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Research Article

# Inventory Control Model of Beef for Rendang Products

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## A B S T R A C T

The definition and function of inventory management reveal the importance of modern industry in formulating policies that regulate the supply of raw materials, semi-finished products, and finished products. Unfortunately, most companies fail to consider the characteristics of their raw materials when determining inventory strategies. Raw materials that are perishable are those that consider their service life and storage time. Inventory management plays a crucial role in supply chain management, especially for perishable raw materials, such as food products. PT X, a food business in Padang, experienced difficulty in meeting the demand for rendang products due to a lack of raw materials. Therefore, this study aims to develop an inventory management model that takes into account the perishable raw materials' expiration time. The model development consists of three stages: model development design, inventory model formulation, and model testing. The proposed model resulted in a storage time interval of five days and an optimal order quantity of 34 kg of meat with a safety stock of 14 kg. Implementing this model led to lower total inventory costs for PT X than the actual conditions of the company. The total inventory cost obtained using this model is Rp279,797,822. This study emphasizes the importance of considering the characteristics of raw materials in determining inventory strategies to optimize inventory management effectively and efficiently. The study's findings can serve as a reference for other food businesses encountering similar inventory management challenges in the perishable food industry.

## INTRODUCTION

Supply Chain Management (SCM) has become increasingly vital in today's business world as it ensures the optimization of the entire process, from the acquisition of raw materials to the delivery of finished products [1]. Within the SCM domain, inventory management is a critical component that requires careful attention. Inventory management involves the supervision and control of the flow of goods within an organization. It includes activities such as tracking inventory levels, determining the appropriate reorder point, and minimizing excess inventory while ensuring that there is always enough stock to meet customer demand. Effective inventory management can result in reduced costs, increased efficiency, and improved customer satisfaction. SCM plays a crucial role in modern business operations, and inventory management is an essential part of the SCM domain. Effective inventory management can have a significant impact on the overall performance of an organization, making it crucial for businesses to focus on this aspect of their operations [2].

Managing inventory is a complex and challenging task for businesses, requiring a delicate balance between meeting customer demand and minimizing the costs associated with carrying inventory [3]. Inefficient inventory management can lead to issues such as stockouts, excess inventory, and increased costs, all of which can negatively impact the organization's bottom line. Therefore, it is crucial to adopt effective inventory management practices to ensure optimal inventory levels, minimize inventory holding costs, and enhance customer satisfaction [4]. The literature highlights several best practices for inventory management. According to a study by Muchaendepi et al. [5], demand forecasting is a crucial factor in inventory management, as it enables businesses to accurately predict customer demand and plan inventory levels accordingly. The study also found that implementing inventory control policies, such as economic order quantity (EOQ) and just-in-time (JIT) inventory, can help businesses minimize holding costs and reduce the risk of stockouts. Additionally, effective communication and collaboration with suppliers can enable businesses to streamline their supply chain and optimize inventory levels [6].

Perishable items refer to raw materials or products that have a limited shelf life and can spoil or become unusable if not sold or used before their expiration date [7]. These items include fresh produce, dairy products, meats, and other food items, as well as

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pharmaceuticals, cosmetics, and other consumer goods. Perishable items have unique characteristics that make managing their inventory challenging [8]. They are subject to spoilage, deterioration, and obsolescence, and their value diminishes rapidly over time, making it imperative to sell them quickly. One of the primary challenges of managing the inventory of perishable items is demand variability. The demand for perishable items can fluctuate rapidly based on factors such as seasonality, weather, and consumer preferences, making it difficult to predict and plan inventory levels [9]. This can result in excess inventory, which can lead to spoilage and increased holding costs, or stockouts, which can result in lost sales and reduced customer satisfaction. Additionally, perishable items require specific storage conditions, such as temperature and humidity control, which can further complicate inventory management [10].

Several studies have investigated the challenges of managing perishable items and proposed solutions to address them. For example, a study by Weraikat et al. [11] found that implementing demand forecasting models and real-time inventory tracking can help businesses manage perishable items more effectively by predicting demand and reducing excess inventory levels. Another study by Annosi et al. [12] highlighted the importance of collaboration and communication among supply chain partners to optimize inventory levels and reduce waste. These findings suggest that businesses need to adopt a proactive and collaborative approach to managing perishable item inventory, incorporating effective demand forecasting, real-time inventory tracking, and supply chain collaboration.

Recent literature on inventory control of perishable items has focused on identifying effective inventory management strategies that can reduce waste, optimize inventory levels, and improve customer satisfaction. Studies have proposed various approaches to address the unique challenges of managing perishable item inventory, including demand forecasting, real-time inventory tracking, and collaboration among supply chain partners. One approach that has gained attention in recent literature is the use of advanced technologies such as blockchain, RFID, and IoT to enhance inventory management of perishable items [13]. For example, a study by Li et al. [14] proposed a blockchain-based solution to address the challenges of managing perishable item inventory, enabling real-time tracking and monitoring of inventory levels, reducing waste, and enhancing supply chain transparency.

