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Development of Inventory Model for Perishable Product with Dynamic Pricing

Teodosius Raditya Ananto
Sepuluh Nopember Institue of Technology

Nurhadi Siswanto
Sepuluh Nopember Institue of Technology

Abstract: Perishable products are products whose value decreases over time. Inventory management for perishable products is a challenge experienced by retailers. Problems arise when inventory costs increase due to a large amount of wasted or waste products. This research aims to maximize profit by providing policy recommendations for inventory procurement under dynamic pricing. This research optimization focuses on determining the optimal order size and reorder level. To solve this problem, a simulation model is created by considering changes in product prices as product quality decreases. The simulation method in this study is a discrete event simulation using simulation software. Events in this inventory simulation include the arrival of customers and the addition or reduction of inventory levels. The replenishment policy in this study is continuous reviews. Simulation scenarios were generated to obtain an optimum order size and reorder level. The best scenario is obtained from a combination of optimum order size and reorder level. An inventory simulation model was generated based on fruit inventory data at one of the major retailers in Indonesia.

Keywords: Perishable product, Inventory model, Dynamic pricing, Discrete event simulation

Introduction

Inventory is one factor determining the level of costs retailers incur in their business activities. In this paper, we focus on perishable product inventory management. Perishable products have a useful life, such as food, vegetables, human blood, etc (Goyal and Giri, 2001). Challenges that can be experienced by retailers in managing the inventory of perishable products are food loss, food waste, and food surplus (Papargyropoulo et al., 2014). Food waste is wholesome edible material intended for human consumption, arising at any point in the food supply chain that is instead discarded, lost, degraded, or consumed by pests (FAO, 2011). Food waste at retailers of a food supply chain imposes a high cost since the operating cost is high while the overall margins on food products are lower (Teller, et al., 2018).

Various problems can be experienced by retailers in managing the inventory of perishable products. An example of a problem is the decreased quality of food products in the warehouse (Fauza, 2013). This decrease in quality will cause food waste because food products are considered unfit for sale. Factors causing the decline in food quality include food, including products that are dynamic or change over time (Heldman, 2011). Feng (2017) researched maximizing inventory profit with perishable product demand as a multivariate function of unit price, freshness condition, and inventory level simultaneously.

In this paper, we focus on maximizing the profit of perishable product inventory under dynamic pricing. Perishable product inventory management has many factors. Chaudary et. al (2018) divide these factors into demand type, shelf life, replenishment policy, and modeling techniques. Dynamic pricing based on quality is often used on perishable products such as apples Kayicki et al. (2022) and meat Buisman et al. (2019). This study will focus on stochastic demand and random shelf life. Simulation-based on dynamic pricing is used to decide the optimal reorder point and order size as the replenishment policy.

Method

Dynamic Pricing Based on Quality for Perishable Products

This research will refer to the model of Kayicki et al., (2022) in dividing the freshness level percentage into multiple stages, namely 100% -80%; 80%-60%; 60%-20%; and <20%. Our research object is avocado fruit so in determining the quality or freshness score, we refer to the research of Sierra et al., (2019). This study used life expectancy units based on fruit firmness according to storage temperature. The relationship between avocado fruit firmness and life span was analyzed by linear regression using the Arrhenius formula. The study stated that the best quality fruit had a firmness level of 143.4 ± 7.9N, while the lowest firmness was 9.8N. We combined these two research as the basis of quality decrease and selling price. Avocado quality and selling price have 3 levels. Optimum quality has the highest selling price, while the lowest quality will be disposed of. Premium, medium, and poor-quality limits are 120 N, 80 N, and 40 N, respectively. After passing these 3 quality levels, the fruit is considered unfit for sale and becomes waste.

Conceptual and Simulation Model

The conceptual and simulation model of the perishable product inventory was made before optimization. The model's Variables consisted of state, parameter, decision, response, and binary. The decision variables were reorder level (kg) and order size (kg). The main response variables are profit (Rp) and loss from expired (kg). Table 1 provides further details on all variables used in the simulation.

