

Perishable Inventory Control Model for Food Production in Pizza Restaurant

NurSyahirah Ahznizam¹, Cik Sri Mazzura Muhammad Basri^{1*}

¹ Department of Mathematics and Statistics, Faculty of Applied Sciences and Technology, UTHM Kampus Cawangan Pagoh, Hub Pendidikan Tinggi Pagoh, KM 1, Jalan Panchor, 84600 Pagoh, Muar, Johor, MALAYSIA.

*Corresponding Author: mazzura@uthm.edu.my

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Abstract

Inventory management plays an important role in every business to ensure a smooth production process and fulfillment of customers' demands. A failure to control the inventory will result in increased inventory costs and shortage costs. In a pizza restaurant, too much inventory of perishable items in one period will cause damaged items due to their shelf life. Thus, this study investigates the essential task of inventory management in a pizza restaurant in order to achieve minimum total cost. This study focuses on the design of an inventory control model to minimize item costs while ensuring adequate stock levels and no wastage. Key factors considered in this model include the cost of purchasing per unit, holding costs, and ordering costs, along with other factors such as lead time and inventory shelf life. Through this study, the model reveals the optimum storage times for the items and leads to the identification of the optimum quantity of the items that should be ordered in each order. The finding shows that the implementation of this model has the potential to significantly increase the profit by reducing the overall inventory expenses. Despite the study's limitations, such as constant demand, the findings indicate that the proposed inventory control model successfully reduces the total inventory costs. So, this study provides valuable insights for restaurant managers to manage inventory efficiently and ultimately contribute to improved financial performance and sustainability in the industry.

1. Introduction

The food and beverage industry is an industry that produces food and beverages by processing raw materials. In the food and beverage industry, controlling food costs is very important since it necessitates careful budgeting and reduces waste, especially in the restaurant industry. This industry is known for its fast turnaround time and wide variety of foods. In a restaurant, monthly data and operating statements are required to monitor the operations and to determine whether the business is making or losing it. To manage the raw materials in a restaurant, proper inventory control is needed to help the restaurant in optimizing the inventories.

Inventory control is very important since it necessitates careful budgeting and reduces waste. Without effective management, expenses will result in waste and cannot maximize profit. Various control models are used in most industries to help bring maximum profits. The proposed inventory model in this study is the perishable inventory control model.

In a restaurant, most of the inventory have limited lifetimes, and when this inventory meets its expiration date, it cannot be used and will cause loss and shortage. So, this inventory model was developed to help the restaurant to order the inventory with the optimum quantity so that the inventory will be used before the expiration time.

The objective of this study includes determining the optimum quantity of inventory and the optimum storage period to minimize the total inventory cost while reducing the shortage cost. This study will focus on a pizza restaurant as it is one of the restaurants that have many branches. The software that used in this study to do the calculation of the model is Microsoft Excel. There are some assumptions used in this study to use the perishable inventory model, which is the demand is fixed and the storage capacity is able to meet all the demand [9]. This study hopes that the perishable inventory model will succeed in determining the optimum quantity and optimum storage period with the limit of lifetimes of the inventory to help the pizza restaurant minimize the total inventory cost.

