Development of a Three-Phase Inventory Management Model for Perishable Products (Chili) by Considering Quality Deterioration

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Abstract

One of the challenges faced by the food industry when managed supplies are perishable products. Perishable products are products that have a short lifetime. A short lifetime will make a decrease in value over time. The problem with inventory management for perishable products is how to determine the amount of supply needed to used/stored before the product's life runs out and will achieve profit maximization. In this research, an inventory management model product will make by doing a renewal process. This model has three inventory phases. Each phase stores a different type of product, where inventory in the first phase will change to the second phase through a specific process. The renewal process is to change a product in the previous phase and becomes a different product in the next phase. By doing the renewal process, the rest of the product from the previous phase can be used and not wasted. The purpose of doing the renewal process is to extend product lifetime. The problem in this study will perform in several case scenarios that can represent real system conditions. It also can prove that doing the renewal process can provide higher profits.

Keywords
Inventory Management, Quality Deterioration, Perishable Products, Renewal Process.

1. Introduction

The biggest challenge that will be faced by the food industry that requires the supply of perishable products. How to determine the amount of supply needed to be used/stored before the age of the product runs out. The quality of perishable products is one of the characteristics that need to be considered in a supply chain (Sahin et al. 2007). Some research on inventory management has already done before. The development of an optimal inventory management model with consideration of late payments has been carried out by (Sahin et al. 2007; Ibrahim 2018). Ibrahim (2018) has also developed a supply model with consideration of gas emissions. Other research determines optimal inventory for perishable products with a single vendor and multi buyers system (Chen 2018). Other research states that by integrating production and distribution, the results will depend on the level of freshness of the product when distributing. How can the minimization of supply costs be achieved, which includes costs incurred due to damaged products (Amorim et al. 2012).

Inventory management problems will become more complicated if the product under study is perishable. Perishable products have a limited lifetime. The quality of their products will decline from time to time. Duration of time and temperature influence the level of freshness for perishable products (Song and Ko 2016). The customers (more than 50%) would check the expiration date before buying a product (Tsiros and Heilman 2005). In order to guarantee safety and quality and produce optimum profits, managers of perishable product supply chains must have a strong commitment (Wang and Li 2012). Not all food will improve in quality when stored (except wine and cheese). Quality loss detects by smell, taste, touch, or visual. This change happens because of several factors, such as oxygen, humidity, light, microbial growth, and temperature (Tanner 2016).

Fresh vegetables that have the best nutrition will obtain when vegetables are harvested and will be reduced over time until the vegetables rot. The quality of a vegetable product is worth 100% when the product already sold at normal prices. Conversely, the quality of vegetable products is 0% when the product has no commercial value (Osvald and Stirn 2008). Fruits also included in perishable products. The vitamin content in fruit can decrease as long as the product is stored.

In practice, it is common methods to maintain the quality of perishable products, including by cooling, drying, and salting process. The low temperature used in cold storage will increase the shelf life of the product becomes longer. With the use of cold storage will have an impact on the high use of energy needed (Zanoni and Zavanella 2012). Other studies provide proof that the salting process can extend the life of the product by using an example of Kimchi products in the research (Shin et al. 2019). Another process to extend the lifetime of a perishable product is drying. The purpose of the drying process is not only to reduce the volume and weight of the product but also to extend the life of the product (Aktas et al. 2007).

In this research, develop an inventory management model for perishable products with the renewal process. This model has three phases of inventory, and each phase stores a different type of product. Where inventory in the first phase will change to the second phase through a specific process. Products in the second phase will change into products in the third phase. The process in this research referred to as the renewal process. Renewal means changing something into something new. So the product in the previous phase will be processed/change and becomes a different product in the next phase. With the renewal process, the product from the previous phase can be used and not wasted. The purpose of the renewal process is to extending product life.

The problem in this research will be more complex because it determines the supply with different types in each phase. It also determines the number of products to directly enter the renewal process to become a product in phase two and phase three. Consideration of quality degradation is needed. Because this model develops for perishable products, where time affects the level of product quality. Three products in each phase have a different shelflife, and it will determine how long the product will be stored. Shelflife is also used to count the number of products wasted. The remaining inventory during the storage period will decrease in quality. This decrease in product quality will affect the selling price of the product. This model will provide an optimal number of supply decisions with the aim of profit maximization. Consider the level of product quality reduction for all three types of products.

2. Methodology

This research is design as an inventory management system model for perishable products. This model will provide solutions to meet demand and extend product shelflife. Inventory management model design becomes essential for perishable products. Because of the quality degradation that occurs in the product will affect the selling price of the product.

2.1. Initial Preparation

In the initial preparation, it is a need to prepare everything related to research. The first thing to do is to study literature in order to get information about the problems to examine. Then develop the conceptual model for management inventory problem. The mathematical model for the inventory management model already done, and then a numerical calculation will be performed with deterministic data. Then the results of numerical calculations will be analyzed and obtained conclusions. In order to more easily understand the development of the model carried out, it shows in the research road map in figure 1.