Table 1. List of variables in simulation

Variable Type	Variable Name	Explanation	Initial Value
State	Inventory	Amount of inventory per time	50
	Firmness	Firmness value per unit time	143,3
	SellPrice	Selling price per kg (Rp/kg)	17000
	ArrTime	Arrival time of fruit supply	-
Parameter	DiscountRate	Discount rate per quality	5%
	InitialSellPrice	Best quality product selling price (Rp/kg)	17000
	MaxStock	Maximum inventory capacity (kg)	50
	Demand	Demand rate from customer	-
	PriceExpectations	Price expectations each customer	NORM (17000;400)
Decision	ReorderLevel	Inventory level to reorder	-
	OrderSize	Quantity of fruit to buy from supplier	-
Response	Profit	Profit in Rupiah	-
	FruitExpired	Number of expired fruit (kg)	-
	AmountLost	Number of lost sales fruit (kg)	-
	LostCustomer	Number of lost customer (person)	-
	DemandMet	Number of demands met (kg)	-
Binary	OrderOn?	Binary decision for fruit supply	0

Initial values on variables were based on the company's data and policy. Limitations of this simulation are maximum order size should not exceed the maximum inventory capacity, which is 50 kg. There is also an assumption that the initial conditions and quality degradation of each fruit in one batch are homogeneous or the same. Fruit quality in the model applies to one batch (kg).

There are two data inputs needed for simulation, which are customer arrival rate and demand per customer rate. Data fit distribution from the company's record is done to obtain the probability distribution expression of these two inputs. The expression for customer arrival rate and demand per customer rate is 3,5 + WEIB (8,41; 1,86) and LOGN (0,571; 0,809), respectively. We make a conceptual model before building a simulation model. Figure 1 provides a conceptual model of perishable product inventory.