There is a large volume of published studies that describing the importance of inventory control in a restaurant and other industries. [11] once stated that inventory control is the most important and effective function of inventory management, and it forms the nerve center of any inventory management organization. Then, in [4], it stated that many organizations can reduce their inventories without increasing the cost using an inventory control model. Inventory control techniques are very important component in this development process. Many organizations can reduce their inventories without increasing the cost using inventory control [4]. In the food and beverage business, cost-control is a process to direct, regulate, and restrain people's actions in order for an enterprise's defined goals to be met [6]. Some of the inventory control models include Material Requirement Planning (MRP) and Economic Order Quantity (EOQ) method. [1] stated that the EOQ had been previously defined by Monks, Lucey, and Schroeder as the ordering quantity, which minimizes the cost between inventory holding cost and reorders cost. While MRP divides components into parts and plans for those parts to be put into stock when needed [7] Both of this technique is to identify the order quantity that minimizes the total costs involved in managing inventory [11]. Besides, raw material inventory management is very important in an enterprise. This is because they have to meet customers' demand by using perishable items that have a short life span. Excessive or insufficient inventory will lead to increased shortage costs [8]. An article from [5] stated that a recent study on inventory control of perishable item has focused on the strategies to optimize the inventory levels minimize the shortage cost. [10] state that managing perishable inventory needs proper replenishment so that the demand is just met. Studies have proposed various approaches to manage perishable items including demand forecasting and real-time inventory tracking. When the basic inventory control model, such as the EOQ model, assumes an infinite shelf life, the Perishable inventory mathematical model highlights the differences between the models that ignore perishability [2].

2. Methodology

The Perishable Inventory Control Model implemented in this study is an inventory control technique that is the same as the Economic Order Quantity (EOQ) method but considers the life time of the items and the lead time of the order. Data collection and analysis are performed to achieve the objectives of this study. Data collection includes an interview method and a statistical dataset method to collect the monthly data. In this study, the selected sample size used is the main ingredients used in pizza making, which are dough and cheese. However, in this restaurant, there are three sizes of dough, and this study is focused on the larger dough, 12-inch dough because of the higher demand.

The production of pizza requires the use of dough and cheese, which are categorized as perishable items. This means these two materials are easily susceptible to damage. However, storing these perishable items is still possible since each perishable item will have its own shelf life to make it easier to manage the item so that the item will be used before it meets its expiration date. Based on the interviews, the data of the shelf life for these two products are collected. The 12-inch dough can last up to 7 days, and it is parallel with the past study from [12], which states that dough can look good for about 7 to 8 days with the help of some mixing, while the shelf life of cheese is 14 days from the interview.

2.1 Formula of Perishable Inventory Control Model

This model requires some data including the purchase cost per unit, p , demand per month, D , lead time, LT , and holding rate per unit, h . This model design begins with the calculation of the storage period, t . The storage period is the interval time between the arrivals of inventory. The value of t is influenced by demand, D , holding cost, h , ordering cost per order, k , shelf life, and backorder cost per item, C_k . The ordering cost includes the staff's salary, transportation cost, and phone bills. After we obtained the value of storage time, t , the optimum quantity, Q can be calculated by using the value of t and the number of demands, D .

The research [9] proposed a raw material inventory control model that considers the shelf life of the inventory. The model aimed to minimize the total inventory cost with optimum quantity. The perishable inventory

control model in this study considers the expiration time, which is based on the company's preference. The total inventory cost, TC calculated represents the monthly total cost of the inventory. The model for the perishable inventory control is presented as follows, where C_o is the ordering cost, C_p is the purchasing cost, C_h is the holding cost, and C_s is the shortage cost.

$$C_o = \frac{k}{t} \quad (1)$$

$$C_p = pD \quad (2)$$

$$C_h = \frac{phDt_1^2}{2t} \quad (3)$$

$$C_s = \frac{C_k D \left(t - 2t_1 + \frac{t_1^2}{t} \right)}{2} \quad (4)$$

From the formula above, we obtained the total inventory cost:

$$TC = pD + \frac{k}{t} + \frac{phDt_1^2}{2t} + \frac{C_k D \left(t - 2t_1 + \frac{t_1^2}{t} \right)}{2} \quad (5)$$

To obtain the optimum storage period, t then TC is derived with respect to t .

$$t = \sqrt{\frac{2k + phDt_1^2 + C_k Dt_1^2}{C_k D}} \quad (6)$$

While the backorder cost per item, C_k is obtained from the data, with condition, if $t < t_1$, then $t = t_1$ [7]. From equation (6), the optimum quantity, Q and the number of orders, N can be calculated by:

$$Q = tD \quad (7)$$

Which is the demand, D obtained from the data collected.

$$N = \frac{n}{t} \quad (8)$$

To calculate the Reorder Point, ROP we multiply the lead time, LT , with the Demand, D .

$$ROP = LTD \quad (9)$$

3. Results and Discussion

Table 1 shows the data collected from the interviews. From the table, phone bills, when divided by 31 days and 24 hours, we will get RM0.63 per hour. The holding cost is 26% of the purchasing cost per unit. It includes the storage fee and the electric bills for the storage.

