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Application of the simplex method on profit maximization in Baker's Cottage

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ABSTRACT

Linear programming is an operational research technique widely used to identify and optimize management decision. Its application encourages businesses to increase their output. Instead, however, many organizations most commonly adopt the trial-and-error method. As such, companies find it challenging to distribute scarce resources in a manner that maximizes profit. This study focuses on implementing linear programming to optimize the profit of a manufacturing sector based on the optimized (best possible, efficient) use of raw materials. Our study uses the data gathered on five market bread types from Baker's Cottage reports, i.e., chicken floss, spicy floss, Frank Cheese, Mexico bun, and doughnut. This attribute has been recognized as a linear programming problem mathematically built that was solved using Excel software. The result showed that the Baker's Cottage unit had to produce 332 loaves of Chicken Floss and 196 loaves of Frank Cheese, as these products objectively contributed to the profit. In contrast, other types of bread did not have to be produced, as their value turned to zero to achieve the maximum monthly profit.

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1. INTRODUCTION

Each organization or corporation must make a profit to maintain its continued survival and competitiveness. The key branch of any economy is the food industry, which positions itself at the centre of the agricultural raw materials and food supply production process. The commercial bakery is a business found around the nation. It allows bread, desserts, pastries, cream rolls, and cookies. Every generation loves food. The dough is partly attributed to its high carbon content, which can lead to energy supply. Other nutrients such as protein and vitamins are also found in the bread. Small business owners with limited capital may find it as tough to compete with others to maintain their business. It is even more challenging for new business owners as they tend to use trial and error in managing their finances when it comes to purchasing products from suppliers. The main problem faced by the bakery entrepreneur is to determine the optimal amount to produce maximum profits. Therefore, in this study, an optimum combination is investigated in bread production to maximize profits for the bakery entrepreneur. While making every effort to maximize the efficiency of every production component, there will undoubtedly be obstacles, which will emerge, from the restricted capacity of production factors such as raw materials, equipment, and manpower [1].

The Baker's Cottage in Tampin, Negeri Sembilan, Malaysia, in the course of the bread-making process, encounters a number of difficulties in creating five different varieties of bread. Of course, there are many other kinds of materials required in the production of bread on a large scale. These substances have not been used to their full potential. When the supply of resources is not fully used, the earnings that may be gained are not at their maximum levels. This is due to the fact that the Baker's Cottage has not adopted linear programming and has a limited knowledge of mathematics in the manufacturing process that is being carried out at the time. Using an estimated technique of buying raw materials, Baker's Cottage plans its output in order to meet demand. This is one of the reasons why companies do not achieve maximum profitability, and it is for this reason that linear programming must be used in the manufacturing process in order to maximize the efficiency of raw materials in the bakery.

Linear programming is a mathematical model for determining the optimum combination of products to maximize benefits or minimize costs. Linear programming is often used for handling processes to choose the right option for many kinds of problems such as division of money, liability, and materials where linear programming works to select the best course of action from many alternatives [2]. Linear programming is a term that encloses mathematical techniques targeted at optimizing outcomes by combining resources. Linear programming models discuss the efficient usage of usable raw materials to manufacture various business goods [3]. It is necessitating to minimize production cost to increase sales in the process of transforming raw material into finished goods [1]. The problem is summarized as estimating the quantity of each raw material to minimize production costs and maximize profit. This process will help companies to improve their production according to suggestions from the results obtained from linear programming.

The use of a computer programmer application to help in the computation of the linear programming mathematical model is intended to make it easier and faster to complete the calculation. It is possible to solve linear programming problems using the Microsoft Excel solver [4], which is a computer software. The advantages of Excel include the strength and depth of their quantitative analytical tools, as well as their intuitive grid-like user interface, which many users are acquainted with and comfortable with. The reasons for using Excel for optimization include the fact that it is free to download and install on any Windows platform, that it is simple to use, and that data transfer to and from Excel is very flexible [5]. The research that will be conducted this time has five variables by using the simplex method. In this study, the production factors used in raw materials are solved by linear programming using Microsoft Excel solver.