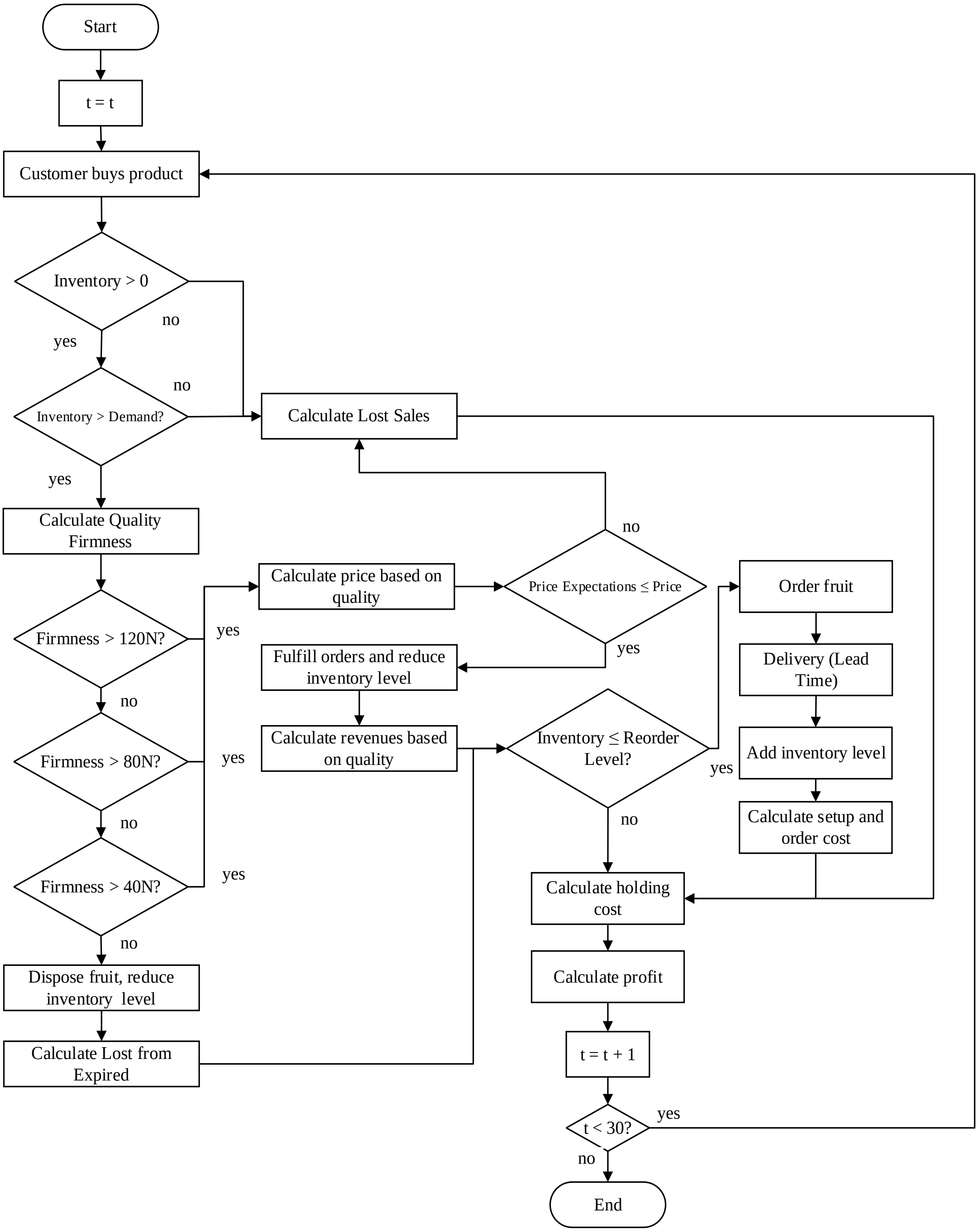

Figure 1. Conceptual model for perishable product ınventory

The simulation model runs once every day. The time unit t in the conceptual model represents days 1 to n. The stopping criterion in this simulation model is when the simulation has been running for 30 days. The simulation begins with the arrival of customers per time. Consumers who come have a number of orders for avocados with a certain probability distribution. Customer requests will be met if inventory is available, and vice versa becomes lost sales if inventory is not available. If the inventory level has touched the reorder point, the retailer will order products from the supplier in the amount of order size. The price of the product will decrease as the quality decreases. Profit will be calculated from revenue based on quality minus lost sales costs, ordering costs, and lost expired costs. Another measured performance is the number of expired fruits based on the number of fruits discarded during the simulation.

Experimental Design and Optimization using Simulation

The experimental design and optimization of scenarios of the perishable product inventory were investigated by using the simulation method. Scenarios are generated using OptQuest ARENA tools. The input needed to use this tool is objective, constraints, and the range value of each decision variable. The best scenario is the combination of optimum reorder level and order size. Table 2 provides the experimental design used in the optimization process.

Table 2. Experimental Design for Optimization

Decision Variable	Variable Value Range (kg)		
	Minimum	Maximum	Increment
Order Size	5	50	5
Reorder Level	5	50	5

The model's objective is to maximize profit with a limitation of maximum order size (50 kg). All decision variables have the same minimum, maximum, and increment values. Every possible scenario combination based on the decision variable value range will be run until the optimum solution or scenarios are found.

Results and Discussion

Optimum Solution

After all possible scenarios have been generated, the optimization is continued with OptQuest. Table 3 shows the 3 best scenarios resulting in maximum profit. Mark * in #NewBest indicates the best-case scenario as optimization progresses. The best scenario results are in the ninth iteration: the combination of the decision variables Order Size 15 kg and Reorder Level 5 kg.

Table 3. Optimum Scenarios for Profit Maximation

#NewBest	Iteration	Objective Value (Profit)	Constraint Order (≤50)	Order Size (kg)	Reorder Level (kg)
*	7	431102,01	30	30	5
*	8	454768,38	20	20	5
*	9	477299,70	15	15	5

This scenario generates a maximum profit of approximately IDR 477299.70 / month. The summary of maximum profit results from each iteration can be seen in Figure 2.