Table 1 The primary data of the study

Items	Description
Phone bills	RM450/month
Staff's salary	RM7.20/hour
Transportation cost	RM50/order
Holding rate	26%
Order lead time	3 days
Shelf life of dough	7 days
Shelf life of cheese	10 days
Backorder cost for 12-inch dough	RM500
Backorder cost for cheese	RM1500

By totalling phone bills, staff's salary, and transportation costs, then the ordering cost obtained is RM57.83. This cost represents the ordering cost for each inventory in the restaurant. So, we can use this value for both calculations, which is 12-inch dough and cheese.

3.1 Optimal solution for 12-inch dough

We substitute the value of demand, D , the ordering cost, k , the purchasing cost per unit, p , holding rate, h , the shelf life of item, and the backorder cost per item, C_k into equation (6) to get

$$t = \sqrt{\frac{(2)(RM57.83) + (RM5)(0.26)(0.2258)^2(135)}{(RM500)(135)}} = 0.2299 = 7.13 = 7 \text{ days} \tag{10}$$

From the value obtained from equation (10), we can calculate the optimum quantity, Q for 12-inch dough using equation (7) and the number of orders, N in a month using equation (8), which are

$$Q = \left(\frac{7}{31}\right)(135) = 30.48 \approx 31 \text{ trays} \tag{11}$$

$$N = \frac{31}{7} = 4.43 \approx 4 \tag{12}$$

Then, we calculate the total item purchased by multiplying the result in equation (11) and (12) and the total item purchased will be the new demand, with condition if $QN < D$, then new demand will be $Q(N+1)$.

$$D = 31 \times 5 = 155 \tag{13}$$

Thus, by using equation (9), the Reorder point, for the 12-inch dough is calculated as

$$ROP = \frac{3}{31}(155) = 15 \text{ trays} \tag{14}$$

Reorder points acquired from this perishable inventory model are 15 units for 12-inch dough. A replenishment order is needed when the inventory level reaches those amounts of units. The reorder point is aligned with the business demand pattern to ensure the order placement arrives on time so that there is no shortage of items.

The monthly cost is calculated by summation of the ordering cost, purchasing cost, holding cost, and shortage cost by using the equations (1) - (4).

$$\text{Ordering cost, } C_o = \frac{(RM57.83)}{0.2258} = RM256.11 \tag{15}$$

$$\text{Purchasing cost, } C_p = (RM5)(155) = RM775 \tag{16}$$

$$\text{Holding cost, } C_h = \frac{(RM5)(0.26)(155)(0.2258)^2}{2(0.2258)} = RM22.75 \tag{17}$$

$$\text{Shortage cost, } C_s = \frac{(500)(155) \left[0.2258 - 2(0.2258) + \frac{(0.2258)^2}{0.2258} \right]}{2} = RM0 \tag{18}$$

By substitute the value obtained into equation (5), the total inventory cost is calculated:

$$\text{Total Inventory Cost} = RM256.11 + RM775 + RM22.75 + RM0 = RM1053.85 \tag{19}$$

Table 2 shows the test of t value for 8 days and 9 days to check the accuracy of the model. From Table 2, shows that the minimum total inventory cost is at a t -value of 7. The result of this testing is consistent with the result of the Perishable Inventory Control Model. In conclusion, the optimum quantity of 12-inch dough is 31 trays, with a storage time seven days and a total cost of RM1053.85 per month. An order should be placed when the inventory level reaches 13 trays so that the inventory will be delivered when the inventory level is equal to zero. Based on Table 2, it can be seen the total inventory cost for 8 and 9 days is higher because of the occurrence of shortage cost.

