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RESEARCH ARTICLE

AN INVENTORY POLICY ON AGROINDUSTRY SUPPLY CHAIN: A CASE STUDY OF FRUIT SEASONAL IN EAST JAVA

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ABSTRACT

To forestall the overstock or understock, inventory policy often considers thoroughly the optimal order quantity and order time. It is considerably getting more complex in the case of agroindustry as its commodity mostly is classified as perishable goods. The increase of order at a particular season sometimes is not counterbalanced with the number of stocks. The prevalent rationale of this problem is due to none of the appropriate inventory policy is implemented. The purpose of this research is to develop an inventory policy system in the case of agroindustry considering the inventory cost, deterioration rate of perishable fruits, and seasonal variable. Thus, it can be used to maintain the stability of demand while considering those variables. This study employs the periodic review (R,s,S) to construct an inventory policy. The periodic review is determined by order interval (R), a combination of reorder point (s), and maximum level (S). The experimental case study is presented to provide an example of an inventory policy. The inventory policy can alleviate the stocking problem of perishable and seasonal fruits encountered by the agroindustry. The method is able to minimize inventory cost by controlling the inventory systems. This paper offers a model of inventory policy on agroindustry to control and optimize the stocks while reckoning the inventory cost, deterioration rate, and seasonal to fulfil the demand.

KEYWORDS

inventory management, fruit supply chain, periodic review, perishable goods.

1. INTRODUCTION

Agro-Industry is one of the promising sectors in Indonesia as an agricultural country of which occupy around 54 percent of the national economy (Kementan, 2020). Agro-industry aims to augment value-added to the agriculture products. As the technology, particularly in agriculture and fresh food industry, grows rapidly, it is expected to increase the sustainability in chain of agro-industry products. The agriculture sector contributes to about 15,46 percent of the second-quarter GDP. Indeed, this sector would still be a dominant factor that stimulates the economy of Indonesia, all the more in this pandemic era where people need agricultural products. On the other hand, according to BPS (Statistics Bureau), the number of imports in the sector of non oil and gas, including fruits and vegetables, has declined recently. Figure **1** depicts this trend over periode 2019 and 2020. It is clearly seen that compare to 2019, the number of imports of non oil and gas in 2020 has slightly declined on the same period, particularly on May.

Suryaningrat argued that fruit processing industries, which are commonly available in East Java, can be considered as an important agro-industrial sector to create employment particularly in every chain of fruit product (Suryaningrat, 2016). Fresh fruit, according to the Food Agricultural Organization's is commonly defined as the portion of a plant housing seeds which usually eaten as dessert (FAO, 2020). Accordingly, in other words fresh fruits are considered as agro-industrial products that can be consumed raw, whether whole or prepared. Herein, prepared means that fruits have undergone a minimal processing methods i.e. peeling, slicing or shredding, however, have not undergone any treatment to ensure preservation (e.g. chemical, physical or biological) other than chilling (Soto-Silva *et al.*, 2016). Fruit is also considered as a perishable product owing to the fact of its short lifetime affected by the possible of spoilage. The nature of deterioration and the uncertainty of demand are those factors influencing the spoilage rate by which it could lead to the shortage of fruit stock and may cause substantial loss of the retails (Yang, Xiao and Kuo, 2017).

In agroindustrial system, it is prevalently found in many countries that they encountered similar problems in terms of shortage of raw material, product quality, the inadequacy of supply particularly the seasonal raw material, deficiency of trained labor workforce, high cost of imported supporting materials, infrastructure, and deficiency in technological innovation (Suryaningrat, 2016). On the other hand, to fulfil the increasing demand there is an urge to integrate agrifood chains of local and cross-border. However, it may lead for both a threat and a challenge especially to those of local agricultural and rural development (Van der Vorst, Da Silva and Trienekens, 2007). The common problem encountered by the local agro-industrial is to maintain both customer needs of fruits supply as well as to maintain the inventory and other holding costs at the minimum level. Nevertheless, it is quite complex for the local producer or reseller to built such an inventory policy of fresh fruit products owing to its nature of deterioration and the seasonal factor.