2. LITERATURE REVIEW

Linear programming is a strategy that requires either minimizing or optimizing a given quantity [3]. Nowadays, linear programming is applied in every field as it has many applications to real-life situations, see e.g. [6]. The operational research is a subject that consists of analytical methods in assisting to make better decisions. The operational research has been used in many industries like logistics, finance and transportations. For some applications on aircraft routing, see e.g. [7] and [8]. The linear programming was used to effectively model various real-life problems ranging from scheduling airline routes to oil transport from refineries to towns to achieve minimum standard requirements by finding the minimum cost. There are many techniques in improving the decision making such as optimization, neural networks, fuzzy logic, queueing theory etc. Some discussions of neural networks are available in [9] and the application of fuzzy logic in [10].

Mohan [11] claims that manufacturing firms encountered difficulties in managing the resources accessible for optimum profit because the linear programming that provided a practical quantitative approach to decision-making was not completely implemented. Used a linear programming approach to optimize the profit for allocating raw materials in the bakery to corresponding variables (big loaf, giant loaf, and small loaf) [11]. Researched McDonald's Malaysia menu by implementing linear programming to identify the cheapest menu and the healthiest menu [12]. The researcher developed a linear programming model for McDonald's Malaysia menu that conforms to Malaysia's Recommended Nutrient Intake 2017 (RNI 2017). Whereas, Mohamed *et al.* [13] formulated the mathematical model of the problem as linear integer programming where the objective function is the total cost for the proposed set menu and the constraints involved are the amounts of calories, carbohydrates, protein, fats, salt and sugar. The problem was solved by using the Solver tools in MS Excel.

Dweekat *et al.* [14] recommended dispatching a minigrid with modest conventional generators and a high degree of solar PV energy penetration, as well as a residential load demand. The resultant nonlinear stochastic scheduling problem is approximated into a linear equivalent that can be addressed using the efficient MILP approach. Hussin *et al.* [15] emphasizes the superiority of the suggested MILP-based technique for addressing co-optimized generation and transmission maintenance scheduling with SCUC over the LR-based approach. The results show that the MILP-based method is superior to other approaches in tackling high-dimensional maintenance problems because it can generate better solutions.

Woubante [16] regarded the information gathered from Ethiopia's apparel industrial unit to approximate the generated linear programming model parameters. Improved the model by utilizing LINGO

16.0 applications and demonstrated that linear programming could increase the company's profit by 59.84 percent while satisfying consumer orders [16]. Tesfaye *et al.* [17] also conducted an analysis obtained from the Ethiopian manufacturing industry and utilized a linear programming model. They suggested that the linear programming model will expand the company's capital by 46.41 percent over the actual use of resources. Tesfaye *et al.* [17] have also found that the company's profit will rise by 145.5 percent by implementing their model. Shakirullah *et al.* [4] applies to Bangladesh's knit garment manufacturing unit located in the Gazipur district. Data obtained by analyzing monthly resource consumption amount, inventory value, and profit per unit on various goods received from the case industry. The data obtained were used as parameters for the suggested linear programming to test the model's validation. The model has been applied and implemented by Microsoft Excel Solver and AMPL. The analysis demonstrated that the linear programming model would raise the case company's profit by 22 percent if there is great demand. That can be 12.33 percent if the consumer demands. On the other hand, the linear programming model could minimize the costs by 37 percent.

The objective in [18] is to examine linear programming in profit maximization of GT food Benin City, Edo State. Adopted the revised simplex method for the standard maximization problem using the echelon rule [18]. Based on secondary data, Ozokeraha and Paul [18] proposed that the chicken production sector gives the business more control in higher profit. Maurya *et al.* [19] studies using a linear programming model to optimize the profit of an Ethiopian chemical company located in Adama. An objective function is generated based on the decision variables of manufacturing, revenues, and profit over a while, utilizing these variables' quantitatively accessible data. Model equations with sufficient restraints considering production restrictions are solved using the MS-Excel solver. The results noted that the company had a maximum profit of Birr 107,353.17 per day. Aluminum sulphate was wholly used in the Ethiopian chemical business with an idle filtration and evaporation period of 5 and 7 hours a day and an insufficient demand for sulphuric acid of 4,452 tonnes per day. Oladejo *et al.* [20] used a linear programming model to achieve an optimum investment portfolio, with financial risks of $15,000,000.00 invested in crude oil, mortgage notes, cash crops, deposit certificates, fixed deposits, treasury bills, and construction loans. The results indicated that the other alternatives' spending had seen a marginal decline. When the original data's interest rates increased by 5 percent, the profit on investment also increased by almost 17 percent. Meanwhile, the amount of money on treasury bills and construction loans increased. The amount of money on the other alternatives decreased, except for mortgage securities, which showed a modest increase.