Another focus of recent literature on perishable item inventory control is the role of collaboration and communication among supply chain partners. Studies have highlighted the importance of effective collaboration in enhancing supply chain efficiency, reducing waste, and improving inventory management. For instance, a study by Manzouri et al. [15] emphasized the need for collaboration among retailers, wholesalers, and suppliers to optimize inventory levels, reduce waste, and improve customer satisfaction. Despite the recent advancements in perishable item inventory control, there is a significant research gap regarding the effectiveness of these strategies in diverse industries and contexts. Previous studies have primarily concentrated on general industries and have not delved into the feasibility of these strategies in specific contexts, such as the food industry. Therefore, forthcoming research may investigate the effectiveness of these specialized industries and contexts to determine the most efficacious strategies for perishable item inventory control.

Meat inventory is a unique type of perishable item that requires special attention due to its distinct characteristics. According to Saleheen et al. [16] the perishability of meat products is one of the most significant challenges in inventory management. Meat has a short shelf life and is prone to spoilage due to various factors such as temperature, humidity, and exposure to oxygen. The authors suggest that effective inventory management strategies should focus on minimizing the time between production and consumption to ensure the freshness and safety of meat products. In addition to perishability, the variability in demand and supply is another challenge in meat inventory management. According to Chaudharyet al. [17], the demand for meat products can fluctuate due to various factors such as seasonality, consumer preferences, and economic conditions. The supply of meat can also be affected by factors such as weather conditions, disease outbreaks, and transportation disruptions. The authors propose a stochastic inventory control model that takes into account the variability in demand and supply to optimize the inventory levels of meat products.

Furthermore, compliance with regulations related to food safety, labeling, and traceability is another critical aspect of meat inventory management. According to Kotsanopoulos and Arvanitoyannis [18], regulations such as the Food Safety and Inspection Service (FSIS) in the United States, require strict compliance with standards for meat production, labeling, and packaging to ensure its safety and quality. The authors suggest that effective meat inventory management should include robust tracking and monitoring systems to ensure compliance with regulations. In conclusion, the unique characteristics of meat inventory, including perishability, variability in demand and supply, and compliance with regulations, make it challenging to manage effectively. Effective inventory management strategies for meat products should consider these challenges and develop specialized approaches to ensure the freshness, safety, and compliance of meat products [19].

Several recent studies have investigated inventory control strategies for meat/beef products. In a study by Moghaddam et al. [20], the authors proposed a mathematical model to optimize the inventory control of beef products in a supply chain network. The model considers factors such as lead time, demand uncertainty, and storage capacity to minimize the total cost of inventory while ensuring adequate availability of beef products. Another study by Sebatjane and Adetunji [21] investigated the impact of supply chain integration on the inventory control of meat products. The authors found that integrating the supply chain can improve the visibility of demand and supply information, reduce lead times, and improve inventory control performance. They also suggested that the use of advanced technologies such as the Internet of Things (IoT) can improve the accuracy of demand forecasting and facilitate real-time inventory management.

In a study by Herbon et al. [22], the authors proposed a dynamic pricing strategy for fresh meat products to improve inventory control performance. The strategy uses a machine learning algorithm to predict demand and adjust prices accordingly to optimize inventory levels and reduce waste. The authors found that the dynamic pricing strategy significantly improved inventory turnover and profitability for the meat retailer. Similarly, Gredell et al. [23] proposed a predictive inventory control system for beef products using a deep learning algorithm. The system predicts demand and inventory levels based on historical data and adjusts inventory levels accordingly to reduce waste and improve availability. The authors found that the predictive inventory control system significantly improved inventory performance compared to traditional inventory management approaches.

One recent study by Suryani et al. [24] evaluated the effectiveness of a dynamic simulation model in optimizing beef inventory management in traditional markets in Indonesia. The study found that the developed dynamic simulation model can help improve the effectiveness of beef inventory management in traditional markets. This model can be used to identify the critical factors affecting the effectiveness of beef inventory management in traditional markets. By using the model, traditional market managers can make informed decisions to manage the inventory of beef products efficiently and effectively.

Overall, these studies suggest that inventory control for meat/beef products can be optimized using advanced mathematical models, supply chain integration, and predictive analytics. However, a gap in the literature is the limited consideration of the impact of external factors such as meat expiration date and temperature conditions on meat inventory control. Future research could explore the integration of external factors into inventory control models to improve the accuracy and effectiveness of meat inventory management. The main objective of the proposed idea of developing an inventory model for the case of meat/beef inventory control is to improve the efficiency and effectiveness of meat/beef inventory management. By using the appropriate inventory model, the aim is to optimize the inventory level, reduce inventory costs, and prevent losses due to spoilage. The development of a good inventory model can assist companies in making more accurate decisions in procuring and storing meat/beef inventory, which can improve overall company performance and profitability. The literature review will be used to identify and select suitable inventory models, and the resulting model will be used to address the inventory control issues.