Table 2 Testing of *t*-value for 12-inch dough

<i>t</i> (day)	<i>t</i> (month)	<i>Q</i>	Number of orders	Amount purchased	Ordering cost	Purchasing cost	Holding cost	Shortage cost	Total Inventory cost
7	0.2258065	31	5	155	256.10	775.00	22.75	0.00	1053.85
8	0.2580645	35	4	140	224.09	700.00	17.98	141.13	1083.20
9	0.2903226	40	4	160	199.19	800.00	18.27	573.48	1590.94

From the data obtained, the actual total quantity of 12-inch dough delivered in May 2023 is 134 trays with the number of orders, *N* is 10. By assuming the quantity delivered per order is the same, the storage period, *t* obtained using equation (8).

$$t = \frac{31}{10} \div 31 = 0.1 \quad (20)$$

Since the demand, *D* is 135 but the actual quantity delivered is 134, the restaurant bear the shortage of 1 tray with back order cost RM500 per tray and yields the shortage cost, C_s RM500. By using the actual total quantity which is 134 as demand, *D* and *t* = 0.1 into equation (1)-(3), we calculate the actual total inventory cost using equation (5) and obtain RM1767.21.

The actual inventory cost for the 12-inch dough is RM1767.21, while the inventory cost by the model is RM1053.85, which shows a difference of RM713.36.

3.2 Optimal solution for cheese

Since the ordering cost for each inventory in the restaurant is RM57.83, thus the ordering cost for cheese will be the same value. By using the same calculation as for the 12-inch dough and data from Table 2, we get the following result.

The optimum storage period is

$$t = \sqrt{\frac{(2)(RM57.83) + (RM307.68)(0.26)(0.3226)^2(35) + (RM1500)(35)(0.3226)^2}{(RM1500)(35)}} = 0.3344 = 10.37 = 10 \text{ days} \quad (21)$$

The optimum quantity for cheese is

$$Q = \left(\frac{10}{31}\right)(35) = 11.29 = 12 \text{ boxes} \quad (22)$$

The number of orders in a month is

$$N = \frac{31}{10} = 3.1 \approx 3 \quad (23)$$

The total quantity purchased is

$$D = 12 \times 3 = 36 \quad (24)$$

The Reorder point is

$$ROP = \frac{3}{31}(36) = 3.48 \text{ boxes} \approx 3 \text{ boxes} \quad (25)$$

By substitute the value obtained in equation (21), (22), and (24) into equation (1)-(4), we get the following result.

$$\text{Ordering cost, } C_o = \frac{(RM57.83)}{0.3226} = RM179.27 \quad (26)$$

$$\text{Purchasing cost, } C_p = (RM307.68) (36) = RM11076.48 \tag{27}$$

$$\text{Holding cost, } C_h = \frac{(RM307.68) (0.26) (36) (0.3226)^2}{2(0.3226)} = RM464.50 \tag{28}$$

$$\text{Shortage cost, } C_s = \frac{(1500) (36) \left[0.3226 - 2(0.3226) + \frac{(0.3226)^2}{0.3226} \right]}{2} = RM0 \tag{29}$$

By substituting the results from (26)-(29) into equation (5), the total inventory cost for cheese is obtained.

$$\text{Total Inventory Cost} = RM179.27 + RM11076.48 + RM464.50 + RM0 = RM11720.25 \tag{30}$$

Next, we repeat the process to test the *t*-value for eleven and twelve days, as shown in Table 3.