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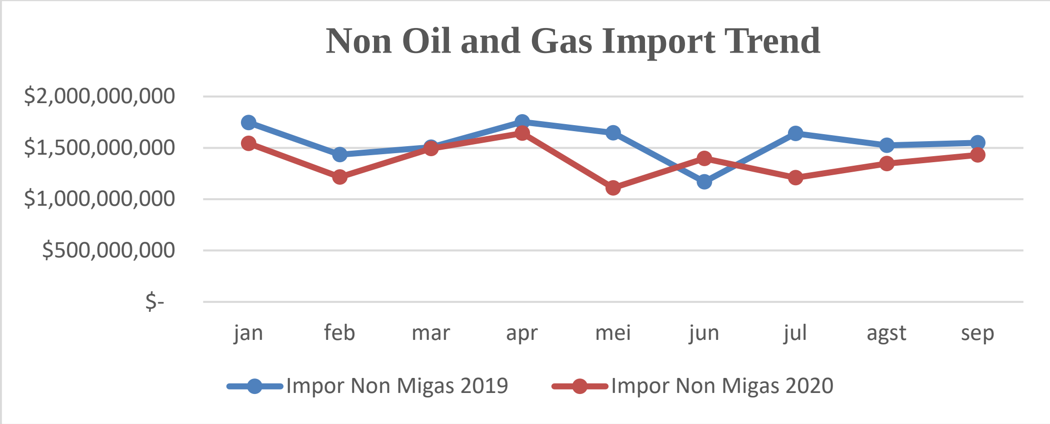

Figure 1: Trend of import non oil and gas. Source: BPS, 2020

Thus, the objective of this study is to develop an inventory policy in the case of agroindustry. The policy considers several key variables such as the inventory cost, deterioration rate of perishable fruits, and seasonal variable. To provide an illustration of the proposed model, a case study of fruits demand in East Java is presented. The remaining of this paper is organized as follows.

Section 2 outlines the literature review in regard to the agrifood supply chain and inventory policy. Section 3 presents the methodology used in this study. Meanwhile, section 4 discusses the result of proposed model as well as presents a numerical experiment to show to implementation of the proposed model. Finally, section 5 concludes the study by drawing some key points and suggesting a future work.

2. Literature Review

2.1 Agrifood Chains

The number of supermarkets has grown rapidly in both developed and developing countries which led to a transformation landscape of agrifood production and its chain systems (Van der Vorst, Da Silva and Trienekens, 2007). Indonesia is also experienced in the growth of agrifood industry which evidently can be seen from the number of premium supermarkets in most big cities serving any fresh agrifood products. High quality of fruits and vegetables usually are bought by larger retailers, while the small retailers often take the second-grade products. In addition, the agricultural commodity on the open market mostly its value depends on at least two factors i.e. availability (quantity, quality and/or timing) and costs (production, inventory, preservation) (Wilson, 1996).

Vorst, et al. argued that agrifood chains and network both significantly affect the producers from developing countries in providing access to the markets either local, regional or export markets (Van der Vorst, Da Silva and Trienekens, 2007). A rigorous chains system will be beneficial to the provision of fresh agrifood products demand. To build such chains, however, many challenges encountered by the agro-indutrial players, notably the agrifood products are classified as perishable goods having a possible of spoilage. Several issues in this regard are Cold Chain, Fragmented Supply Chain, Linkage and Integration, Infrastructural, Packaging, Technological, Farmer's knowledge and awareness, Quality and Safety, Processing, Supply chain efficiency, Financial, Post-harvest losses, Transportation, Information (Negi and Anand, 2015). Soto-Silva, et al. also suggested several challeges possess in the fresh fruit supply chain, those are the challenge of organic fruit production, climate adaptation, food security and seasonability's issues (Soto-Silva *et al.*, 2016).