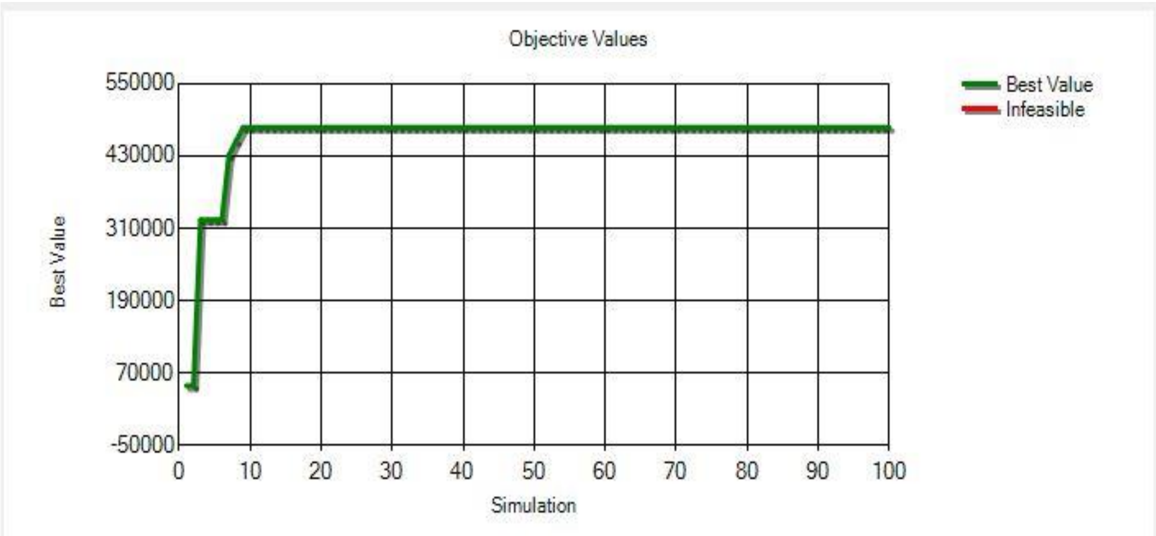

Figure 2. Maximum profit of simulation

The graph above shows the maximum profit from all scenarios as the optimization progresses. The graph shows no change in the maximum profit after the 9th scenario until the end of the optimization.

Sensitivity Analysis

Sensitivity analysis is performed by changing the price, discount rate, and order size to profit. An important variable used for sensitivity analysis is *PriceExpectations* or price expectations from customers. This variable represents the customer's shopping interest which is influenced by price expectations and the selling price itself. The analysis was carried out with the Process Analyzer and displayed in graphs.

Effect of Selling Price to Profit

The initial selling price of the simulation model is IDR 17,000. This value will be changed with a certain range to see the effect on profit. Other variables have fixed values, namely order size (15kg), reorder level (5kg), and discount (10%). Figure 3 shows a comparison of the selling price and profit.

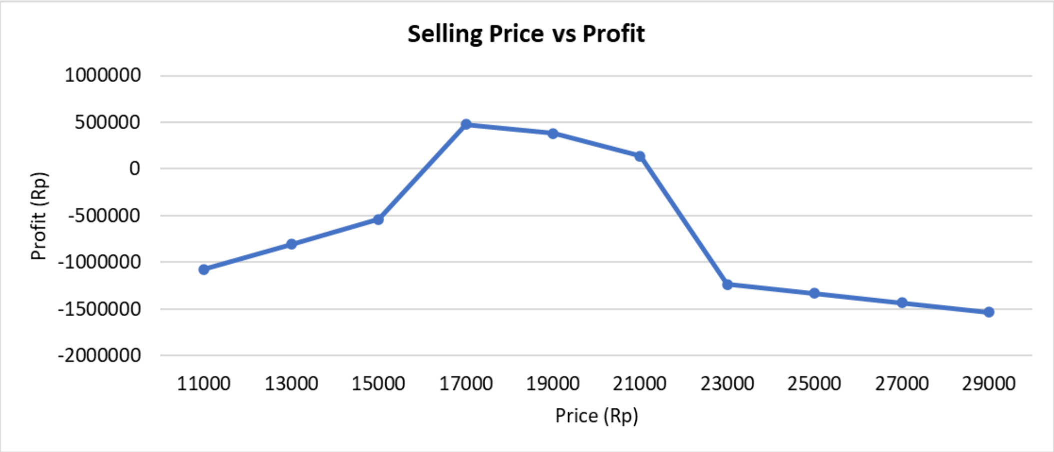

Figure 3. Sensitivity analysis selling price vs profit.