Table 3 shows that the minimum total inventory cost is at *t*-value 10 which is consistent with the result of the Perishable Inventory Control Model. Thus, the optimum quantity of cheese is 12 boxes and the storage time is ten days with a total inventory cost RM11720.25. An order should be placed when the inventory level reaches three boxes to the inventory delivered when the inventory level is 0. The total inventory cost when 11 and 12 days is higher with the occurrence of shortage cost.

Table 3 Testing of *t*-value for cheese

<i>t</i> (day)	<i>t</i> (month)	<i>Q</i>	Number of orders	Amount purchased	Ordering cost	Purchasing cost	Holding cost	Shortage cost	Total Inventory cost
10	0.322580645	12	3	36	179.27	11076.48	464.50	0.00	11720.25
11	0.35483871	13	3	39	162.98	11999.52	457.46	85.78	12705.74
12	0.387096774	14	3	42	149.39	12922.56	451.59	338.71	13862.25

From the data obtained, the actual total quantity delivered for cheese is 528kg, which is 33 boxes, and has the same number of orders made, *N* which is 10, and the storage period, *t* is the same as equation (20). Since the demand, *D* is 557.44kg but the actual quantity delivered is 528kg, the restaurant bears the shortage of 1.84kg which is two boxes with back order cost of RM1500 per box and yields the shortage cost, *C_s* RM3000. By using the actual total quantity which is 33 boxes as demand, *D* and *t* = 0.1 into equation (1)-(3), we calculate the actual total inventory cost using equation (5) and obtain RM14327.83.

The actual inventory cost of cheese is RM11720.25, while the inventory cost using the model is RM14327.83, resulting in a cost difference of RM2607.58. These results indicate that the model gives a lower cost compared to the actual cost. Therefore, it can be concluded that this model is one of the most effective models to minimize the total inventory cost in the food industry.

3.3 Total inventory cost for pizza dough

The lead time used in this study is three days for all items in this restaurant. Sensitivity analysis revealed that the holding cost is influenced by the lead time. The longer the lead time, the higher the holding cost. A shorter lead time can be achieved by investing in new production equipment or speeding up production planning itself [3]. We use the same calculation of the model to calculate the total inventory cost for another type of dough, as shown in Figure 1. Figure 1 shows the total inventory cost for all pizza dough types by using the Perishable Inventory Control Model. From Figure 1, the highest costs are 6-inch dough and 9-inch dough, which is RM1517.06, and the lowest inventory cost is 12-inch thin crush with RM762.36. The main factors that influence the total inventory cost are the purchasing cost per unit, *p* and demand, *D*.