## METHOD

PT X is a food business located in Padang City, West Sumatra, which was established in 1978. The company is a Limited Liability Company (PT). PT X produces catering food for various events and also sells typical West Sumatran cuisine. PT X sells various rendang products such as beef rendang, lung rendang, meatball rendang, and beef jerky. Based on interviews conducted with staff at PT X, it was found that the company was unable to fulfill the demand for rendang products during a certain period in 2019 and 2020 due to the unavailability of meat. PT X does not store beef as it values the freshness of the rendang meat, and therefore the shortage of raw materials is due to the absence of a stock policy for the primary raw material for rendang, which is meat. The lack of a policy regarding the supply of raw materials for rendang is due to concerns about expiration, which may result in losses if the meat cannot be used anymore.

The production of rendang requires raw meat materials that are susceptible to damage, such as rotting and losing nutritional content. However, storing raw meat supplies is still possible. Fresh meat can last 2-3 days at temperatures below four °C (in the chiller), and it should be placed in the freezer at -18°C for longer storage. At a temperature of -18°C to -23°C, the meat can last up to three months. If stored correctly, the meat will remain durable and fresh when used after the storage period. Another factor contributing to PT X's inability to meet the demand for rendang products is fluctuating customer demand. Sales data for PT X's rendang products in 2019, as shown in Figure 1, indicate that sales increased in January and March, decreased from April to July, and then increased again from September to December.

The majority of processing industries, particularly the food processing industry, face challenges related to raw material control. The expiration date of raw materials is a crucial factor that must be considered in controlling the quality and safety of food products. As most raw materials in the food industry have a limited lifespan, it is essential to maintain strict inventory control measures to ensure that the raw materials are used before they expire. To address this issue, a raw material inventory control model is needed that can provide optimal inventory control results for materials with a limited lifetime. This model will help food processing companies manage their raw material inventory effectively, minimizing waste and reducing the risk of producing unsafe products. By implementing this model, food processing companies can improve their production efficiency and maintain high product quality standards, which is essential for customer satisfaction and long-term success in the industry. The methodology of this research was conducted in three stages.

### *Stage 1: Model Development Design*

The model design stage begins with calculating the optimal order interval (T). This T value is influenced by demand, holding cost, order cost, and expiration time. This holding cost is influenced by storage and labor costs. After that, search for the value of Q and the value of r. The search for the value of r is influenced by quantity, lead time, and shelf life.

The basic model used in this study is a model that has been developed in previous research by Prasetyo et al. [25]. The rationale for adopting the model is that it has been developed to consider the expiration date and unit discount factor in inventory control of raw materials. In their research, Prasetyo et al. [25]

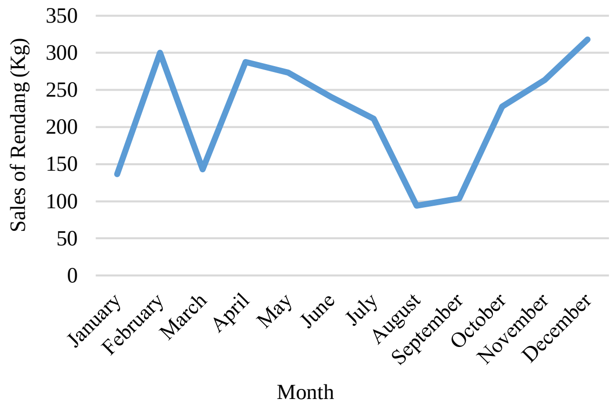


Figure 1. Sales of Rendang at PT X


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proposed a raw material inventory control model that considers the expiration date. The model aimed to provide optimal inventory control results for raw materials with a limited lifetime, taking into account the possibility of losses due to expiration.

The justification for using the model proposed by Prasetyo et al. [25] in the current research is that the inventory problem being addressed in this study involves raw materials with a limited lifespan, which is similar to the focus of the previous research. Furthermore, the consideration of expiration date in the model is also relevant to the inventory control problem being addressed in the current study. Therefore, the model is well-suited for addressing the inventory problem in this research. The elaboration of the models led to a proposed model that aims to minimize the total inventory cost by considering the lifespan of the meat. The model parameters utilized for this inventory problem are presented in Table 1.

