Optimization Consumer Cost of Food Industry with Perishable Characteristic

I Rizkya 1*, A A Nasution 2, K Syahputri1, R M Sari1, I Siregar1, Erwin1
1Industrial Engineering Department, Faculty of Engineering, Universitas Sumatera Utara
2Accounting Department, Faculty of Economic and Business, Universitas Sumatera Utara

Email: indahrizkya@usu.ac.id*

Abstract. Food product has time limit usage, namely expired date. The time limit for product usage (expiration) is one of the factors affects the number of inventory and total inventory costs. Expiration factors are important in planning because they do not only affect the costs to the company but also includes product safety issues when consumed. Products are close to expire date will decrease in sales value until they have no value at all. Expiration factors must be considered in determining the optimal number of inventory capable to minimize the number of expired products and minimize the number of lost sales. This paper describes the Q method approach to obtain optimal order size capable to minimize expired products and lost sales to the consumer. Q model approach is used for product inventory models are undurable. The product inventory model for undurable product calculates the inventory not only minimize due to demand but also due to damage. The study was conducted to minimize the total costs by consumers cost and considering expired factors and lost sales. The results obtained in this article shows that the total cost of consumers is IDR 3,430,756/month and acceptance frequency is 22 times per month.

1. Introduction
In a real system even though the supply system is implemented well, sometimes stored product is damaged [1]. Therefore, the effect on inventory depletion is not only demand but also damage, such as direct spoilage (decay), physical depletion (exhausted physically) for volatile liquids, or deterioration for electronic components [2].

Food is included in perishable products where the value will decrease by time, because food has an expiration date. In the food industry, expiration is one of the factors affects the total cost of inventory. When food products have passed expiration, food cannot be consumed again [3]. The American Heritage College Dictionary defines inventory as the amount of stored products and materials [4]. Inventories related to capital, use of storage space, maintenance, products damage, unused time products stored due to expiration, taxes outcome, insurance needs, possibility theft, and loss [5]. The value of the product also decreases and even disappears. Each unit exceeds the specified expiration date is considered outdated, and must be discarded [6].

Expiration time is a problem that must be considered in planning a finished product because it is includes product safety issues when consumed [7]. Industries produce perishable products experience deterioration and obsolescence [8]. Deterioration refers to damage, spoilage, vaporization, depletion,
and decay. Obsolescence is the product loss of value due to the new arrival and better products [9]. The product will have a lower selling value along with the approaching of lifetime (expiration time), not even having a sales value overall when the product has expired [10]. Therefore handling in the food industry has its own uniqueness because of the time limit on products usage and a calculation is needed in determining the optimal total cost as an outcome by consumers with considering the frequency of product acceptance to consumers.

Many previous studies have been conducted to handle the problems of perishable products with different solutions. Rosi et.al. doing research at the hospital in Semarang to get the optimal lot size for the drugs categorized as death stock return [11]. Another study was also conducted by Ludmila et al. by analyzing the problems of carrying out inventory control of goods subject to deterioration during warehousing [12]. The same research was also carried out by Dalfard and Nosratian which is presented a constraint cost by single-product inventory-production models in perishable food to maximizing the total profit [13]. Singh et al also developed an inventory model for expired products where the demand rate is constant but varies for a certain time interval [14].

The other research is also carried out by Sushil and Rajput presented an inventory model for perishable items with time varying stock dependent demand under inflation [13]. The purpose of this research is to minimize the present value of retailer’s total cost. Numerical examples are also given to demonstrate the presented mode. The result of this research when the credit period is short then the retailer wants to order less and decrease the chargeable interest. When the credit period is large enough then the retailer wants to order more and he earns enough revenue on his sell to pay the purchasing cost therefore the credit period attracts the retailer to buy more or less. Other studies examined a number of inventory models considering the existence of inventory shortages related to expired products with different demand patterns [14].

Another study was also conducted by Nagare and Dutta that presented an inventory model for continuously deteriorating goods having random shelf life and displayed inventory dependent demand [7]. The results obtained from proposed model conform to the corresponding results for the basic EOQ model when cycle ending inventory is zero, inventory dependent inventory factor and deterioration rate approaches zero. The results indicate that reserve inventory eat into profit and have negative linear relationship with profit. Further, profit is deeply impacted by deterioration rate and followed by inventory dependent demand rate. However, studies in handling the problems of perishable inventory have been done before have not considered the total cost of the consumer in optimizing product acceptance. This study aims to optimize the number of cake receipt by considering the total cost of consumers and the product expired to be reduced.