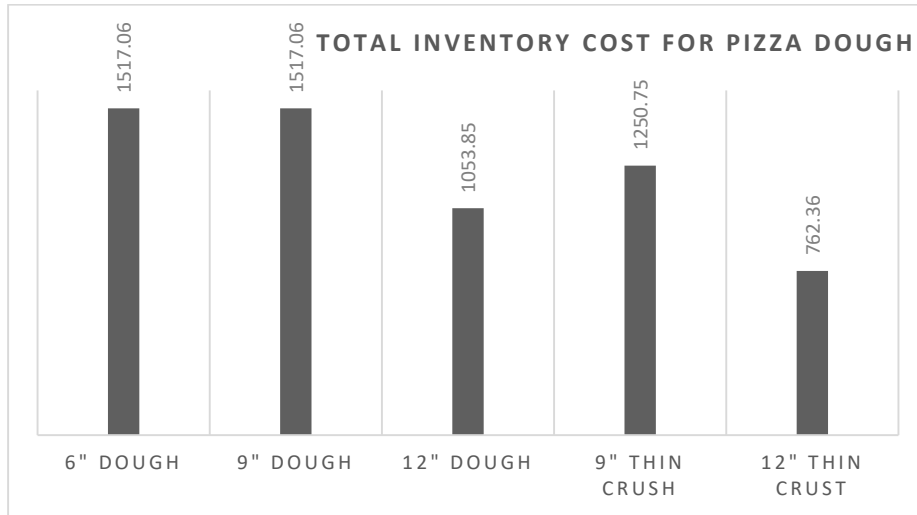


Fig. 1 Total inventory cost for all pizza dough type

3.4 Total cost analysis by cost testing

Figure 2 shows the result of t -value (day) and the total inventory cost if the backorder cost is changed, but the value of purchasing cost per unit, p the holding rate per unit, h the demand, D and the shelf life of the item, t_1 , remains the same. It can be seen the value of shortage cost depends on the storage period, t . The longer the storage period, the larger the shortage cost. From Figure 2, the minimum total inventory cost is when the backorder cost is RM80 per unit while the largest total inventory cost is when the backorder cost per unit is RM35. It can be concluded that the total inventory cost, TC , cannot be minimized if the backorder cost is smaller, but it depends on all of the values, which are purchasing cost, p , demand, D , and shelf life, t_1 .

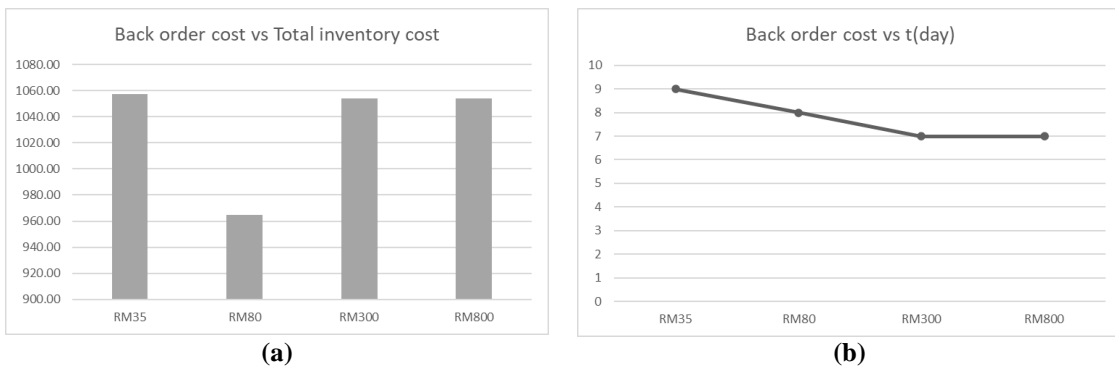


Fig. 2 Back order cost vs (a) Total inventory cost; (b) t (day)

4. Conclusion and Recommendation

In conclusion, this study successfully achieves the objective of minimizing the total inventory cost of the perishable items, which are the main two raw materials in pizza production, 12-inch dough and cheese. The result of the testing using this model is a six-day storage time of dough and ten-day storage time of cheese, and it will lead to the optimum order quantity of 12-inch dough being 31 trays and 12 boxes for cheese. This result satisfied the first objective. The total inventory cost for the 12-inch dough is RM1053.85 while the actual total cost for the 12-inch dough is RM1767.21, which is larger than the cost using the perishable inventory control model, and the total inventory cost of cheese is RM11720.25, where it is smaller than the actual total cost for cheese which is RM14327.83. This inventory control disclosure has provided important insight into optimizing operational control. The analysis obtained from this study shows that the model used can increase profits from the reduction of inventory expenses. It is successfully achieving the overarching objectives of reducing shortage cost and determining the optimum quantity by considering shelf life.

As for the recommendation, this study recommends the use of demand-driven ordering system so that the demand pattern can be more accurate. Besides, this study recommends reducing the holding cost and back order cost per unit to help the restaurant reduce inventory costs.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Nur Syahirah Ahznizam, Cik Sri Mazzura Muhammad Basri; **data collection:** Nur Syahirah Ahznizam; **analysis and interpretation of results:** Nur Syahirah Ahznizam, Cik Sri Mazzura Muhammad Basri; **draft manuscript preparation:** Nur Syahirah Ahznizam. All authors reviewed the results and approved the final version of the manuscript

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