On the other hand, in the case of raw material provision, continuity and resource factor are considered to have a very strong and strong influence, respectively, to the performance of fruit industries (Suryaningrat, 2016). Some studies have undertaken to deal with perishable food supply chain. (Yang, Xiao and Kuo, 2017) proposed a model of perishable food supply chain design by which evaluate the pricing strategy, shelf space allocation, and replenishment policy in dealing with stochastic demand. Meanwhile, (Widodo, Prihadianto and Hartanto, 2018) focused their study to probe a pricing model with multi period criteria for managing the local fruit supply chain.

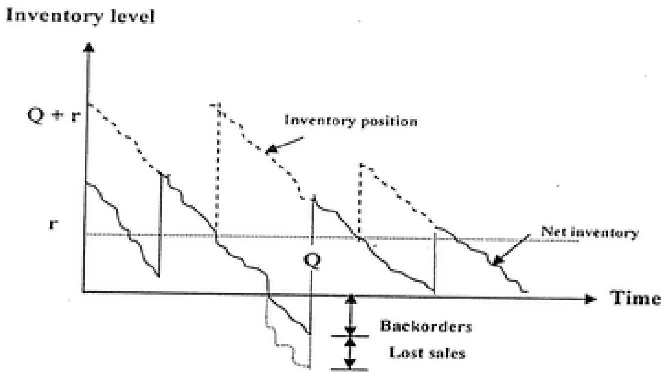

Figure 2: Inventory model (Fergany, 2016)

2.2 Inventory Policy

Inventory policy plays a significant role in the agrifood chains system. By applying an appropriate policy, we could determine how much of each item to procure and stock while considering the inventory cost and at the same time diminish the shortage. Inventory is defined as an idle resource of which waiting for further processes (Bahagia, 2006). These processes, in the case of fresh fruit preparation, can be those of cleaning, preservation, packaging, and selling. Figure 2 shows the inventory model under two restrictions (i.e. backorder and lost sales cost) with variying mixture of shortage cost, where Q and r are the order quantity and reorder point, respectively (Fergany, 2016). The maximum level of inventory is equal to $Q + r$ and when the stock at the level of r or below, then reorder should be taken to elude the backorders or even lost sales. In case of fresh fruits, the time window is narrower at particular seasons of particular items and vice versa. This is due to the nature of fresh fruits that can be perished as they spoiled.

The primary purpose of inventory is to decouple the supply and demand of which serves as a buffer to maintain: 1) supply and demand, 2) finished goods and component availability, 3) requisite for an operation and the output of proceeding operation, 4) parts and materials (Arnold, 2008). Moreover, Arnold also mentioned the common way to classify the inventory is based on the flow of materials of those can be classified as raw materials, work in progress (WIP), and finished goods (Arnold, 2008). To maintain the level of inventory in agrifood chains, it is important to consider the deterioration rate and seasonal variables. (Yang and Tseng, 2015) proposed an inventory model which take into account the deterioration aspect of chilled food to quantify the quality and its remaning value. They mentioned that the deterioration can be categorized into: 1) constant, 2) time-dependent, 3) in-control and out-of-control, and 4) temperature-dependent.

Since the fresh fruits has many varieties and types, so that it is plausible to classify the inventory into some classes. ABC analysis is one of methods to classify the inventory by identifying the importance of items to be used in controlling the inventory. The ABC principle is based on the observation that a small number of items often dominate the results achieved in any situations. The relationship between percentage of items stored and the percentage of annual cost is found to follow a pattern of three groups:

- **Group A**, about 20% of the items account for about 80% of the cost.
- **Group B,** about 30% of the items account for about 15% of the cost.
- **Group C,** about 50% usage of the items account for about 5% of the cost.

The percentage are approximate and should not be taken as absolute. This type of classification can be used to help in controlling the inventory (Arnold, 2008).