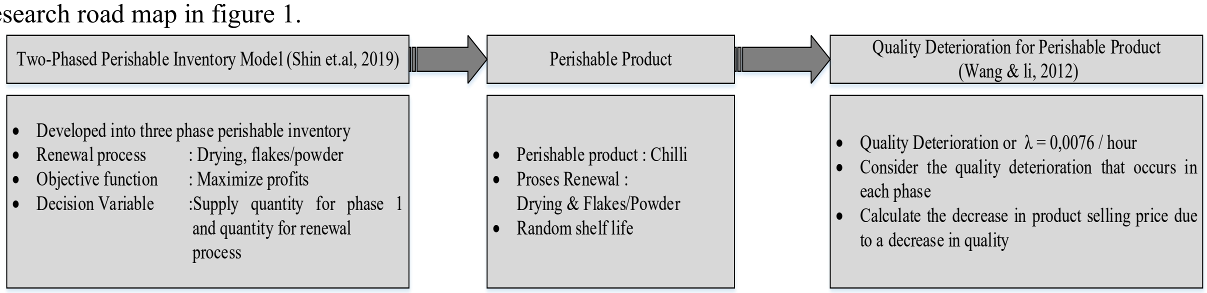

Figure 1. Research road map.

The first stage of development is developing from the model owned by previous research (Aktas et al. 2007). Inventory management developed into three phases of inventory with three different types of products in each phase. For the renewal process between phases one and two, it was drying. Then the renewal process between phases 2 and 3 will be made in powder/flakes. In previous studies, the objective function was to minimize the gap between supply and demand. In this research, it will be profit maximization with the decision variable determining the quantity of supply and quantity to be made in renewal into products in phase two and phase three.

The second stage of understanding the concept of perishable products, product shelflife categories, and methods for extending product life (renewal process). The last or third stage regarding the concepts and formulas for decreasing product quality based on the length of the storage period. It was using the rate of quality degradation from previous research by Wang and Li (2012) for vegetable products. The rate of quality loss used to calculate the level of quality loss that occurs in each period in all phases. The amount of this quality decline will affect the selling price of the product. The quality decline will affect the total income and profits obtained.

2.2. Research Purpose

In this research, a mathematical model will make so it can represent the problem of the inventory management system described earlier. So the purpose of this study can be described in the following points:

1. Design a three-phase inventory management model for perishable products by doing a renewal process.
2. Achieve the optimal amount of supply to meet demand in all three phases.
3. Achieve a decision number of products for the renewal process in order to meet the demands in each phase.
4. Get profit maximization by considering product quality degradation that affects product selling prices.

2.3. The cost component used

This quality loss will later affect the objective function, which is the maximum profit. All costs will use for units per kg of product. The following costs are using:

- Purchase costs
- Production cost
- Renewal costs
- Holding costs
- Lost sales costs

During the planning period, there will be products that experience a decrease in quality. The decline in quality will affect the selling price of the product and will affect the total income. This quality reduction will continue to occur until the product not save for consumption. Quality degradation that occurs is related to the storage period of the product in each phase. For the first phase of shelflife for one week, the second and third phases for two weeks each. After passing the shelflife period of each phase, it will become a salvage value. The salvage value in this study is 10% of the product price in each phase.

2.4. Assumption and limitation

In this study, the authors will provide performance parameters that will be used by setting limits and assumptions first. In this study, the authors limit only one supplier, one manufacturer, and three types of supply for three products in each phase. The assumptions used include:

1. The level of consumer demand is deterministic.
2. In the event of shortages, it is considered lost sales.
3. Holding costs and lost sales for all three types of products the same.
4. The level of quality loss in this research will use from Wang and Li (2012).
   Quality loss or λ = 0.0076 / hour (1.277 / week).
5. The amount of quality loss is considered the same for all types of products.
6. If the inventory is stored longer than the specified shelflife, it will become a salvage value. The salvage value is 10% of the product price.
7. The renewal process time is not significant & there is no process failure and product defects.
8. Conversion of kilogram units of products 1, 2, and 3 are considered the same. Product 1 as much as 1 kg, if converted to product 2, will still be 1 kg.
9. Shelflife of Product :
   Product A = 1 week
   Product B = 2 weeks
   Product C = 2 weeks

3. Numerical Calculation

At this stage, a numerical experiment solves with the SOLVER tools offered in the Microsoft Excel software package. The numerical experiment result will show the performance of the model. Input parameters given include the cost of a product purchase, renewal costs, and the level of product demand at each phase. After that analysis of the results of numerical experiments is carried out. An analysis is performed for numerical calculations with several scenarios that have made. Does the model that has been made can still provide an optimal solution, especially if there is a change in parameters. This study will develop an inventory management model from Shin et al. (2019) and quality degradation fromWang and Li (2012).