The graph above shows that the profit will increase as the selling price increases to IDR 17,000/kg. The 17,000-intersection point represents the maximum profit and minimum lost fruit. After that, the profit will decrease significantly. This is because prices that are too high will reduce customer interest in fruit shopping. Figure 4 shows the number of fruits sold for each price.

Figure 4. Fruit sold at each price.

Lost sales and expired fruit will increase as the price rises to IDR 23,000. Figure 5 shows the graphic of the number of lost on each price. This sensitivity analysis suggested that retail does not increase the selling price by more than IDR 17,000 to maintain the maximum profit value of IDR 477,299.70.

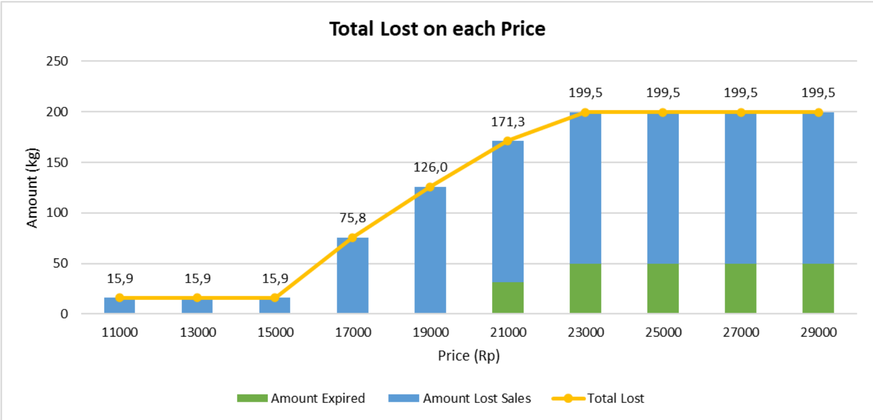

Figure 5. Fruit lost on each price

Effect of Discount Rate on Profit

The initial discount rate on the model is 10%. This value will be changed with a certain range to see the effect on profit. Other variables have fixed values: order size (15kg), reorder level (5kg), and a selling price of IDR 17,000/kg. Figure 6 shows a comparison of the discount rate and profit.

