the company increases number quantity of wafers, then the

company can gain extra profit about 14.68%. The same situation happened on situation 6, where if the increase quantity of raw material, the company could gain extra profit for about 10.00%.

3.4 Sensitivity Analysis for Case 2

Some situations when changing the quantity raw materials, it will give effect on optimum profit of model.

Table 4: Six situations that will effect on optimum profit of case study 2

Situation	Detail of Situation
Situation1	The quantity of flour increases to 377000 gram
Situation 2	The quantity of yeast increases to 13000 gram
Situation 3	The quantity of water increases to 28000 gram
Situation 4	The quantity of egg increase to 73000 gram
Situation 5	The quantity of milk increases to 231000 gram
Situation 6	The quantity of butter increases to 45000 gram
Situation 7	The quantity of sugar increase to 55000 gram

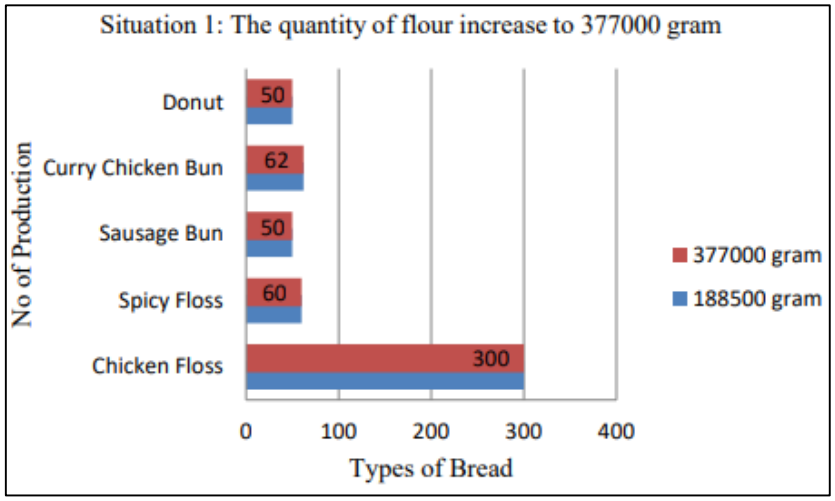

Figure 5: Situation 1

By using linear programming method, the changing of quantity of flour from 188500 to 377000 grams will not give any effect on optimum profit. It is because the optimum profit still remains the same which is RM 370.50 per weeks. The production value of five types of bread is still same which are chicken floss (300 units), spicy floss (60 unit), sausage bun (50 unit), curry chicken bun (62 units) and donut (50 unit). It can be concluded that the company should not increases the quantity of flour as the company will not gain any profit. This same goes to situations 2 to 6 also not contribute any profit when increased the quantity of raw materials.

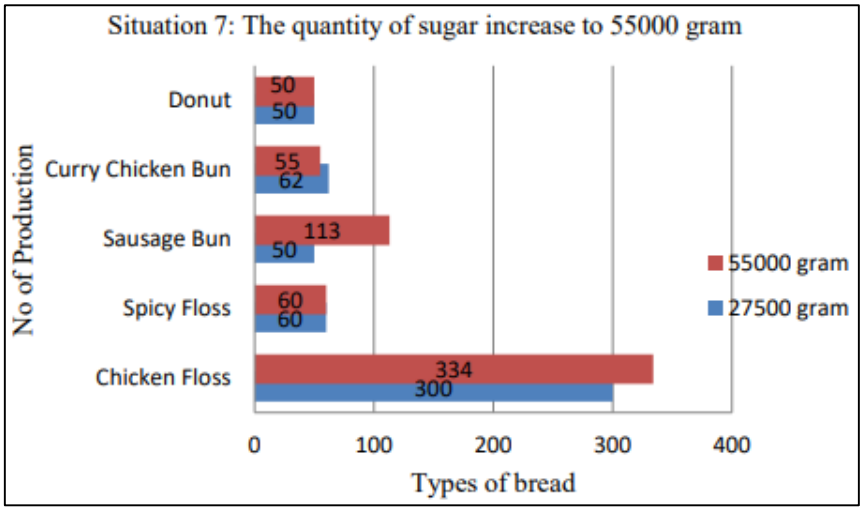

Figure 6: Situation 7

The change in quantity of sugar from 27500 to 55000 grams will have an effect on optimum profit as it increases optimum profit to RM 425.26 per weeks. The production value of five types of bread is chicken floss (334 units), spicy floss (60 unit), sausage bun (113 unit), curry chicken bun (55 units) and donut (50 unit). It can be concluded that if the company increases quantity of sugar, then the company can gain extra profit about 14.78%.

4.0 Conclusion

This study has successfully fulfilled all its objectives. First, to develop a linear programming mathematical model for two datasets of food types. From this, it is recommended that this company know the profit for each product and the amount of each raw material needed to produce a product. To develop a mathematical linear programming model for case study 1, there are three decision variables and six constraints. While in case study 2, there are five decision variables and seven constraints. Second, is to determine the optimum result for each food type to maximize the profit for the food industry. Mathematical programming techniques were used to generate the optimum profit result for each company. The linear programming model approach has developed a menu within the product and raw materials groups of constraints for each case. To obtain the optimal profit for each case, statistical software such as Microsoft Excel is used. From this, the optimum profit and optimum production value were obtained. Third, to analyse the flexibility of the linear programming model using sensitivity analysis and visualize the result using descriptive analysis. The company can use this analysis to determine the impact on optimal profit when the quantity of raw materials changes. Thus, it will help the company lead for decision-makers. In some cases, for example, increasing the quantity of raw materials will result in an increase in the optimal profit value, whereas maintaining it will not.

Throughout this study, there are some limitations and recommendations should be implemented for better research in future. To begin with, both of studies have small number of production lead to a small dataset. Therefore, it suggested for future study consider another company which have large dataset. Next, no information about customer demand was provided in this research study. Demand from customers should be considered in determining the production values that should be produced. The data collection about the demand for each product from customers should be done by survey. Based on this, it is possible to recommend which products should be produced. Last but not least, the price of foods in this study may be too low since food prices are increasing day by day. The price of food items should monitor as well in the future, although the price has already been approved by KPDNHEP.

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