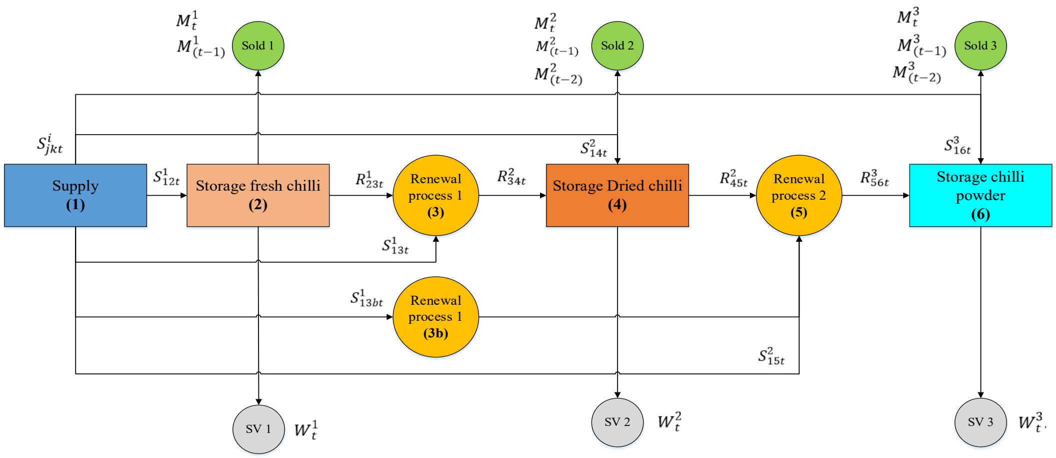

Figure 2. Three-phase inventory management.

Figure 2 shows a picture of the product flow from the supply to the final phase. With the three phases of inventory, it will have three different products with different product ages. For example, the first phase is fresh chili, then the second phase is dried chili, and the last phase is flakes/powder. From the first phase to become the second phase must go through a renewal process, namely drying. Various drying methods can be used either naturally or using tools. After the second phase, the third phase must also go through a renewal process, and the product will be in powder or flakes.

Each phase can receive a direct supply of products from suppliers. The renewal process can also directly accept product supplies for processing. The remaining products in phases 1 and 2 can enter renewal processing. If the renewal process capacity is still available if not, the remaining product will become a salvage value. In each phase, the product sold will have three different levels of quality. Products sold with perfect quality, then sell at a quality that has declined after being stored for 1 and 2 weeks. With three different qualities, the selling price of the product will also be different.

3.1 Mathematical model

This section will explain mathematical notation and model for three-phase inventory management. Here is the notations shown in table 1.

This three-phase inventory management model aims to maximize profit. Profits obtain by reducing total revenue with all necessary costs from purchase to product storage.

$$\text{MaxZ}= \left[\sum_{t=1}^{t_e} \sum_{i=1}^{3} \left(M_t^i x P_{Old}^i\right) + \left(M_{(t-1)}^i x P_{new1}^i\right) + \sum_{t=1}^{t_e} \sum_{i=2}^{3} \left(M_{(t-2)}^i x P_{new2}^i\right)\right] + \left[\sum_{t=1}^{t_e} \sum_{i=1}^{3} \left(W_t^i x SV_i\right)\right] + \left[(S_{12t}^1 x PC_1) + (S_{14t}^2 x PC_2) + (S_{16t}^3 x PC_3)\right] + \left[(S_{13t}^1 x PR_1) + (S_{13bt}^1 x PR_{1b}) + (S_{15t}^2 x PR_2)\right] + \left[(R_{23t}^1 x RC_1) + (R_{45t}^2 x RC_2)\right] \quad (1)$$

Total income in each phase obtains from the equation contained in the objective function. The number of products sold multiplied by the price of each product in each phase. This calculation for each phase from the beginning to the end of the planning period. The selling price of the product depends on the quality of the product sold. Selling price reduction happens due to a decrease in quality during the shelf life of the product. The quantity of product remaining when the shelf life ends will become a salvage value. After obtaining income from each phase, then the revenue of each phase will be added up.

Production costs required during the planning period are holding costs, product purchases cost, production cost, and renewal process cost and lost sales costs. Holding costs obtain by multiplying the quantity of inventory during that period with a predetermined cost. Then to purchase products and renewal processes will be the main decision to determine the number of products. The rest product from the previous phase will be renewed, as well as the number of products to go directly into the renewal process. The decision will have different costs through phase 1 (storage product 1) first or directly enter the renewal process.

Table 1. Model notation.

Notation		Definition
t	=	**Time index during the planning period (t =1... t_e)**
t_e	=	**The end of the planning time index (t_e = 12)**
i	=	**Product type index (i = 1,2,3)**
j	=	**Index of origin of product supply (j=1,...5)**
k	=	**Product supply destination index (k=2,...6)**
S^i_{jkt}	=	**Supply product i (i=1,2,3) which moves from j (j=1,..5) towards k (k=2,...6) in period t (t=1,... t_e)**
R^i_{jkt}	=	**Remaining product i (i=1,2,3) which moves from j (j=2,..5) towards k (k=3,...6) in period t (t=1,... t_e)**
D^i_t	=	**Demand quantity for product i in period t**
I^i_t	=	**Inventory levels of products i in period t**
l^i_t	=	**Quantity of lost sales for product phase i period t**
W^i_t	=	**The quantity of product i is wasted in the period t / Salvage value**
M^i_t	=	**The quantity of product i sold with perfect quality in period t**
$M^i_{(t-1)}$	=	**The quantity of product i sold with the 1st quality loss in period t**
$M^i_{(t-2)}$	=	**The quantity of product i sold with a second quality loss in period t**
PC_i	=	**Purchase costs for a product i**
PR_1	=	**Cost of producing product 1 to become product 2**
PR_{1b}	=	**Cost of producing product 1 to become product 3**
PR_2	=	**Cost of producing product 2 to become product 3**
RC_1	=	**Cost of renewal process 1 for the remaining product 1 becomes product 2**
RC_2	=	**Cost of renewal process 2 for the rest of product 2 becomes product 3**
HC_i	=	**Holding costs for product i**
LC_i	=	**Lost sales cost for product i**
SV_i	=	**Salvage value for product i**
P^i_{Old}	=	**Selling price for product i (i=1,2,3) with perfect quality**
P^i_{new1}	=	**Selling price for product i (i=1,2,3) with a quality decrease 1**
P^i_{new2}	=	**Selling price for product i (i=2,3) with a quality decrease 2**
C_i	=	**Storage capacity for a product i**
CR_1	=	**Renewal process capacity 1**
CR_2	=	**Renewal process capacity 2**