2. Methodology

The study was conducted in Small Medium Enterprise (SMEs) which is produces 5 types of cakes in Medan city, that is brownies, bika ambon, lapis legit, bolu pandan, and caramel cakes. This study focuses on the number of expired products produced by SMEs. The undurable product model is an inventory model where the inventory calculation is not only minimize due to demand but also due to damage. Economic Order Quantity (EOQ) approach model assumes that the demand is constant and the product is damaged exponentially. Some forms of product damage includes direct spoilage, physical depletion, and deterioration[15].

This research began by conducting direct observation to obtain information on real conditions in the SMEs. Observation results are known to problems happen and important variables in order to formulate optimal lot size acceptance for consumers are able to minimize consumer costs. The research variables include the number of demand at each product, the number of expired products at each period, product capacity, frequency of acceptance, product sales cost, ordering costs, acceptance costs, storage costs, and expiration costs. Based on these data, the optimal income is calculated by considering the total cost of consumers and the number of expired products decreases.
When \( t = 0 \), product orders come at \( Q \) and the inventory level reaches the maximum point. Then by time, the inventory level starts to decrease with the demand, the demand rate is constant but \( T_1 \) is product time until product expired. The product expired in 3 days. After the product expired it is no longer sold to consumers. Expired products are returned to the producer and sold in kilos as animal feed. When returns are made, the inventory level reaches zero. Stockout occurs during the interval and handle by full backorder because the product returned sent back by the supplier simultaneously with the delivery of company orders in the following period.

Calculation of the optimal acceptances lot size is done in several stages. First, calculating the aggregate demand. The aggregate demand is obtained by determining the conversion factor first. After obtaining the total demand in aggregate units, the next step is to determine the total income. Total income can be obtained by determining the time interval and size of the acceptance of the finished product first. The time interval is obtained from the ratio between the planning cycle (\( T \)) and the frequency of acceptance (\( n \)). Calculation of time intervals can be done using the formula [16]:

\[
\text{Time interval (t)} = \frac{T}{n}
\]

Whereas, to get acceptance lot size for finished products, we must be know the rate of deterioration product began. The using a formula:

\[
\text{Acceptance Lot Size (qB)} = \frac{D}{\theta B} \left[ e^{\theta BT} - 1 \right]
\]

When \( D \) is a product demand for a month, \( \theta B \) is the rate of deterioration for finished products in consumers. Based on the two formulas before, the total cost of consumer will be obtained by multiple time interval of acceptance obtained by the acceptance lot size of the finished product. The next step is to calculate the total cost for the consumer. Total consumer costs are cumulative results from ordering costs, cost of acceptance finished products, cost of storing finished products to consumers, expiration costs to consumers. The equation is obtained for the total cost of consumer (agents) supplies as follows:

\[
TC_A = \frac{A}{T} + F_B x \frac{n}{T} + \left[ \frac{De^{\theta BT} - D + D e^{\theta BT}}{\theta B} \right] \times H_B \times \frac{n}{T} + \left[ \frac{D}{\theta B} (e^{\theta BT} - 1) - D \times t \right] \times P_B \times \frac{n}{T}
\]

\( A \) is the cost of ordering finished products at each order, \( FB \) the cost of acceptance finished products to consumers \( n \) is the number of finished product delivery from producer to the consumer per order \( T \) cycle, \( HB \) is the cost of storing finished products to consumers, and \( PB \) is deterioration finished product cost to consumers.

Ordering cost is all costs that must be incurred when ordering a product. Cost of Product acceptance is all costs that must be incurred when the product has been received by consumers from the agent. The cost of storing finished products is the cost incurred for maintenance, rent, or insurance. 
costs for existing goods/raw materials. Expiration costs are costs incurred by consumers because the goods have passed the lifetime [11]. Based on the value of each of these costs, a total cost will be obtained for consumers so that the optimal amount of product acceptance can be determined by considering the minimum total cost of consumers.

3. Result and Discussion

Agents are first level consumers who obtain goods from producers and distribute them to end consumers. Agents order products to producers marketed to end users. If the agent saves too much product, the inventory of agent is not only minimized because of demand but also because of damage. Figure 2 shows an illustration of agent activity in the supply chain.