Oluwaseyi *et al.* [21] proposed a linear programming approach to decision-making at Benin Bakery University, Benin District, Edo State, Nigeria. Wanted to specify the quantity of bread that the Benin Bakery could manufacture on a day to maximize profits, according to the manufacturing process's restrictions [21]. The problem was formulated in mathematical terms and solved using the linear programming solver (LIPS). The solution collected from a single iteration revealed that 667 units of extra-large bread had to be produced daily by the baker to achieve a maximum daily profit of ₦100,000. Then proposed that the Benin Bakery focus more on extra-large bread production to achieve a maximum profit of ₦100,000 per day [21]. Naik *et al.* [22] used the Simplex algorithm to distribute raw materials among competing products (bread, cookies, cakes, and macarons) bakery to maximize profit. The results obtained after the analysis showed that the baker should produce 103 units of bread, 368 units of cakes, 42 units of macarons, and no cookies, to make Rs324,488. It was observed from the analysis that particularly cakes, bread, and macarons contributed more towards the profit. Thus, cakes need to be produced in higher numbers than the other products to maximize profit.

Garba *et al.* [23] extracted data from the recording unit for an item blend fabrication industry, Fortunate Bakery, Ilorin, Nigeria. Given the data supplied, the researcher developed a linear programming problem to maximize its daily profit. Resolved the optimal daily profit achievable to the item blend's organization to utilize the simplex method [23]. Using the Tora software package, the results showed that the Fortunate Bakery would achieve an ideal daily profit level of ₦9,500. If the baker's manager concentrates on the production of type alone, it is given to Saloon bread and disregards other lines of items produced by the company.

Anggoro *et al.* [24] studied the raw materials to maximize Bintang Bakery's profit. Based on the raw materials, analyzed the maximum profit in Bintang Bakery. The results using the simplex approach and the Lindo tools indicated that the Bintang Bakery home industry results are optimum. The optimum profit of Rp 19,750,000 by manufacturing 3,740 flavored pieces of bread, 1,300 frozen bread rolls, and 520 bread packs of Bintang Bakery industry enhanced profit by Rp 250,000. Ailobhio [1] analyzed the optimal solution in Lace Baking Industry, Lafia, Nigeria. Formulated the problem in linear programming and solved using R statistical software. The results indicated that the baker should produce 1,550 family loaf and 4,650 mini loaf loaves for the Lace Baking Industry to achieve a maximum monthly profit of ₦558,000. Ailobhio *et al.* [1]

reported that the Mini loaf and the Family loaf would make an optimum profit. There was also a need for more Mini loaf and Family loaf to be developed and marketed to maximize profits.

Oladejo *et al.* [25] applied the linear programming problem to secondary data collected from the Landmark University Bakery records. The result obtained from AMPL software revealed that the Landmark bakery should concentrate more on producing 14,000 for Family loaf and 10,571 for Chocolate bread to achieve a maximum monthly profit of ₦1,860,000. Akpan and Iwok [26] used the Simplex method concept to assign raw materials to compete for variables (big loaf, giant loaf, and small loaf) to maximize profits in the bakery. The study was carried out, and the result revealed that 962 units of a small loaf, 38 units of a big loaf, and 0 units of a giant loaf had to be made by the baker to make a profit of N20,385. From the analysis, Akpan and Iwok [26] found that a small loaf and a big loaf contribute objectively to the profit. The result indicated that the bakery should generate and market more small loaves and big loaves to maximize the profit. Ghosh *et al.* [27] developed a linear programming model to reduce the complexity of a Composite Textile Industry's scheduling problem in pursuit of maximizing profit. The model is developed considering process segmentation, utilization of machines, and other resources, concerning lead time. Four different lead-time components are derived, and Microsoft Excel solver is used in solving the model. Ghosh *et al.* [27] found that the maximum profit is $5164, and the Composite Textile Industry will gain this maximum profit if the project is completed within 31 days.

3. RESEARCH METHOD

Currently, there are about 122 retail outlets of Baker's Cottage in Malaysia with many more expected to be opened. The research used a data collection procedure that is quantitative in nature. We obtained the database for this project from a personal interview with Madam Kalisha Ahmad, the manager at Baker's Cottage in Tampin, Negeri Sembilan, Malaysia.