The perishable item inventory model developed in this study takes into account the expiration time of materials to minimize the total inventory cost. The expiration time of raw materials is assumed to be deterministic and based on the company's standards. The total cost (TC) is the overall cost incurred by the company throughout its business activities, from purchasing raw materials from suppliers to producing output products. For an inventory system that considers the expiration time of materials, the total cost is the sum of the costs of the existing inventory. The basic model for the perishable item inventory is presented as follows:

$$C_p = D.P \quad (1)$$

$$C_o = \frac{SD}{Q} \quad (2)$$

$$C_s = \frac{P.h.(Q^2 - Q_{kd}{}^2)}{2Q} \quad (3)$$

$$C_{kn} = \frac{C_k \, .Q_{kd}{}^2}{2Q} \quad (4)$$

$$C_{kd} = \frac{Q_{kd} \, .P \, .D}{Q} \quad (5)$$

$$TC = C_p + C_o + C_s + C_{kn} + C_{kd} \quad (6)$$

$$TC\,(Q, Q_k) = P.D + \frac{S.D}{Q} + \frac{P.h.(Q^2 - Q_{kd}{}^2)}{2Q} + \frac{C_k \, .Q_{kd}{}^2}{2Q} + \frac{Q_{kd} \, .P \, .D}{Q} \quad (7)$$

$$Q^* = \sqrt{\frac{2SD - P_i h Q_{kd}{}^2 + C_k Q_{kd}{}^2 + 2Q_{kd}{}^2 P_i D}{P_h}} \quad (8)$$

$$Q_{kd} = \frac{-\,P\,.D}{P_h - C_k} \quad (9)$$

$$Q^* = \sqrt{\frac{2SD - P_i h(\frac{-\,P\,.D}{P_h - C_k})^2 + C_k(\frac{-\,P\,.D}{P_h - C_k})^2 + 2(\frac{-\,P\,.D}{P_h - C_k})^2 P_i D}{P_h}} \quad (10)$$

### *Stage 2: Inventory Model Formulation*

The model development carried out in this study used several references for the model. The following explains some regards the proposed perishable product inventory control model. Presetyo et al. [25] developed an inventory system model that considers expiration and lifetime constant. The model has the aim of minimizing the total cost.

The purpose of developing this model is to determine the storage period of meat that can minimize the cost of meat inventory and the quantity of meat purchased. The following is the development of the total cost calculation model used to obtain the total cost of inventory using the basic model with a policy of considering the expiration time of meat and finding the length of time during $t_1$. The principle of similarity can be used and seen in Figure 2.

To find the length of time during $t_1$, obtain the following equation:

$$\frac{Q}{t} = \frac{Q - Q_{kd}}{t_1} \quad (11)$$

$$t_1 Q = t(Q - \ Q) \quad (12)$$

$$t_1 = \frac{t(Q - Q_{kd})}{Q} \quad (13)$$

Table 1. Model Parameters and Notation

| **Parameter** | **Nota-tion** |
|---|---|
| Optimum order quantity of meat (kg) | Q |
| Amount of expired meat (kg) | $Q_{kd}$ |
| Meat purchase price (Rp/Kg) | P |
| Total demand for meat in one period (kg/year) | D |
| Ordering fee for each order placed (Rp/order) | S |
| One planning period (year) | T |
| *Meat delivery lead time (years)* | L |
| *Safety stock* (Kg) | ss |
| Meat order time interval (years) | t |
| Expiration time/meat storage period before expiration (years) | $t_1$ |
| Period of meat shortage (years) | $t_2$ |
| Meat storage cost fraction (Rp/kg/year) | h |
| Purchase costs for one planning period (Rp/year) | $C_p$ |
| Ordering costs for one planning period (Rp/year) | $C_o$ |
| Storage cost for one planning period (Rp/year) | $C_s$ |
| Shortage costs during one planning period (Rp/year) | $C_{kn}$ |
| Expiration fee during one planning period (Rp/year) | $C_{kd}$ |
| Expiration fee during one planning period (Rp/year) | $C_k$ |
| Standard deviation | $S_d$ |

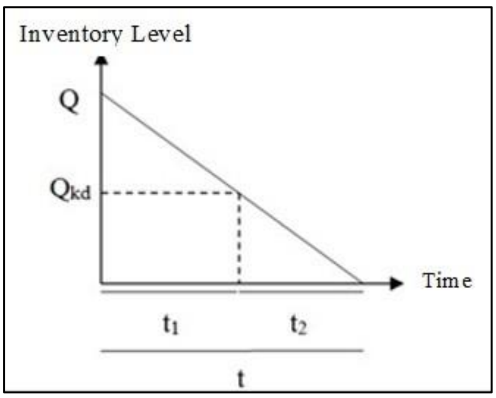


Figure 2. Principle of Inventory Congruence [26]

Since $t = \frac{Q}{D}$, the equation can be written as:

$$t_1 = \frac{\frac{Q}{D}(Q - Q_{kd})}{Q} \quad (14)$$

The length of time during $t_2$ can be found using $t = t_1 + t_2$ because and $t = \frac{Q}{D}$ and $t_1 = \frac{Q - Q_{kd}}{D}$, then

$$t_2 = \frac{Q_{kd}}{D} \quad (15)$$

Because $t_1$ is known, finding Q and $Q_{kd}$ can be explained as follows:

$$t = \frac{Q}{D} \quad (16)$$

$$Q = t.D \quad (17)$$

$$\frac{Q}{t} = \frac{Q - Q_{kd}}{t_1} \quad (18)$$

By substituting equation (17), we get the following equation:

$$Q_{kd} = (t.D) - D.t_1 \quad (19)$$

Find the total cost can be done using the following equation:

Unit Cost ($C_p$)

$$C_o = \frac{S}{t} \quad (20)$$

Holding Cost ($C_s$)

$$C_s = \frac{2.P.h.t.D.t_1}{2t} + \frac{P.h.D.{t_1}^2}{2t} + P.h.Z_\alpha S_d \sqrt{L} \quad (21)$$

Shortage Cost ($C_{kn}$)

$$C_{kn} = \frac{C_k.D.t^2}{2t} - \frac{C_k.t.D.t_1}{2t} + \frac{C_k.D.{t_1}^2}{2t} \quad (22)$$

Expiration Cost ($C_{kd}$)

$$C_{kd} = P.D - \frac{P.D.t_1}{t} \quad (23)$$

Total Inventory Cost (TC)

$$TC = P.D + \frac{S}{t} + \left(\frac{2.P.h.t.D.t_1}{2t} + \frac{P.h.D.{t_1}^2}{2t} + P.h.Z_\alpha S_d \sqrt{L}\right) + \left(\frac{C_k.D.t^2}{2t} - \frac{C_k.t.D.t_1}{2t} + \frac{C_k.D.{t_1}^2}{2t}\right) + \left(P.D - \frac{P.D.t_1}{t}\right) \quad (24)$$

To obtain the optimum storage period T, TC is derived with respect to t. The first derivative of TC with respect to t is equated to zero, and the optimal value of T is obtained.

$$t = \sqrt{\frac{2.S + P.h.{t_1}^2.D + C_k.D.{t_1}^2 - 2.P.D.t_1}{C_k.D}} \quad (25)$$

The purpose of model verification is to check the logic of the model for its suitability. This is done by testing the model dimensions, where the aim is to ensure that the output dimensions are suitable for the inputs.

### *Stage 3: Model Testing*

The testing phase involves performing verification and validation to test the designed model. Model verification is carried out to verify and confirm the developed model's accuracy. The aim of this verification process is to provide objective evidence, which can be achieved through tests using the unit equation. Validation, on the other hand, represents the final stage of modeling, where the designed model is tested to demonstrate that it accurately represents the entire system. Following verification and validation, the model is then applied to the study case. Model verification is carried out to check the suitability of the model logic. Model verification is done by testing the dimensions of the model. Verification aims at the suitability of the output dimensions with the inputs.

## RESULTS AND DISCUSSION

### *Model Dimension Verification*

A Dimensional test is helpful to ensure the output's dimensions with the input. The model dimension test consists of the following:

*Unit Cost ($C_p$)*

$$C_p = P.D$$

$$\text{Rupiah/Year} = \frac{\text{Rupiah}}{\text{Kg}} \text{ x } \frac{\text{Kg}}{\text{Year}}$$

$$\text{Rupiah/Year} = \text{Rupiah/Year}$$

*Ordering Cost (Co)*

$$C_o = \frac{S}{t}$$

$$\text{Rupiah/Year} = \frac{\text{Rupiah}}{\text{Year}}$$

*Holding Cost (Cs)*

$$C_s = \frac{2.P.h.t.D.t_1}{2t} + \frac{P.h.D.{t_1}^2}{2t} + P.h.Z_a S_d \sqrt{L}$$

$$\frac{\text{Rupiah}}{\text{Year}} = \frac{\frac{\text{Rupiah}}{\text{Kg}} \text{x} \left(\frac{\frac{\text{Rupiah}}{\text{Kg}}}{\text{Year}}\right) \text{x Year x} \frac{\text{Kg}}{\text{Year}} \text{ x Year}}{\text{Year}} + \frac{\frac{\text{Year}}{\text{Kg}} \text{x} \left(\frac{\frac{\text{Rupiah}}{\text{Kg}}}{\text{Year}}\right) \text{x } \frac{\text{Kg}}{\text{Year}} \text{x Year}^2}{\text{Year}} + \frac{\text{Rupiah}}{\text{Kg}} \text{x} \left(\frac{\frac{\text{Rupiah}}{\text{Kg}}}{\text{Year}}\right) \text{x} \frac{\text{Kg}}{\text{Year}} \text{x Year}$$

$$\text{Rupiah/Year} = \text{Rupiah/Year}$$

*Shortage Cost (Ckn)*

$$C_{kn} = \frac{C_k.D.t^2}{2t} - \frac{C_k.t.D.t_1}{2t} + \frac{C_k.D.{t_1}^2}{2t}$$