In reality, for managing the inventories, practitioners or managers often adopt the periodic review policy in some stores e.g. drugs store, grocery stores and retail stores (Jauhari and Saga, 2017). Silver et al. mentioned some advantages of using periodic review policy by which enables us to reduce reviewing cost and reduce reviewing errors (Silver, Pyke and Peterson, 1998). In this policy, an order is placed when the quantity on hand falls to a predetermined level called the order point. The quantity ordered is usually predetermined on some basis such as the economic order quantity. The interval between orders varies depending on the demand during any particular cycle of which in the case agrifood products many aspects suppose to be considered such as deterioration rate and seasonal factor. Using the periodic review policy, the quantity on hand of a particular item is determined at specified, fixed time intervals and an order is placed (Arnold, 2008).

3. Research Methodology

This study makes use of quantitative approach to address the inventory problems of perishable fruits product. Figure 3 shows the methodology of this study which structured into five main steps. First, the problem definition is determined. Second, the data, which encompasses relevant literatures, demand data, lead time, and inventory cost, is collected. The demand data is collected from the BPS (Statistics Bureau) of East Java and processed with the consideration of deterioration rate. Third, an ABC analysis is employed to classify the demand by which will yield the classification of A, B, and C depends on a particular criterion. By this way, the classification result will, then, be used in the fourth step that is processing data. Herein, the value of target safety level, reorder point, and maximum level of inventory are determined for each fruit commodity. Fifth, the final step is to apply the inventory policy and carry out an analysis. A numerical experiment is also provided to exemplify the practical use of the proposed approach.

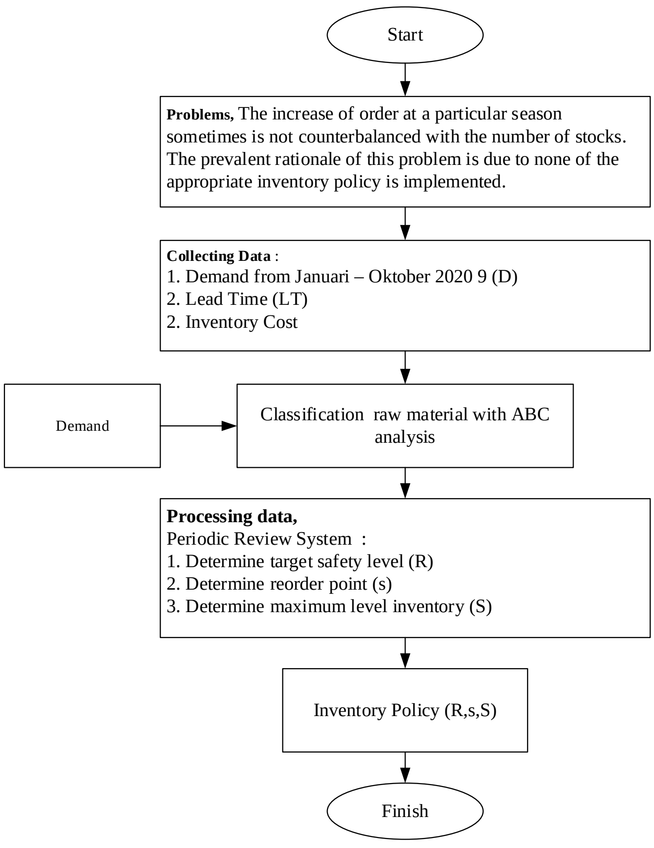

Figure 3: Research Method

In this study, several notations and assumptions were defined to denote the equations used as well as to confine the study. The following Table 1 shows the notation used throughout this paper, meanwhile the assumptions are as follows:

1. The pattern of demand for raw materials is lumpy with the periodic review system (R, s, S) approach.
2. The lead time is deterministic for each type of raw material but is fixed within a certain period of time.
3. The inventory cost is fixed following the cost of the year.
4. The ordering cost of raw materials is deterministic following the seasonal conditions.
5. The shortage cost encompasses the backorder cost and lost sale cost. Meanwhile, the lost sale depends on the deteriorated fruits.
6. The deterioration rate is followed the Weibull distribution: $\theta(t) = \alpha\beta t^{\beta-1}$ where α is the scale parameter, 0 ≤ α < 1, β the shape parameter, β ≥ 1, and t the time to deterioration, t > 0.