When product inventory cannot meet demand, the decision is lost sales. Loss sales will affect total revenue. The more frequent lost sales, it will reduce the revenue and have an impact on the profit. With the policy of lost sales, the model needs to choose to save more inventory or not. Choosing to save more inventory or choosing lost sales will affect total income. In addition to calculating the objective function, limitations on the model need to get optimal results. The limitations of the model will be able to represent real conditions. The following are the limitations that have already made, namely the limitation of storage capacity, renewal process capacity, balance inventory in the renewal process, perishability, and non-negativity.

The first constraint is the storage capacity of the product in each phase. This inventory management model has three phases that store product 3 different products. In phase 1, the stored product 1 (fresh product), in this study, the product which is an example is fresh chili. Phase 2 and 3 store chili products that already become dried chilies and chili powder/flakes. This product storage capacity for store supplies and products that have gone through a renewal process.

The level of inventory at each phase ensures the level of inventory will be following the conditions of the period that occurs. The level of inventory will be affected by the amount of inventory available in the previous period, incoming supplies, units entering the renewal process, and product demand in the current period. At each phase, the level of inventory influence by different things. In the second and third phases, it will be influenced by units that leave the first and second renewal process.

Constraint 1: Storage capacity of each phase :

$$\boldsymbol{I^1_{(t-1)} + S^1_{12t} - D^1_t - R^1_{23t} \leq C_1} \quad (2)$$

$$\boldsymbol{I^2_{(t-1)} + S^2_{14t} + R^2_{34t} - D^2_t - R^2_{45t} \leq C_2} \quad (3)$$

$$\boldsymbol{I^3_{(t-1)} + S^3_{16t} + R^3_{56t} - D^3_t \leq C_3} \quad (4)$$

for t =1,... $\boldsymbol{t_e}$

The second constraint is the capacity for the renewal process. In this model, there is two renewal process. The first renewal process changes the product from phase 1 to product in phase 2. Then the renewal process second changes the product phase 2 to the product in phase 3. The type of product in phase 1 is a fresh product. In this study, use product fresh chili. By doing the renewal one process (drying), it will change the product phase 1 to product phase 2, which is dried chili. Then the third phase is to store chili powder products/flakes. By doing the renewal two processes, the mixer will change the dried chili into chili powder/flakes. By doing this renewal process can extend the life of the processed product to be longer.

Constraint 2: Renewal process capacity

$$\boldsymbol{R^1_{23t} + S^1_{13t} + S^1_{13bt} \leq CR_1} \quad (5)$$

$$\boldsymbol{R^2_{45t} + S^1_{13bt} + S^2_{15t} \leq CR_2} \quad (6)$$

for t =1,... t_e

In addition to ensuring inventory levels at each phase are appropriate, a supply balance is important. Because inventory levels between phases connected, at the inventory level, phase 2 will add units that go to phase 2. The Inventory level between phases connected because there is a renewal process that connects inventory levels between phases.

Constraint 3: Inventory Balance at Renewal Process

$$\boldsymbol{R^2_{34t} = R^1_{23t} + S^1_{13t} - S^1_{13bt}} \quad (7)$$

$$\boldsymbol{R^3_{56t} = R^2_{45t} + S^1_{13bt} + S^2_{15t}} \quad (8)$$

for t =1,... t_e

Limitation of inventory balance where $\boldsymbol{R^1_{23t}}$ show the remaining product 1, which will enter the renewal process to become phase 2. Then $\boldsymbol{S^1_{13t}}$ show the supply of product 1 directly enter the renewal process. Limitation of inventory balance is the number of residual products from phase 1 added to the supply directly entered for the renewal process. The sum of the two supplies for this renewal process cannot exceed the number of products that come out of the renewal process.

Constraint 4: Salvage Value (perishability)

$$W_{1t} = \sum_{t=1}^{t_e} \quad (I^1_2 + I^1_{(t+1)}) \quad (9)$$

$$W_{2t} = \sum_{t=1}^{t_e} \quad (I^2_3 + I^2_{(t+1)}) \quad (10)$$

$$W_{3t} = \sum_{t=1}^{t_e} \quad (I^3_3 + I^3_{(t+1)}) \quad (11)$$

for t = 1,... t_e

The next constraint is salvage value. This constraint ensures the stored product does not exceed shelflife. The product storage time limit is denoted by t. For the first phase, the storage period is decided for one week, and the second and third phases for two weeks. When the amount of inventory in a phase has passed the storage period, it will be considered a salvage value. With perishability restrictions, we can be sure that damaged products will not be sold and can maintain product quality. The last constraint is non-negativity, these constraints ensure that no value is negative.