$$\text{Rupiah/Year} = \frac{\frac{\text{Rupiah}}{\text{Kg}} \text{x} \frac{\text{Kg}}{\text{Year}} \text{x Year}^2}{\text{Year}} - \frac{\frac{\text{Rupiah}}{\text{Kg}} \text{x Year x} \frac{\text{Kg}}{\text{Year}} \text{x Year}}{\text{Year}} + \frac{\frac{\frac{\text{Rupiah}}{\text{Kg}} \text{xKg}}{\text{Year}} \text{xYear}^2}{\text{Year}}$$

$$\text{Rupiah/Year} = \text{Rupiah/Year}$$


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*Expiration Cost ($C_{kd}$)*

$$C_{kd} = P.D - \frac{P.D.t_1}{t}$$

$$\frac{\text{Rupiah}}{\text{Year}} = \frac{\text{Rupiah}}{\text{Kg}} \text{ x } \frac{\text{Kg}}{\text{Year}} - \frac{\frac{\text{Rupiah}}{\text{Kg}} \text{x} \frac{\text{Kg}}{\text{Year}} \text{x Year}}{\text{Year}}$$

Rupiah/Year = Rupiah/Year

*Total Inventory Cost (TC)*

$$TC = C_p + C_o + C_s + C_{kn} + C_{kd}$$

$$\frac{\text{Rupiah}}{\text{Year}} = \frac{\text{Rupiah}}{\text{Year}} + \frac{\text{Rupiah}}{\text{Year}} + \frac{\text{Rupiah}}{\text{Year}} + \frac{\text{Rupiah}}{\text{Year}} + \frac{\text{Rupiah}}{\text{Year}}$$

Rupiah/Year = Rupiah/Year

### *Mathematical Model Validation*

Validation is a stage in model development that is performed to demonstrate that the designed model accurately represents the actual system. In the case of the meat inventory model used in rendang production at PT X, validation was achieved through construction validity. The model was approved by the company because it aligned with the company's existing system. The stages of construction validity are presented in Table 2.

The following data is used to calculate the meat inventory using a perishable item inventory model:

Meat demand (D) : 2,439 kg
Meat price (P) : Rp110,000/kg
Ordering cost (S) : Rp23,720
Inventory holding cost rate (h): 15%
Shelf life : 30 days = 0.083 years
Lead time : 1 day = 0.0027 years
Standard deviation : 8.09 kg/day

Table 2. Model Validation

| Description | Conclusion |
|---|---|
| • System characteristics<br>The system under discussion pertains to the determination of meat supply characteristics, which includes various components such as the number of requests and inventory cost data. | It has been entered and listed in the model. |
| • Objective of the model determination<br>The objective of this study is to minimize the total cost of raw material inventory, which includes ordering costs, holding costs, lost sales, and expiration costs, for the production of Rendang at PT X. | It has been employed as the objective function of the model. |
| • Constraints to be satisfied<br>The constraints related to the determination of raw material inventory have been included in the model as constraints. | It has been included as a constraint function in the model. |
| • Decisions to be made<br>The determination of raw meat supply for Rendang production at PT X is based on varying consumer demands. | It has been incorporated in the model as a decision variable. |

*Order Quantity ($q_0$)*

$$t = \sqrt{\frac{2.S + P.h.{t_1}^2.D + C_k.D.{t_1}^2 - 2.P.D.t_1}{C_k.D}}$$

$$t = \sqrt{\frac{(2 \; x \; Rp23.720) + (Rp135.500 \; x \; 15\% \; x \; 0{,}083^2.2439) + (Rp110.000 \; x \; 90 \; x \; 2439 \; x \; 0{,}083^2) - 2 \; x \; Rp110.000 \; .0{,}083}{Rp135.500 \; x \; 20 \; x \; 2439}}$$

$$t = \sqrt{0{,}000193}$$
$$t = 0{,}0139 \; years$$
$$t = 5{,}01 \; days \; \approx 5 \; days$$

$$Q = t.D$$
$$Q = 0{,}00139 \; x \; 2439$$
$$Q = 33{,}9 \; kg \; \approx 34 \text{ kg}$$

This value indicates the optimal meat order quantity to the supplier. However, this quantity cannot be considered as the optimal order quantity because the meat's shelf life of 30 days is only a constraint in the inventory model calculation, and iterative calculations are required to determine the optimal quantity. Therefore, an order quantity of 5 kg is used as a starting point for recalculating to obtain an approximation of the optimal value. The results of the iterative calculations are shown in Table 3.

Based on Table 3, it is found that the minimum total cost generated at t-value of 5 is Rp279,797,822. This result is consistent with the order quantity obtained using the model. Therefore, the order quantity used in this study is 34 kg for a single order with a storage time of 5 days.