Table 1: Notation

Symbol	Description
D	Demand per unit of time
R	Order Interval
s	reorder point
S	Maximum level of inventory
L	Lead time
h	Holding cost
u	Monthly operating cost
A	Order cost
c	Procurement cost
v	Price of unit
B_3	Shortage cost
μ_R	Mean of demand during review period
μ_{R+L}	Mean of demand during review period and lead time.
σ_R	Standar deviation of review period
σ_{R+L}	Standar deviation of review period duration and lead time
Q_p	Quantity of order
S_0	Minimum limit
$S_p + Q_p$	Maximum limit
$p_{\mu\geq}(k)$	Probability of shortage
t	Seasonal time
$\theta(t)$	Deterioration rate

4. Finding and Discussion

In this section, we present the development of inventory policy model to address the perishable fruits inventory problem considering the variable of inventory cost, deterioration rate, and seasonal. The proposed model is expected to offer a reasonable and efficient policy that may be used to control the inventory system of fresh fruit products.

4.1 Demand and Lead Time

In this study, demand data of each fruit and each season was generated according to the Poisson distribution that is $P(x) = \frac{\lambda^j e^{-\lambda}}{j!}$, where x is said to a random variable to have Poisson distribution with parameter $\lambda > 0, j = 0,1,2 \dots n$. The value of λ was obtained from the average of fruit consumption per week of Indonesian people. In addition, the price data was also generated in the same manner as that of the demand data. Meanwhile, we also considered to take into account the probability of demand growth due to the seasonal factor such that at a particular season the number of fruit production is higher compare to other seasons. To growth factor was generated according to the Uniform distribution $U[0,1]$, meanwhile the Binomial distribution was employed to simulate the seasonal factor. The lead time was obtained by counting the number of months where the fruit has no produce and for those which fructify throughout the season, the lead time was generated according to the Uniform distribution $U[0,1]$. Table 2 shows the simulation data used in this study. In addition, it is important to be noticed that the unit used in this inventory policy is gram/capita. This means that every year the people would have an approximate demand of fruits at that amount. Therefore, in the perspective of reseller it is required to consider the number of customers in order to obtain the real demand.

Table 2: Demand Data

Fruit	Demand/Year (gr/capita)	Price (Rp/gr)	Seasonal (month)	Lead Time (Year)
Avocado	531	918	6	0,500
Star Fruit	41	727	4	0,667
Duku	2187	416	3	0,750
Durian	1592	1.503	5	0,583
Orange	1746	580	4	0,667
Guava	681	513	12	0,003
Mango	411	416	7	0,417
Pineapple	480	540	12	0,042
Nangka	782	1.199	12	0,025
Jackfruit	3605	482	12	0,017
Banana	2071	936	12	0,033
Rambutan	2436	523	4	0,667
Salak	758	426	4	0,667
Sapodilla	89	555	5	0,583
Watermelon	1668	668	12	0,039

Table 3: ABC classification result

Group	Item	Total (%)	Investment (Rp)	Investment Ratio (%)
A	6	40%	7.203.421	79,6%
B	4	27%	1.359.714	15,0%
C	5	33%	492.053	5,4%
Total	**15**	**100%**	**9.055.188**	**100%**

4.2 ABC analysis

Herein, the priority of inventory was determined by taking into account at the investment value and the use of raw materials. First, the annual cost of each fruit was calculated that is *average demand* $\times$ *price* $\times$ *seasonal*. Second, the annual cost was sorted in the decreasing order then calculated the percentage and cumulative percentage. From the cumulative percentage, we classified the items into three groups A, B, and C each of which account for 0-80%, 81%-95%, and 96%-100% of cost, respectively. Table 3 shows the result of ABC classification which indicates that group A consisting of six items account for 79,6% of investment ratio. Meanwhile, group B and C which has four and five items are taking the investment ratio of about 15% and 5,4%, respectively. In this sense, the retailer may consider to put more attention to that of group A which occupies more investment.