Constraint 5: Non-negativity

$\boldsymbol{S^i_{jkt}} \geq \mathbf{0}$ (12)

$R^i_{jkt} \geq 0$ (13)

$I^i_t \geq 0$ (14)

$l^i_t \geq 0$ (15)

$W^i_t \geq 0$ (16)

$M^i_t \geq 0$ (17)

$M^i_{(t-1)} \geq 0$ (18)

$M^i_{(t-2)} \geq 0$ (19)

for t =1,... t_e

3.2 Quality Deterioration

Product quality is also a consideration in this study. Determining the shelflife limits of the products to be sold will affect its quality. Perishable products will experience a decrease in quality over time. Because it's essential to know how much quality degradation is happening. This quality loss will then affect the selling price of the product and affect the profits obtained. The quality loss model used from previous research (Wang and Li 2012).

Deteration product quality:

$q(t) = q_0 - \sum_{i=1}^{m} \lambda_i t_i$

λ_i = 0.008 /hours

λ_i = 1.277 /weeks

In this study, the decrease in product quality for all products in each phase is assumed to be the same. Then for the unit of time used in units of weeks. The calculation of product quality drop is only for periods after one week and two weeks. This loss of quality will affect the selling price of the product. On table 2 show the quality level for each product.

Table 2. Quality deterioration.

Product	**Shelflife (weeks)**	**Quality level**	**Shelflife (weeks)**	**Quality level**
1	1	98.7232	-	-
2	1	98.7232	2	97.4464
3	1	98.7232	2	97.4464

In this study, it is assumed that the amount of quality reduction in the three products is considered to be the same. In period 1 (after 1 week) the product will have a quality level of 98.7232 and period 2 (after two weeks) of 97.44464. After getting the level of product quality in the period under the shelflife of each product, the next step is to calculate the decrease in the selling price of the product. Because the purpose of this study is profit maximization, product sales are a necessary component of calculating profits. This loss of quality will affect the selling price of the product. Here are in table 3 show the initial prices of the highest quality products and product prices after a decline in product quality.

When the product is in period 1 (after one week is stored), then the quality and selling price of the product will decrease. The new selling price obtained by multiplying the initial product price with the product's quality level. For product 1 (fresh chili), the initial price of IDR 45,000 has dropped to IDR 44.425. Likewise, with period two, the initial price of product 2 was IDR 55,000 after 2 weeks, down to IDR 53,596. The decrease in selling prices of product 1 in period two is empty because product 1 has a shelflife of one week. So if the product passes the shelflife, the product will be considered salvage value. Likewise, for products 2 and 3 having a shelflife of two weeks, more than that, it will become a salvage value.

Table 3. Product price reduction.

t	Product	Product price	Product price after quality deterioration	
1	1	IDR 45,000	IDR 44,425	/Kg
	2	IDR 55,000	IDR 54,298	/Kg
	3	IDR 65,000	IDR 64,170	/Kg
2	1	IDR 45,000	-	/Kg
	2	IDR 55,000	IDR 53,596	/Kg
	3	IDR 65,000	IDR 63,340	/Kg

3.3 Numerical Experiment Design & Data

Numerical experiments performed with some of the scenarios that have already made. The scenario is tested on the proposed model to determine the performance of the model. These three scenarios will be carried out by considering the renewal process and without the renewal process. Experiments were conducted to find out whether doing the renewal process can provide higher profits. Several scenarios are tested on the proposed model to determine the performance of the model:

- Scenario 1: The level of demand for all types of products is the same (Flat)
- Scenario 2: The level of demand is increasing in each period for each type of product.
- Scenario 3: The level of demand fluctuates in each period for each type of product.

To perform numerical calculations with a few scenarios that already made would require preliminary data. These data are created as an initiation to create a model and run a solver. The data includes demand, purchase price, holding costs, process renewal costs, the quantity of inventory initiation, product storage capacity, process renewal capacity, and others. The purpose of making this numerical experimental design is to prove that the renewal process can provide higher profits. The three scenarios with different product demand to represent the real conditions of the system.

Table 4. Production process data.

Initial inventory :		
Product 1	10	Kg
Product 2	10	Kg
Product 3	10	Kg
Shelflife :		
Product 1	1	Weeks
Product 2	2	Weeks
Product 3	2	Weeks
Storage capacity :		
Product 1	300	Kg
Product 2	300	Kg
Product 3	300	Kg
Renewal process capacity :		
Renewal Process 1	200	Kg
Renewal Process 2	200	Kg

Table 4 shows data such as storage capacity and renewal process capacity, and initial inventory for each product. The storage capacity for each product is 300 kg, and the renewal process capacity is 200 kg. The amount of initial inventory for all products is 10 kg. It also informs the shelflife of each product. Product 1 has a shelflife of one week, and products 2 and 3 have a shelflife of two weeks. The number of unsold products will be a salvage value.

Table 5. Production cost data.