Baker's Cottage creates a strategic and important management judgment by making five different bread varieties, which decide the quantity variations of goods produced (product mix). The research used linear programming to evaluate a new mixture of quantities. The cumulative profit contribution of each service in the first quantity of the month is now connected to the aggregate profit contribution produced by the previous product combination calculated by the trial-and-error method [28].

Linear programming needs to be displayed in a general standard type. Linear programming involves a linear objective function, *Z*, such that, if in general $c_1, c_2, \ldots, c_n$ are real number, then the function of real variables $x_1, x_2, \ldots, x_n$ can be defined as:

$$Z = max \sum_{j=1}^{5} c_j x_j \quad (1)$$

the objective function is subject to,

$$\sum_{j=1}^{5} a_{ij} x_j \leq b_i, \qquad i = 1,2,3,4,5,6,7. x_j \geq 0, \qquad j = 1,2,3,4,5. \quad (2)$$

where,
Z represents the value of objective function.
c_j is the coefficients, representing the marginal change in the value of the objective function Z.
x_j is the decision variables that decide each resource, either to use or remove in the optimal formulation.
a_{ij} is the coefficient that indicates the amount of resources.
b_i are the variables, representing the initial quantity of resources.

3.1. Step of the simplex method by Excel's Solver

To solve the maximization problem in linear programming with the Excel solver function.

Step 1: Make sure the Excel solver in your Microsoft Excel 2019 is allowed. The "Solver" icon exists in Microsoft Excel under the "Data" menu.
- If the solver icon is not there on your Excel, activate it under the file tab -> click options -> Add-ins and select Solver Add-in and click on the Go button.
- Check Solver Add-in and click OK.

Step 2: Insert the problem data in Figure 1.
Step 3: Start the Excel's solver at Data -> solver.
Step 4: Fill the Solver Parameters.
- Write the cell location on the set objective field, which we calculate, the profit maximization. For our case, it is cell (J5).
- Minimize or maximize based on the problem objective function. In our case study, we choose Max.

- Changing variable costs for the cells where the values of x_j should exist. In this case study, these are cells from (E4) to (I4).
- Subject to the constraints. A set of constraints to tell excel solver that the total amounts shipped to any destination must equal this destination's requirements. In our case study, this set is J7:J13<= L7:L13.
- Choose Simplex LP and then click the Solve button.

Step 5: Still in the solver, click Answer and Sensitivity and click OK. This should produce the output under your worksheet entitled Answer Report and Sensitivity Report.

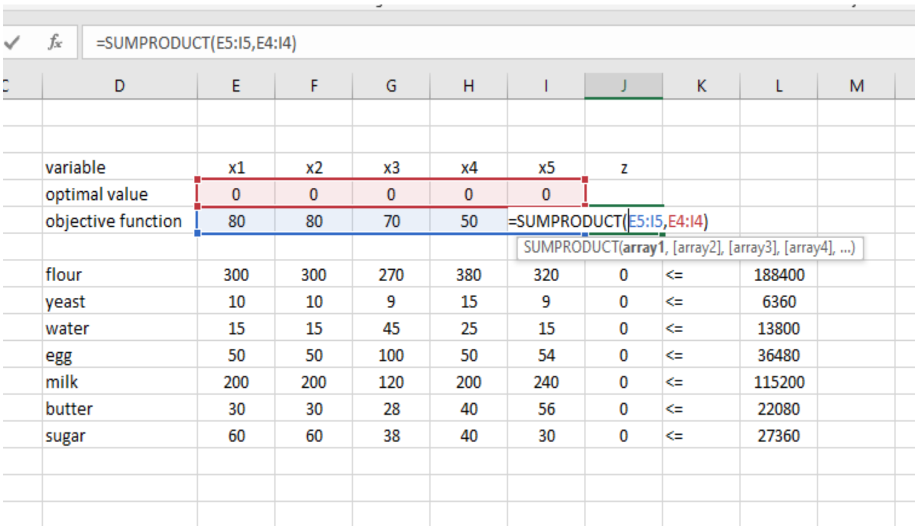

Figure 1. Insert formula for the objective function

4. RESULTS AND DISCUSSION

In this section, the database for this analysis was obtained from Baker's Cottage in Tampin, Negeri Sembilan, Malaysia. The collected data are focused on the bakery's varieties of bread for one month. The data is collected by focusing on the actual content used in the manufacturing style of bakery products. The content of each portion of the bread generated per unit is shown in Table 1. Table 2 shows the basic seven (7) raw materials used to make bread at Baker's Cottage. The table also includes the combination of the quantities of the seven basic raw materials (raw material mix) for bread production per loaf (in gram). It also shows the total quantity of each raw material retained in store for monthly production.