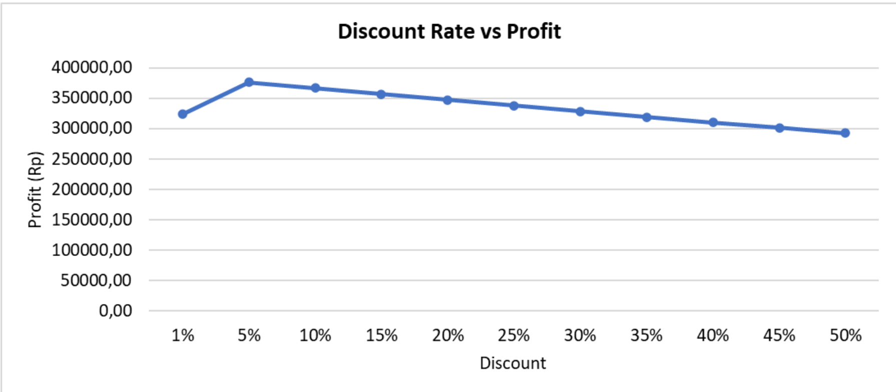

Figure 6. Sensitivity analysis discount rate vs profit

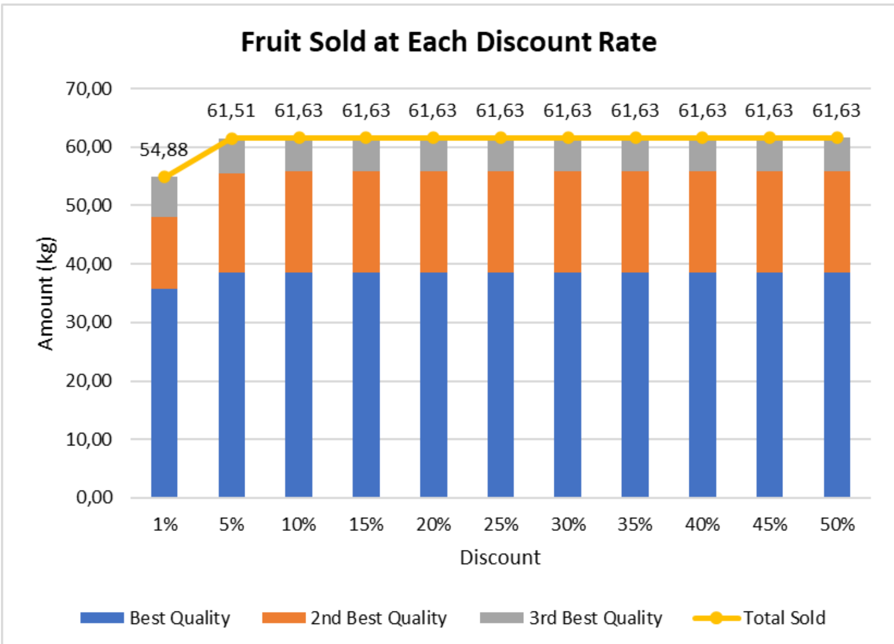

Figure 7. Fruit sold at each discount rate

The graph above shows that the profit will increase as the discount percentage increases to 5%. The 5% discount intersection point represents the maximum profit and minimum lost fruit. After that, the profit will decrease significantly. Initially, the profit value will increase as the discount given increases. A large discount value will increase customer shopping interest, increasing profit value. Furthermore, the profit value decreases at a discount rate of 5% and above. A discount that is too large causes total revenue to decrease, so it cannot cover revenue costs even though shopping interest remains high. Figure 7 shows the number of fruits sold for each discount rate.

After touching the discount rate of 5% and above, the number of fruits sold for each quality has the same value. This is because price expectations from customers have been fulfilled since the 5% discount was given. The profit value still has a difference caused by the difference in the selling price of each discount. The greater the discount given, the effect on the decrease in income received. Figure 8 shows the number of lost on each discount rate.

Figure 8. Fruit lost on each discount rate

The total lost value has the same result from 10% off and above. This is also related to the total value of the number of fruits sold, which is stable after a certain discount. So, this sensitivity analysis suggests that retail does not increase the discount percentage by more than 5% to maintain the maximum profit value, which is approximately IDR 376,182.4.

Effect of Order Size on Profit

The order size value on the model is 15kg. This value will be changed with a certain range to see the effect on profit. Other variables have a fixed value: the reorder level (5kg), a 10% discount, and a selling price of IDR 17,000/kg. Figure 9 shows a comparison of the order size and profit.