Holding cost :		
Product 1	IDR 50	Kg/weeks
Product 2	IDR 50	Kg/weeks
Product 3	IDR 50	Kg/weeks
Lost sales cost :		
Product 1	IDR 50.000	/Kg
Product 2	IDR 50,000	/Kg
Product 3	IDR 50,000	/Kg
Purchase cost :		
Product 1	IDR 30,000	/Kg
Product 2	IDR 50,000	/Kg
Product 3	IDR 65,000	/Kg
Production cost:		
Product 1	IDR 25,000	/Kg
Product 1	IDR 30,000	/Kg
Product 2	IDR 35,000	/Kg
Renewal process cost :		
Renewal Process 1	IDR 5,000	/Kg
Renewal Process 2	IDR 5,000	/Kg

Table 5 shows the data needed for the total production cost. The holding cost and lost sales in this study is assumed to be the same for all products, which is IDR 50 / kg/week and Rp. 50,000 / kg. The purchase fee for product 1 is IDR 30,000, product 2 is IDR 50.000, and product 3 is IDR 65,000. The purchase fee is the cost of buying a finished product, to get dried chili products, a purchase fee of IDR 55,000 is required. As for supplies that directly enter the renewal process, they will have different costs. For product supply 1 (fresh chili), which processing into dry chili, the required cost is IDR 25,000. Then for fresh chili, which processing into chili powder requires a fee of IDR 30,000. Meanwhile, dried chili, which processing into powdered chili, costs IDR 35,000. Called the production cost because costs displayed are costs for the purchase and renewal process. A fee of IDR 5,000 for renewal processes 1 and 2 is the cost required for the remaining products in product storage 1 and 2.

Table 6. Salvage value.

Product	Salvage value
1	IDR 4,500
2	IDR 5,500
3	IDR 6,500

Table 6 shows the cost of salvage value. Products that stored past the shelflife deadline will have two choices. The first choice, if the renewal process capacity is still available, will be the rest of the products entering the renewal process. The second choice is products that cannot be sold will become a salvage value. In the research, the salvage value is 10% of the product selling price. The next data needed is the level of demand for each product. In this study, the level of demand data is deterministic, following the scenario that made for numerical calculations, where the level of demand will have three variations.

4. Result & Discussion

In this chapter, analysis and discussion of the results of numerical calculations will be shown. Numerical calculations performed with several scenarios that have been made. There are three scenarios with different levels of product demand. The level of demand for these products is flat, increasing, and fluctuating. The results of numerical calculations will be analyzed, starting from the number of profits obtained, total revenue, salvage value, and product sales in detail. The existence of the renewal process or not will affect the benefits obtained. Table 7 shows the result from a numerical calculation.

Table 7. Maximum profit from numerical calculation results.

Demand	Scenario		Profit
Flat	SK1-1	With RN process	IDR 43,874,998
	SK1-2	Without RN process	IDR 16,349,981
Trend (increase)	SK2-1	With RN process	IDR 53,458,872
	SK2-2	Without RN process	IDR 19,503,335
Fluctuating	SK3-1	With RN process	IDR 84,907,224
	SK3-2	Without RN process	IDR 22,179,314

The three scenarios with different levels of product demand will be calculated with the conditions considering the existence of a renewal process and without a renewal process. Overall, the scenario by doing the renewal process to provide higher profits. In the SK1-1 scenario, a profit of IDR 43,874,998 obtains by considering the renewal process. When the calculation performs without a renewal process, the profits are less, namely in the SK1-2 scenario of IDR 16,349,981. In the second scenario, the level of product demand increases during the period.

The profit gained in the SK2-1 scenario is IDR 53,458,872. In the SK2-1 scenario, the calculation is done by considering the renewal process. In comparison, the calculation results without the renewal process gained a profit of IDR 19,503,335. In the SK2-2 scenario, the profit gained is smaller than the previous scenario, with a difference of IDR 33,955,536.

This also happens in the third scenario, the results of numerical calculations considering the renewal process obtain higher profits. The numerical calculation performs by considering the renewal process, which is the SK3-1. In the SK3-1 scenario, the amount of profit obtained is IDR 84,907,224. While on SK3-2, when the numerical calculation carried out without the renewal process gained a profit of IDR 22,179,314. In the third scenario, the level of product demand fluctuates over 12 periods for all types of products.

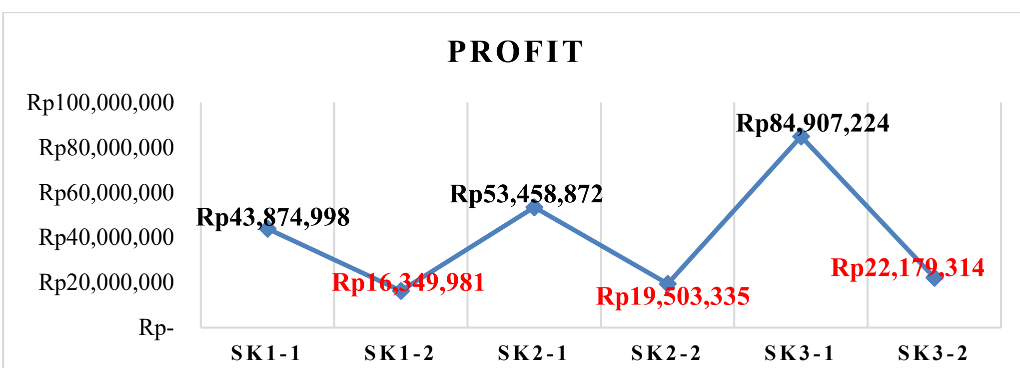

Figure 3. Graph of the profit.