*Safety Stock (SS)*

$$\text{SS} = Z_\alpha S_d \sqrt{\text{L}}$$
$$\text{SS} = 1{,}65 \text{ x } 8{,}08 \text{ x } \sqrt{1}$$
$$\text{SS} = 13{,}34 \; \approx 14 \text{ kg}$$

This value indicates the safety stock that a company must maintain to cope with a daily increase in consumer demand of 14 kg. The total inventory cost is the sum of the purchase cost, ordering cost, and holding cost. The calculation of the total inventory cost can be seen as follows:

Unit Cost ($C_p$)

$$C_p = P.D$$
$$C_p = Rp110.000 \; x \; 2448$$
$$C_p = Rp269.280.000$$

Ordering Cost ($C_o$)

$$C_o = \frac{S}{t}$$
$$C_o = \frac{Rp23.720}{0{,}0137}$$
$$C_o = Rp1.698.710$$

Holding Cost ($C_s$)

$$C_s = \frac{2.P.h.t.D.t_1}{2t} + \frac{P.h.D.{t_1}^2}{2t}$$

Table 3. Testing of t-Value by Calculating Total Inventory Cost

| t (Day) | t (Year) | Q | The amount of purchases (Kg) | Unit Cost | Ordering Cost | Holding Cost | Shortage Cost | Expiration Cost | Total Inventory Cost |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0027 | 7 | 2443 | Rp268,730,000 | Rp8,493,550 | Rp1,159,610 | Rp20,804,841 | Rp0 | Rp299,188,001 |
| 2 | 0.0055 | 14 | 2450 | Rp269,500,000 | Rp4,246,775 | Rp2,296,116 | Rp9,718,819 | Rp0 | Rp285,761,710 |
| 3 | 0.0082 | 21 | 2457 | Rp270,270,000 | Rp2,831,183 | Rp3,424,922 | Rp6,045,530 | Rp0 | Rp282,571,635 |
| 4 | 0.0110 | 27 | 2457 | Rp270,270,000 | Rp2,123,388 | Rp4,549,877 | Rp4,225,423 | Rp0 | Rp281,168,688 |
| 5 | 0.0137 | 34 | 2448 | Rp269,280,000 | Rp1,698,710 | Rp5,672,522 | Rp3,146,590 | Rp0 | Rp279,797,822 |
| 6 | 0.0164 | 41 | 2460 | Rp270,600,000 | Rp1,415,592 | Rp6,793,626 | Rp2,438,394 | Rp0 | Rp281,247,612 |
| 7 | 0.0192 | 47 | 2491 | Rp274,010,000 | Rp1,213,364 | Rp7,913,631 | Rp1,941,990 | Rp0 | Rp285,078,985 |
| 8 | 0.0219 | 54 | 2511 | Rp276,210,000 | Rp1,061,694 | Rp9,032,810 | Rp1,577,956 | Rp0 | Rp287,882,460 |
| 9 | 0.0247 | 61 | 2532 | Rp278,465,000 | Rp943,728 | Rp10,151,348 | Rp1,302,169 | Rp0 | Rp290,862,244 |
| 10 | 0.0274 | 67 | 2546 | Rp280,060,000 | Rp849,355 | Rp11,269,372 | Rp1,088,155 | Rp0 | Rp293,266,882 |

$$C_s = \frac{2\,x\,Rp110.000\,x\,15\%\,x\,0,011\,x\,2448\,x\,0,083}{2\,x\,0,0137} + \frac{Rp110.000\,x\,15\%\,x\,2448\,x\,0,083^2}{2\,x\,0,0137}$$

$$C_s = Rp5.672.522$$

Shortage Cost ($C_{kn}$)

$$C_{kn} = \frac{C_k.D.t^2}{2t} - \frac{C_k.t.D.t_1}{2t} + \frac{C_k.D.t_1{}^2}{2t}$$

$$C_{kn} = \frac{Rp110.000\,x\,2448\,x\,0,011^2}{2\,x\,0,0137} - \frac{Rp110.000x\,0,011\,x\,2448\,x\,0,083}{2\,x\,0,0137} + \frac{Rp110.000\,x\,2448\,x\,0,083^2}{2\,x\,0,0137}$$

$$C_{kn} = Rp3.146.590$$

Expiration Cost ($C_{kd}$)

$$C_{kd} = P.D - \frac{P.D.t_1}{t}$$

$$C_{kd} = Rp110.000\,x\,2448 - \frac{Rp110.000\,x\,2448\,x\,0,0137}{0,0137}$$

$$C_{kd} = 0$$

Total Inventory Cost (TC)

$$TC = C_p + C_o + C_s + C_{kn} + C_{kd}$$

$$TC = Rp269.280.000 + Rp1.698.710 + Rp5.672.522 + Rp3.146.590 + Rp0$$

$$TC = Rp279.797.822$$

The inventory of meat used for rendang production must be well-planned to support the production process carried out by PT X. A mathematical model of perishable item inventory is developed to control the inventory of meat to minimize inventory costs. The model is required to comply with the existing system at PT X. The expiration time of meat used in this study is 30 days. This time is obtained from expert interviews and also from the standard equipment used by PT X. The equipment used to store meat is a freezer, and the standard meat storage time is 30-90 days. Therefore, to maintain the quality of the meat, the minimum storage time used is 30 days.