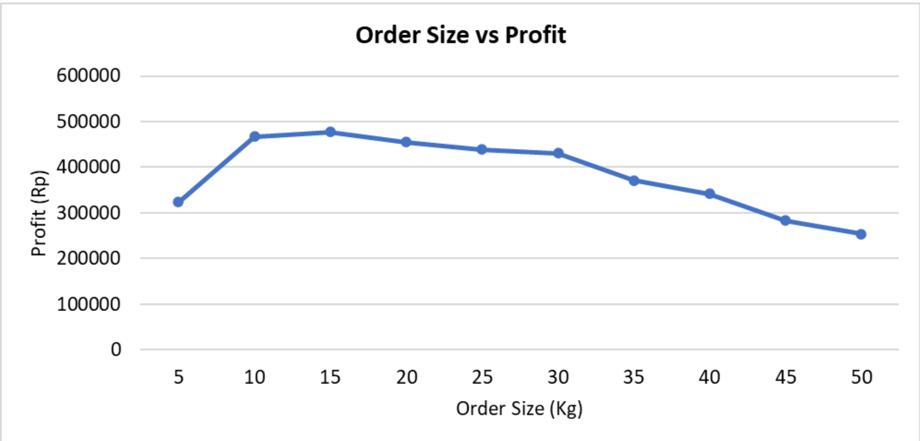

Figure 9. Sensitivity analysis order size vs profit

The graph above shows that profit will increase as the order size value increases to 15 kg. The intersection point of the 15 kg batch size represents the maximum profit and the minimum number of fruits lost. After passing this point, profits will decrease significantly. The profit value will initially increase as the batch size value used increases. A high batch size value will increase the amount of inventory, thereby reducing the possibility of lost sales. Furthermore, the profit value begins to decrease in the order size value of 15 kg and above. An order size value that is too large makes the inventory too high to exceed the customer's shopping interest. As a result, there will be an increase in expired or expired fruit. Figure 10 shows the number of fruits sold for each order size.

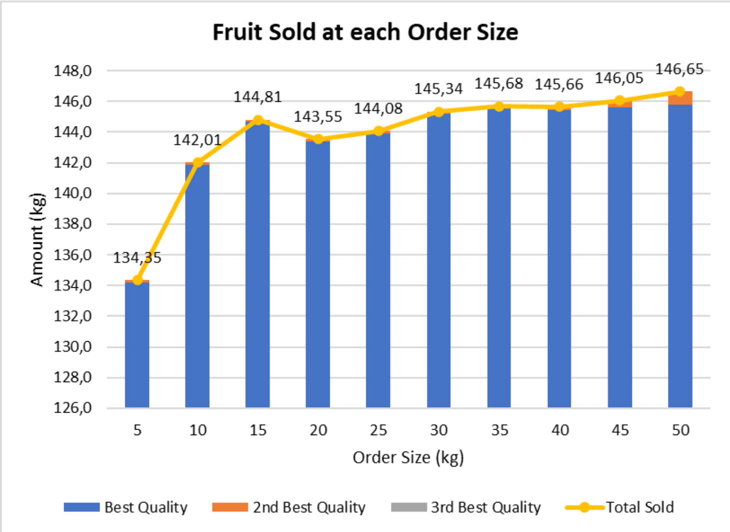

Figure 10. Fruit sold at each order size

The total number of fruits sold has an increasing trend as the batch size value increases. Most of the fruit sold is premium quality. This means that the demand for fruit is high, so the fruit sold has not experienced a decline in quality. Figure 11 shows the number of lost on each order size.

Figure 11. Fruit lost on each order size

Most of the lost are lost sales due to unfulfilled customer requests. The expired amount value in each order size has a value of 0. This means that customer demand is high, so the supply has run out before the fruit expires. So, in this sensitivity analysis, it is suggested that retail does not use an order size value of more than 15 kg to maintain the maximum profit value of approximately IDR 477,299.70.

Conclusion

This research uses simulation to optimize the order size and reorder level of perishable product inventory on retailers. The quality type of fruit firmness is used to determine the dynamic pricing of the product. The inventory simulation model obtains a maximum profit of IDR 477,299.7 with a scenario combination of order size and reorder level. The optimum order size value is 15 kg, and the reorder level value is 5 kg. Sensitivity analysis shows that the value of order size, discount rate, and selling price impact the profit value. Research suggests that the order size value is no more than 15 kg, the discount is no more than 5%, and the selling price is no more than IDR 17,000/kg so that profits do not decrease.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Acknowledgements or Notes

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Author Information

Teodosius Raditya Ananto
Sepuluh Nopember Institue of Technology
Surabaya, Indonesia
Contact e-mail: *anantoteo@gmail.com*

Nurhadi Siswanto
Sepuluh Nopember Institue of Technology
Surabaya, Indonesia

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