From Figure 3, we can see profit reduction occurs in all scenarios created. With three levels of product demand that have been made, the results obtained remain the same. When numerical calculations are carried out without the renewal process, the profits are not as great compared to other scenarios. From the results of numerical calculations and looking at the graph of the profits obtained, it can be concluded that by doing the renewal process provides higher profits. The profits become an opportunity for profit that can be achieved when renewal performs. The difference between the SK1-1 and SK2-1 scenarios is IDR 27.525.017. In other words, the opportunity to get an additional profit of IDR 27.525.017 is lost because it does not carry out a renewal process.

By doing the renewal process can save production costs. Production costs have several cost components, one of which is the purchase cost. By doing the renewal process, it will reduce the purchase costs needed. The cost required will be cheaper when compared to directly buying dried chili to meet demand. In addition, with the renewal process, there will be more products that can be stored and processed to meet demand. So that the income obtained becomes greater.

Total production costs and total revenue obtained are important cost components to determine the profits obtained. From the results of numerical calculations that have been done with the renewal process produces higher profits. In this study, the objective function to be achieved is profit maximization. To determine the number of profits can be seen from the difference between total revenue and production costs.

Table 8. Production costs and total income.

Demand	Scenario		Production Cost	Total Revenue
Flat	SK1-1	With RN process	IDR 136,129,492	IDR 180,004,490
	SK1-2	Without RN process	IDR 182,817,824	IDR 199,167,805
Trend (increse)	SK2-1	With RN process	IDR 134,579,868	IDR 188,038,740
	SK2-2	Without RN process	IDR 207,232,958	IDR 226,736,293
Fluctuating	SK3-1	With RN process	IDR 162,597,423	IDR 247,504,647
	SK3-2	Without RN process	IDR 263,506,978	IDR 285,686,291

Table 8 shows the total production costs and the total income obtained when doing or not doing the renewal process. Production costs needed when numerical calculations with renewal processes are less. The amount of total income obtained does not guarantee that the profits obtained are also higher. To find out how much profits obtained, we need to compare production costs and income. Figure 4 displays a comparison chart between production costs and revenue obtained by each scenario.

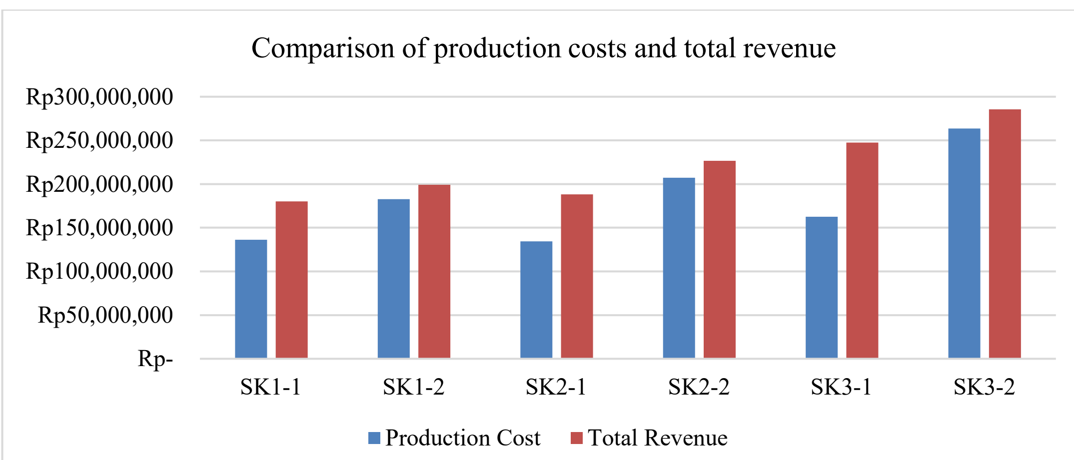

Figure 4. Comparison graph of production costs and total revenue.

Can be seen for series one or the production costs of all the scenarios that have the lowest production costs are the SK1-1, SK2-1, and SK3-1 scenarios. These three scenarios carry out numerical calculations taking into account the renewal process. The highest total income obtains from the SK3-2 scenario, which is a calculation without a renewal process. However, the amount of income obtained will not provide a higher profit if the required production costs are also enormous. To find out which scenario provides the highest profit is to look at the difference between production costs and income. Other cost components that affect the profits derived are total revenue.

This total income obtains from the number of products sold. Because the product in this study is perishable, and the level of product quality into consideration. The level of product quality will affect the selling price of the product. When the quality of the product goes down, the selling price of the product will also go down. To find out why the production costs needed can be lower in the scenario that does the renewal process. Then it is necessary to know the cost components included in the production costs, such as holding cost and lost sales cost. Table 9 shows the holding cost and lost sales cost result from the numerical calculation.

Table 9. Holding costs and lost sales.

Demand	**Scenario**		**Holding Cost**	**Lost Sales**
Flat	SK1-1	With RN process	IDR 152,912	IDR 17,781,365
	SK1-2	Without RN process	IDR 117,436	-
Trend (increased)	SK2-1	With RN process	IDR 137,198	IDR 40,418,009
	SK2-2	Without RN process	IDR 167,593	IDR 1,948,890
Fluctuating	SK3-1	With RN process	IDR 125,528	IDR 43,131,369
	SK3-2	Without RN process	IDR 235,758	IDR 2,876,037

If the storage costs and the cost of lost sales totaled, then the scenario that does the renewal process will have a higher cost. However, if we see which scenario has a more significant advantage is a scenario that does the renewal process. This conclusion has resulted from numerical experiments with three different levels of product demand. Even though the numerical calculation results without the renewal process have a small lost sales cost, it does not guarantee a significant profit.