The scope of this research is in the consumer (agent). Agents receive certain quantities of products from producers. Consumer markets the product and sells it to end users. Delivery of products from producers to consumers in a fixed amount and fixed delivery intervals. In this study the assumptions used are:

- The planning period is known in monthly terms,
- All orders are assumed to be fulfilled or do not allow for deficiencies,
- Demand rate is known,
- Damage rate is known and constant
- Acceptance Lot size of products from producers to consumers are constant, and
- Assumed to be single items, where different types of existing products aggregated to become the same aggregate unit.

The aggregate demand is used because the model used for single product items. The aggregate demand is demand converted into the same unit of product and the calculation of inventory is easy. Conversion factor is a numerical factor used as a multiplication factor or division of a quantity expressed into a unit or other quantity which is has similarities. The Aggregate demand is calculated by determining the conversion factor, based on the raw material requirements to produce at each product. The aggregate demand is calculated by every demand for finished products on cycle of planning \((T = 1\) month\). Demand at each unit product converted into brownies unit and accumulated. Because the model used is for single product items. The demand at each product is multiplied by each conversion factor and total demand is obtained. The result of total aggregate demand for finished products is amounted to 17,312 brownies units for 30 days. Figure 3 shows the total demand for perishable products in aggregate units for 1 month.
The consumer total cost is equal from orders, inventory cost, acceptance cost, and expired cost for products passed their lifetime. Order cost is cost spent by the consumer when orderi finished products to the manufacturer. This costs includes the cost of contacting the manufacturer, typing orders, delivery orders, and delivery cost. Order cost is assumed to be constant at each message. Acceptance cost of finished products is the cost spent when the consumer receives the finished product from the producer. The storing cost of finished products to consumers is the cost spent by consumers when storing finished products. These costs includes capital accumulation costs related to owning inventory, damage cost and depreciation, inventory handling costs include administrative costs and transfers, cleanliness, labor costs in warehouses, etc.

Expired costs to consumers are costs spent by the consumer when the finished product being expired. Expirated costs are the difference between cost appears from unsold products and returning cost products expires on the value of products expired.

Total income is obtained by determining time interval and the acceptance lot size of finished product by using formula 1 and 2. Determination of interval time is done by trial and error method with the frequency of delivery \( n = 1, 2, 3, \ldots \) etc until the lowest total cost of consumers is obtained. Based on the formula 2, it was found that the acceptance lot size of finished product with frequency of product acceptances 22 times in 30 days amounted to 786.9 unit brownies with optimal total product acceptance of 17.312 unit brownies. The iteration of frequency of order, acceptance lot size and consumer total cost can be seen in Table 1.

Based Table 1, it can be obtained that the optimal consumer total cost is equal to IDR 3,430,756/month with a frequency of acceptance of 22 times of acceptance in one month with a acceptance lot size equal to 786.9 unit brownies.

The amount of consumers actual total cost is IDR 22,116,898 when the total cost of the recommendation consumer is IDR 3,430,756. The consumers actual total cost is greater than the recommendation consumer total cost. The saving obtained with the recommendation model are 84.48%. During this time the agent don’t consider the number of products order and inventory cost of finished product is bigger.

Figure 3. Aggregate Demand of Perishable Product in a Month.
Table 1. Iteration of Acceptance Lot Size and Consumer Total Cost.