Table 1. Bread produced by Baker's Cottage

Name of product	Production cost per bun (cent)	Selling price per bun (cent)	Profit (cent)
Chicken Floss (x_1)	280	360	80
Spicy Floss (x_2)	280	360	80
Frank Cheese (x_3)	260	330	70
Mexico Bun (x_4)	230	280	50
Doughnut (x_5)	250	280	30

Table 2. Quantities of raw materials used for bread production per baking

Raw materials	Type of bread and their raw material mix x_1	x_2	x_3	x_4	x_5	Total quantity per month (gram)
Flour	300	300	270	380	320	188,400
Yeast	10	10	9	15	9	6,360
Water	15	15	45	25	15	13,800
Egg	50	50	100	50	54	36,480
Milk	200	200	120	200	240	115,200
Butter	30	30	28	40	56	22,080
Sugar	60	60	38	40	30	27,360

As seen below, in the linear programming model, we added objective function and constraint values.

$Maximize\ \ z = 80x_1 + 80x_2 + 70x_3 + 50x_4 + 30x_5.$

$Subject\ to{:}\ Flour{:}\quad 300x_1 + 300x_2 + 270x_3 + 380x_4 + 320x_5 \leq 188400,$

$Yeast{:}\ 10x_1 + 10x_2 + 9x_3 + 15x_4 + 9x_5 \leq 6360,$

$Water{:}\ 15x_1 + 15x_2 + 45x_3 + 25x_4 + 15x_5 \leq 13800,$

$Egg{:}\ 50x_1 + 50x_2 100x_3 + 50x_4 + 54x_5 \leq 36480,$

$Milk{:}\ 200x_1 + 200x_2 + 120x_3 + 200x_4 + 240x_5 \leq 115200,$

$Butter{:}\ 30x_1 + 30x_2 + 28x_3 + 40x_4 + 56x_5 \leq 22080,$

$Sugar{:}\ 60x_1 + 60x_2 + 38x_3 + 40x_4 + 30x_5 \leq 27360,$

$x_1, x_2, x_3, x_4, x_5 \geq 0.$

Seven slack variables s_i $(i = 1, 2, 3, 4, 5, 6, 7)$ were added to describe the above Linear Programming model in canonical form. The slack variables changed the sign of disparity to equality in the constraint aspect of the model. After output, the usable amount of raw materials will be compensated for by a slack variable. As a consequence, the Linear Programming model above yields:

$Maximize\ \ z = 80x_1 + 80x_2 + 70x_3 + 50x_4 + 30x_5.$

$Subject\ to{:}\ Flour{:}\quad 300x_1 + 300x_2 + 270x_3 + 380x_4 + 320x_5 + s_1 = 188400,$