Table 10. Purchase cost, production cost & renewal process cost.

Demand	Scenario	Purchase , Production & Renewal cost			Total
		Product 1	Product 2	Product 3	
Flat	SK1-1	IDR 56,149,087	IDR 42,352,784	IDR 19,693,344	IDR 118,195,216
	SK1-2	IDR 182,700,388	-	-	IDR 182,700,388
Trend (increased)	SK2-1	IDR 46,118,818	IDR 41,320,149	IDR 6,585,694	IDR 94,024,661
	SK2-2	IDR 205,116,475	-	-	IDR 205,116,475
Fluctuating	SK3-1	IDR 61,490,107	IDR 50,924,052	IDR 6,926,368	IDR 119,340,526
	SK3-2	IDR 260,395,182	-	-	IDR 260,395,182

From table 10 can be seen overall, the purchase costs required in the scenario without doing the renewal process are much higher. In the first scenario SK1-2, the total cost required is IDR 182,700,388. When compared with numerical calculations using the renewal process, the total cost required is IDR 118,195,216. By doing the renewal process gives higher profits because when there is a renewal process that can make savings, savings occur because of buying raw materials at low prices and then processed themselves. For example, to make dried chili, fresh chili is needed, which is processing by drying. The price of fresh chili and the cost of this drying process is lowest than buying dried chili directly.

Likewise, in scenario two, the demand level is increasing. The total cost required for numerical calculations without renewal is greater IDR 205,116,475. While numerical calculations with the renewal process get a smaller total cost, that is IDR 94,024,661. The same thing happens in the third scenario, where, without doing the renewal process, it requires a higher cost.

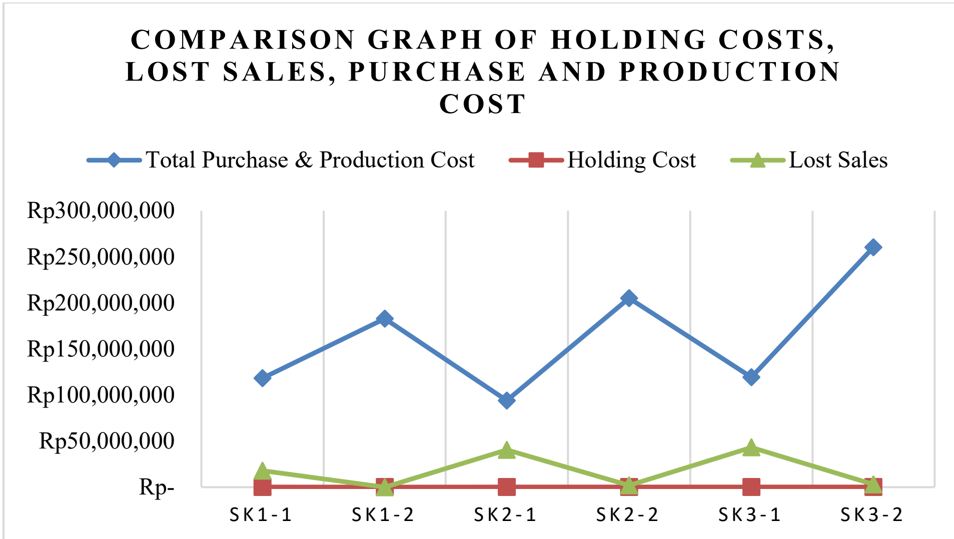

Figure 5. Comparison graph of holding costs/ lost sales, purchase, and renewal process.

It can be seen in figure 5, that the low cost of lost sales and holding does not affect profit. The most influential cost components on profit are the costs of purchase, production, and renewal process. Product storage costs for all scenarios are not much different, but the cost of lost sales that occur is volatile. Lost sales costs increase if the renewal process performs, but this does not affect the profit earned. If the total cost of the purchase, production, and renewal process is high, the profits will decrease. It can be seen in the scenario without doing the renewal process, and all three scenarios have high total purchase, production, and renewal costs. Nevertheless, the three scenarios without doing the renewal process have smaller profits compared to the scenario that applies the renewal process.

5. Conclusion

At this stage, the conclusion is obtained. The purpose of this study will be answered based on the results of numerical experiments summarized in conclusion. In this research, inventory management has three phases, the first phase is fresh chili, the second phase is dried chili, and the third phase is chili powder/flakes. By doing a renewal process that can change the first phase product into the second phase product as well as the second phase product into the third phase product. The decision needed on this issue is how many supplies products for each phase. Then how many products will processing to renewal process either to become the second or third phase products.

This model has an objective function of profit maximization, which also considers a decrease in product quality. The decrease in the quality of this product will affect the price of the product, which becomes the cost component to calculate total income. The three-phase inventory management model is solved by using Solver in Excel. The model can provide the best solution for various situations. The conclusion obtained by the model can produce optimal solutions with profit maximization objective function. From the results of numerical calculations, it can be concluded that the renewal process can provide higher profits compared to without doing the renewal process.

For further research, it can be done by removing the assumptions and limitations that exist in this study. Like using different other methods for deciding product selling price, or using other perishable product, it will have different quality degradation. Also can consider other factors in the decrease in quality besides time, namely temperature or method of storage of products.

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