The present study employs a perishable item inventory model with a time constraint of 30 days expiration. Therefore, if the obtained value of t is less than 30 days, the model will identify no expired meat and yield a value of 0 as demonstrated in Table 3. The perishable item inventory model is applicable provided all necessary data is obtainable. The data required for the model comprises of customer demand for rendang products, while the parameters employed in the model include purchase cost, ordering cost, holding cost, expiration cost, shortage cost, expiration time, and lead time.

The perishable item inventory model developed has several advantages and disadvantages. The advantages of this model are its ability to determine the meat storage interval that considers five cost aspects, namely purchase cost, holding cost, ordering cost, expiration cost, and shortage cost. Furthermore, this model also considers the meat expiration time. Unlike previous models, this model considers the purchase, ordering, and holding costs. The disadvantage of this model is that the expiration time used is still deterministic.

The perishable item raw material inventory system model has considered the expiration time and can be used by food industries, both food production and food distribution companies. Apart from the food industry, this model can also be applied to industries that produce products using perishable raw materials. This model can help companies design inventory systems to reduce the amount of expired raw materials, which can result in costs incurred by the company. Currently, the inventory system implemented by PT X does not involve storing meat for rendang production. Instead, the meat is ordered directly from suppliers and produced into rendang on the same day. This eliminates the cost of storage for meat, but increases the cost of ordering since it is done every day when producing rendang.

The company's purchasing policy for meat is based solely on estimated consumer demand. Purchases are made every day with varying amounts, resulting in no specific measurement for the amount of purchase. The development of the perishable item inventory model has provided the company with a profitable solution. The output of this model is the optimal amount of meat to be ordered and the storage interval for the meat. This model uses various parameters such as purchase cost, ordering cost, holding cost, expiry cost, shortage cost, and meat expiration time to determine the storage interval for meat. This storage interval is

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then used as an input to determine the optimal amount of meat to be ordered from suppliers. The goal of this model is to minimize the cost of meat inventory.

The actual inventory cost amounts to Rp302,688,640, while the inventory cost using the model totals Rp279,797,822. These results indicate that the actual inventory cost is higher compared to the inventory cost using the model. The model's lower inventory cost is due to its ability to minimize inventory shortages, even with perishable items that may expire due to fluctuating demand. Inventory shortage costs occur when there is a demand from consumers but the company does not have the necessary inventory of meat, which results in the inability to produce rendang. Therefore, it can be concluded that the implementation of the perishable item inventory model can address the inventory shortage problems at PT X since the company does not have an inventory system in place in actual conditions.

## CONCLUSION

In conclusion, this research successfully achieved its aim of developing a mathematical model for determining meat inventory for rendang production with the goal of minimizing inventory costs. The model incorporates various inventory costs, including purchase, order, holding, expiration, and stockout costs, and considers the expiration time of the meat. The study provides practical recommendations to PT X in its production process by resulting in a storage time interval of 5 days and an optimal order quantity of 34 kg of meat with a safety stock of 14 kg, leading to lower total inventory costs compared to actual conditions of the company. The developed inventory model has significant implications for PT X's inventory management and decision-making processes. By considering all relevant inventory costs and the expiration time of the meat, PT X can effectively manage its meat inventory levels to meet customer demand while minimizing inventory holding costs. Moreover, this study can serve as a reference for other food companies in the perishable food industry that face similar inventory management challenges. Future studies can extend the proposed model to other perishable food products or consider other relevant factors, such as seasonality or demand variability, to provide more comprehensive solutions to inventory management problems. In summary, this research provides a valuable contribution to the industrial engineering-related domain by offering practical and applicable solutions to inventory management challenges in the perishable food industry.

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## NOMENCLATURE

| | |
|---|---|
| Q | Optimum order quantity of meat (kg) |
| $Q_{kd}$ | Amount of expired meat (kg) |
| P | Meat purchase price (Rp/Kg) |
| D | Total demand for meat in one period (kg/year) |
| S | Ordering fee for each order placed (Rp/order) |
| T | One planning period (year) |
| L | *Meat delivery lead time (years)* |
| ss | *Safety stock* (Kg) |
| t | Meat order time interval (years) |
| $t_1$ | Expiration time/meat storage period before expiration (years) |
| $t_2$ | Period of meat shortage (years) |
| h | Meat storage cost fraction (Rp/kg/year) |
| $C_p$ | Purchase costs for one planning period (Rp/year) |
| $C_o$ | Ordering costs for one planning period (Rp/year) |
| $C_s$ | Storage cost for one planning period (Rp/year) |
| $C_{kn}$ | Shortage costs during one planning period (Rp/year) |
| $C_{kd}$ | Expiration fee during one planning period (Rp/year) |
| $C_k$ | Expiration fee during one planning period (Rp/year) |
| $S_d$ | Standard deviation |

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