| Frequency of Acceptance order (n) | Acceptance Lot Size (qB) in unit | Consumer Total Cost (TC) in IDR |
|-----------------------------------|----------------------------------|---------------------------------|
| 1                                 | 17.312,0                         | 85.488.457                      |
| 2                                 | 8.656,0                           | 39.999.014                      |
| 3                                 | 5.770,7                           | 26.094.788                      |
| 4                                 | 4.328,0                           | 19.362.177                      |
| 5                                 | 3.462,0                           | 15.390.861                      |
| 6                                 | 2.885,3                           | 12.771.305                      |
| 7                                 | 2.473,1                           | 10.913.763                      |
| 8                                 | 2.164,0                           | 9.527.974                       |
| 9                                 | 1.923,5                           | 8.454.481                       |
| 10                                | 1.731,2                           | 7.598.411                       |
| 11                                | 1.573,8                           | 6.899.787                       |
| 12                                | 1.442,6                           | 6.318.831                       |
| 13                                | 1.331,7                           | 5.828.125                       |
| 14                                | 1.236,6                           | 5.408.156                       |
| 15                                | 1.154,1                           | 5.044.656                       |
| 16                                | 1.082,0                           | 4.726.954                       |
| 17                                | 1.018,4                           | 4.446.908                       |
| 18                                | 961,7                             | 4.198.197                       |
| 19                                | 911,2                             | 3.975.841                       |
| 20                                | 865,6                             | 3.775.861                       |
| 21                                | 824,4                             | 3.595.042                       |
| 22                                | 786,9                             | 3.430.756                       |
| 23                                | 752,7                             | 3.680.835                       |
| 24                                | 721,3                             | 3.743.473                       |
| 25                                | 692,5                             | 3.917.156                       |
| 26                                | 665,8                             | 4.049.603                       |
| 27                                | 641,2                             | 4.192.723                       |
| 28                                | 618,3                             | 4.362.585                       |
| 29                                | 597,0                             | 4.599.383                       |
| 30                                | 577,1                             | 4.712.420                       |
The more products ordered, the risk of expired product is greater and also affects the consumers total cost. The frequency of delivery of finished products from producers to consumers is 22 times of delivery in one month, with an interval of 1,364 day delivery. To disaggregated The acceptance lot size to each unit product can using the conversion factors. The conversion factor used for disaggregation must be the same value as the conversion factor used at the time of aggregation. Table 2 shows the results of acceptance lot size disaggregation to units of each product.

Table 2. The Result of Aggregation Item of Acceptance Lot Size.

| Product     | Total demand of product (in unit of brownies) | Acceptance Lot Size (in unit of brownies) | Acceptance Lot Size (in every unit of product) |
|-------------|-----------------------------------------------|------------------------------------------|-----------------------------------------------|
| Round cake  | 3.426                                         | 156                                      | 62                                           |
| Bika ambon  | 8.793                                         | 398                                      | 124                                          |
| Caramel     | 1.905                                         | 87                                       | 35                                           |
| Lapis legit | 3.030                                         | 138                                      | 69                                           |
| Brownies    | 158                                           | 8                                        | 8                                            |
| Total       | 17.312                                        | 787                                      |                                               |

The total demand for each unit is obtained by observing at each proportion of demand for each product. The total demand in aggregate units is multiplied by the percentage of each product unit. The lot size of each unit receipt is obtained from the lot size for aggregate units multiplied by the percentage of each unit. Acceptance lot size is disaggregated into units of each unit based on conversion factors. The conversion factor of round cake and caramel 2.5, bika ambon 3.2, lapis legit 2.0 and brownies 1.0. By using the recommendation policy the amount of product returns has decreased. The old policy of 100% of bread sent 23.2% of bread returned because it was damaged, while using the policy recommendation with the same demand rate parameter the amount of bread returned was 5.77%.

4. Conclusion

Product with a perishable characteristic have finite lifetime. Foods included in perishable items where the value will decrease over time, because the food has an expiration time. The product will have a lower sales value along with the approaching of the lifetime (expiration time), does not even have a sales value overall when the product has expired and the calculation of consumer total cost is needed to minimize consumer cost by considering the frequency of product acceptance. By calculating the total cost of consumers to minimize consumer costs, it is obtained that the optimal total cost of consumers by considering the frequency of product acceptance is equal to IDR 3,430,756/month with a frequency of acceptances of 22 times of acceptances in a month and product acceptance lot size of 787 unit of brownies.

References

[1] Zipkin P H 2000 *Foundations of Inventory Management* (New York: McGraw-Hill)
[2] Ghare P M and Schrader S F 1963 *Journal of Industrial Engineering* 1 (4) 238-243
[3] K Y Joo, K C Soo, H Hark 2003 *Asia Pacific Management Review*, 8 (4) 509-521
[4] Gattorna J L 1998 *Strategic Supply chain Alignment* (Hampshire: Gower)
[5] Fogarty D W, Blackstone J H and Hoffmann T R J 1983 *Production and Inventory Management. 2nd edition* (United States of America: South-Western Publishing Co)
Acknowledgement
The author is very grateful for the support of participants, especially to Universitas Sumatera Utara who have provided funding support for this paper. We also appreciate all participants who contribute financially and non-financially to this paper so that it can be published.