4.3 Inventory Model of Periodic Review (R, s, S)

Periodic review, herein, employs a heuristic power approximation to determine the optimum inventory parameters. The approach aims to minimize the total inventory cost as well as increase the service level by minimizing the backorder. Thus, the shortage cost was considered in this algorithm which could be backorder or lostsale cost (Silver, Pyke and Peterson, 1998).

Step 1: Calulate the parameter Q_p and S_p using the equation (1) and (2), respectively.

$$Q_p = 1.3\mu_R{}^{-0.494}\left(\frac{A}{vh}\right)^{0.506}\left(1+\frac{\sigma_{R+L}^2}{\mu_R^2}\right)^{0.116} \tag{1}$$

$$S_p = 0.973\mu_{R+L} + \sigma_{R+L}\left(\frac{0.183}{z} + 1.063 - 2.192z\right) \tag{2}$$

Where,

$$z = \sqrt{\frac{Q_p r}{\sigma_{R+L} B_3}} \tag{3}$$

$$B_3 = 0.06v + \theta(t)v \tag{4}$$

$$\mu_R = DR \tag{5}$$

$$\mu_{R+L} = D(R+L) \tag{6}$$

$$r = \frac{h}{R} \tag{7}$$

The shortage cost B_3 was constructed by the backorder cost, which is set at 6% of the price unit, and the lost sale which obtained from the decayed fruits. Thus, the lost sale was incorporated the deterioration rate $\theta(t)$. After the Q_p and S_p were obtained, we proceeded to the step 2 as follows.

Step 2: If $\frac{Q_p}{\mu_R} > 1.5$, then

$$s = S_p \tag{8}$$

$$S = S_p + Q_p \tag{9}$$

Otherwise, proceed to the step 3.

Step 3:

$$s = minimum\{S_p, S_0\} \tag{10}$$

$$S = minimum\{S_p + Q_p, S_0\} \tag{11}$$

Where,

$$S_0 = \mu_{R+L} + k\sigma_{R+L} \tag{12}$$

$$p_\mu \geq (k) = \frac{h}{B_3 + h} \tag{13}$$

4.4 Numerical Example

To illustrate the abovementioned inventory policy, firstly, it is required to determine the stock cost which often used to procure and operate the inventory. The stock cost may consist of the ordering cost (A), holding cost (h), and shortage cost (B_3) (Bahagia, 2006). The ordering cost (A) is calculated based on equation (14), where f_i is the frequency of order and c is the procurement cost. The frequency of order is simply divided into two, that are for the seasonal fruits (every 3 months) and non seasonal fruits (every 2 months). Meanwhile, the value of procurement cost (c) is set as a constant to Rp 1.247.400.

$$A = f_i \times c \tag{14}$$

Then, for the holding cost (h) of each item is calculated according to the equation (15) where u is the monthly operating cost which is set to a constant Rp 936.389. To calculate the shortage cost (B_3), equation (3), first we need to obtain the deterioration rate $\theta(t)$ of which can be calculated based on equation (16). The value of parameter α and β are set to 0.01 and 1.5, respectively. Meanwhile, the value of t depends on the seasonal month of the corresponding item.

$$h = \frac{12 \times u}{\sum_i^n D_i} \tag{15}$$

$$\theta(t) = \alpha\beta t^{\beta-1} \tag{16}$$

Herein, we use the star fruit to provide an illustration of the periodic inventory policy. Accordingly, we can obtain the following parametric values in appropriate unit:

D	:	41 gr/capita/yr
L	:	8 months = 0,667 yr
R	:	0,25 yr
v	:	Rp 727/gr
h	:	Rp 589/gr/yr
B_3	:	Rp 65/gr
A	:	Rp 3,742,200
σ_R	:	2,59

Step 1: Calculate Q_p and S_p,

$$\mu_R = DR = (0,25)(41) = 10,25$$

$$\mu_{R+L} = D(R+L) = 37{,}58$$

$$\sigma_{R+L} = \sigma(R+L) = 2{,}37$$

$$r = \frac{h}{R} = \frac{589}{0{,}25} = 147/\text{internal review}$$

$$Q_p = 1.3(65)^{-0.494}\left(\frac{3.742.200}{(727)(589)}\right)^{0.506}\left(1+\frac{(2{,}59)^2}{(10{,}25)^2}\right)^{0.116} = 2{,}11$$

$$z = \sqrt{\frac{(2{,}11)(147)}{(2{,}37)(65)}} = 1{,}42$$

Thus, S_p value can be obtained as follows:

$$S_p = (0.973)(37{,}58) + (2{,}37)\left(\frac{0.183}{1{,}42} + 1.063 - (2.192)(1{,}42)\right) = 32{,}04$$

Step 2:

$$\frac{Q_p}{\mu_R} > 1{,}5$$

$\frac{2{,}11}{10{,}25} = 0{,}205$, thus, we need to proceed to the step 3.

Step 3: Get the k value,

$p_{\mu\geq}(k) = \frac{147{,}25}{65+147{,}25} = 0{,}692354711$

$$S_0 = 37{,}58 + (0{,}692354711)(2{,}37) = 39{,}22$$

Then, reorder point (s) and maximum level (S) are:

$$s = \min\{S_p, S_0\} = \min\{32{,}04; 39{,}20\} = 32{,}04 \approx 32$$

$$S = \min\{S_p + Q_p, S_0\} = \min\{34{,}15; 39{,}20\} = 34{,}15 \approx 34$$

Table 4: Parameter inventory policy (R, s, S)

Fruit	Group	R	s	S
Banana	A	0,17	414	415
Papaya	A	0,17	658	658
Watermelon	A	0,17	352	352
Durian	A	0,25	1346	1346
Jackfruit	A	0,17	150	150
Pineapple	A	0,17	98	99
Rambutan	B	0,25	2176	2177
Guava	B	0,17	114	115
Orange	B	0,25	1570	1570
Duku	B	0,25	2211	2211
Avocado	C	0,25	406	407
Mango	C	0,25	266	267
Salak	C	0,25	682	683
Sapodilla	C	0,25	68	69
Star Fruit	C	0,25	32	34

Accordingly, in case of star fruit it can be conluded that the reorder point is 32 and the maximum level of inventory is 34 with the periodic review 0,25. The reorder point indicates that the lowest inventory of star fruit to plan reordering and to fullfil the availment up to the maximum level. Thus, at the same time, we can manage the inventory cost incurred. By means of the same rules and equations, we can obtain the inventory policy of other fruits. Table 4 shows the inventory policy ($\boldsymbol{R}, \boldsymbol{s}, \boldsymbol{S}$) applied to the rest of fruits. It can be observed that the value of ($\boldsymbol{s}$) never exceeds the maximum inventory limit ($\boldsymbol{S}$).

5. Conclusion and Further Research

In this paper, one of the most important issues in the agro industry, that is the fruits inventory system has been studied. The study presented a development of inventory policy of perishable agri-foods using the periodic review approach. The inventory model was developed under the consideration of inventory cost, the seasonal factor, and the deterioration rate. Under this situation, the proposed model was able to determine the reorder point (s), by which indicates the minimum level of inventory, and also the maximum level of inventory (S) with the given periodic of interval (R). A numerical illustration was provided to demonstrate the effectiveness of the proposed model. Meanwhile, the future work could consider to calculate the service level and total inventory cost. Moreover, the changes of parameters could also be observed to understand the model sensitivity.

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