$Yeast{:}\ 10x_1 + 10x_2 + 9x_3 + 15x_4 + 9x_5 + s_2 = 6360,$

$Water{:}\ 15x_1 + 15x_2 + 45x_3 + 25x_4 + 15x_5 + s_3 = 13800,$

$Egg{:}\ 50x_1 + 50x_2 100x_3 + 50x_4 + 54x_5 + s_4 = 36480,$

$Milk{:}\ 200x_1 + 200x_2 + 120x_3 + 200x_4 + 240x_5 + s_5 = 115200,$

$Butter{:}\ 30x_1 + 30x_2 + 28x_3 + 40x_4 + 56x_5 + s_6 = 22080,$

$Sugar{:}\ 60x_1 + 60x_2 + 38x_3 + 40x_4 + 30x_5 + s_7 = 27360,$

$x_1, x_2, x_3, x_4, x_5, s_1, s_2, s_3, s_4, s_5, s_6, s_7, \geq 0.$

4.1. Analysis of Excel's solver

The above data is analyzed using Excel's Solver for the Simplex method, and the result is represented in Tables 3-5. Table 3 shows the optimal solution for the objective function's value of a linear programming model using Excel's solver. The result was obtained using excel's solver is 40270.42254. Whereas, Table 4 represents the results for the variable cells i.e. for each type of bread using excel's solver. The result shows at the end of the month, the optimal values for x_1, x_2, x_3, x_4 and x_5 are 331.8309859, 0, 196.056338, 0, and 0, respectively. Table 5 shows the answer report for the constraint on each raw material using excel's solver. The table shows the binding and not binding constraints. The binding constraints in the context of linear programming problems are those certain limitation which cause immense changes in optimal and feasible solution due to some variation. Not binding are the limitations which would not change or alter optimal solution or area of feasibility due to variation in the constraint.

Table 3. Result answer report for the objective cells using excel's solver

Cell	Name	Original value	Final value
J6	objective function, z	0	40270.42254

Table 4. Result answer report for the variable cells using excel's solver

Cell	Name	Original value	Final value	Integer
E4	optimal value x_1	0	331.8309859	Contin
F4	optimal value x_2	0	0	Contin
G4	optimal value x_3	0	196.056338	Contin
H4	optimal value x_4	0	0	Contin
I4	optimal value x_5	0	0	Contin

Table 5. Result answer report for constraint using excel's solver

Cell	Name	Cell value	Formula	Status	Slack
10	egg *z*	36197.1831	$50x_1 + 50x_2 100x_3 + 50x_4 + 54x_5 \leq 36480$	Not Binding	282.8169014
11	milk *z*	89892.95775	$200x_1 + 200x_2 + 120x_3 + 200x_4 + 240x_5 \leq 115200$	Not Binding	25307.04225
12	butter *z*	15444.50704	$30x_1 + 30x_2 + 28x_3 + 40x_4 + 56x_5 \leq 22080$	Not Binding	6635.492958
13	sugar *z*	27360	$60x_1 + 60x_2 + 38x_3 + 40x_4 + 30x_5 \leq 27360$	Binding	0
7	flour *z*	152484.507	$300x_1 + 300x_2 + 270x_3 + 380x_4 + 320x_5 \leq 188400$	Not Binding	35915.49296
8	yeast *z*	5082.816901	$10x_1 + 10x_2 + 9x_3 + 15x_4 + 9x_5 \leq 6360$	Not Binding	1277.183099
9	water *z*	13800	$15x_1 + 15x_2 + 45x_3 + 25x_4 + 15x_5 \leq 13800$	Binding	0

4.2. Analysis of results

The Excel Solver analysis results on the linear programming model using the simplex approach determined the objective function's value to be RM40270.42. The inputs to the objective function of the five variables x_1, x_2, x_3, x_4, x_5 are 332, 0, 196, 0 and 0. The result reveals that only x_1 and x_3 variables contributed significantly to improve the objective function at 332 and 196, respectively. Based on the implications of the linear programming model, the focus on the production of x_1 (Chicken Floss) and x_3 (Frank Cheese) is optimal and profitable for Baker's Cottage, Tampin's branch, Negeri Sembilan, Malaysia. The result will support the bakery optimally from the expense of raw materials and the maximum profit is about RM40270.42 per month.

5. CONCLUSION

In this project, we analyzed five different bread varieties produced by Baker's Cottage, Tampin's branch, Negeri Sembilan, Malaysia using Excel's Solver. Based on the analysis result, we recommend Baker's Cottage to focus more on Chicken Floss and Frank Cheese's production based on the available monthly raw materials. The results indicate that the bakery's manager should concentrate more on the production of Chicken Floss and Frank Cheese. Other types should be less produced since their value is zero to achieve a maximum profit of RM40270.42. Linear programming also demonstrated that Chicken Floss and Frank Cheese provided an objective contribution to the highest and maximum profit. Therefore, the baker's cottage needs to produce and sell more Chicken Floss and Frank Cheese.

This study's limitation should be recognized when analyzing the results and developing further studies to maximize profit. We can consider other factors that can affect sales, such as the marketing strategy, advertising, location, equipment, manpower and price. But our limitations in this study are focusing on the Baker's Cottage in Tampin, Negeri Sembilan, Malaysia and also raw material to maximize profit. In addition, to expand this analysis, the researcher should include other cities and towns to present a more representative overview of the factors influencing consumers' consumption to buy bread.

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