Inventory control analysis of frozen processed shrimp using silver meal heuristic method (case study at PT. X Malang, East Java, Indonesia)

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Abstract. Shrimp is the leading commodity in fishery exports in Indonesia. PT. X is one of the companies producing frozen processed shrimp for export. To fulfill export needs, the availability of shrimp raw materials becomes important for the company to maintain. But on the other hand, the supply of shrimp also needs to be controlled at an appropriate amount to avoid costly waste. The purpose of this study was to compare the performance of raw material inventory control applied by the company and the Silver Meal Heuristic method. Silver Meal Heuristic is a method used to determine lot size by considering inventory costs. The results of this study indicate that the company controls inventory by ordering raw materials which are constant every 1 week for shrimp products and once every 2 weeks for others. The total cost of inventories incurred by the company was IDR 263,730,918.63 in the period June 2020 to May 2021. Inventory control using the Silver Meal Heuristic method has different frequencies where the frequency produced is smaller than the company ordering frequency. The total inventory cost using the Silver Meal Heuristic method is IDR 223,622,213. By applying the Silver Meal Heuristic method, total inventory costs were saved by 15% or IDR 40,108,706 in the period June 2020 to May 2021.

1. Introduction

The agribusiness sector in Indonesia which has great potential is the fisheries sector. One of the potential fishery products in Indonesia is shrimp. Shrimp is a leading national fishery export commodity [1]. Based on data from the Ministry of Marine and Fisheries, the volume of shrimp production in 2013-2017 shows a positive growth trend with an average growth per year of 15.7% and the export value has increased from USD 1.42 billion to USD 1.80 billion.

PT. X is a company that produces various kinds of frozen processed shrimp for export to various countries. PT. X orders shrimp according to the number of customer requests, so the shrimp supply is uncertain. Raw materials are one of the most vital factors for the production process. Raw material supplies such as shrimp are more at risk of being damaged. The shelf life of shrimp in a frozen state at -50°C to -100°C is 25 days, while the shelf life of shrimp stored frozen at -150°C to -200°C is 70 days.

Error! Reference source not found. Availability of raw materials is important and needs to be considered so that the production process runs smoothly. The availability of raw materials needs to be controlled at an optimal amount because excessive inventory levels result in a waste of costs while low...
inventories will result in a lack of raw materials for the production process, causing the production process to be hampered. This condition is riskier in fluctuating demand, which causes the demand to not be fulfilled. Therefore, it is necessary to control the raw material inventory to determine the number of orders, when the raw materials must be ordered, and the total cost for ordering.

Optimal inventory control can be done by using lot sizing. The method commonly used to determine the order size (lot sizing) is the Silver Meal Heuristic [3]. Silver Meal Heuristic is a method used to determine lot size by considering inventory costs. This method is more suitable to be applied in highly fluctuating demand conditions during the planning period [4], as happened at PT. X. Therefore analysis is needed to determine the optimization of raw material supplies so that the total inventory at PT. X can be minimized as best as possible. This study aims to determine the results of the comparison between the cost of inventory control applied by the company and inventory control costs by Silver Meal Heuristic Method.

2. Materials and Methods

The assumptions used in this study are as follows: the lead time for frozen processed shrimp supplies is constant, raw material suppliers can fulfill all orders made by PT. X, there is no shortage of raw material inventory during the forecast period and the utility costs (electricity, water, telephone) for the frozen shrimp supply do not change over the forecast period. Data processing in this study was carried out through several stages, namely: product demand forecasting using the time series method, calculation of raw material requirements using the bill of materials, calculation of raw material inventory using the Silver Meal Heuristic method, and calculation of safety stock and reorder point.

2.1. Product demand forecasting

Product demand forecasting will be carried out in the period from June 2020 to May 2021 based on product sales data from June 2018 to May 2020. The demand forecasting was carried out using five-time series methods include multiplicative decomposition, additive decomposition, moving average, single exponential smoothing, and double exponential smoothing. The results of demand forecasting with the smallest error value are used as data input in the calculation of the supply analysis for frozen shrimp products.

2.2. Calculation of raw material requirement

The results of the demand forecast with the smallest error value are interpreted as raw material requirements and drawn into the bill of a material tree. Bill of a material tree for frozen processed shrimp describes the components and sub-components is required in the production and the percentage of raw material in the product.

2.3. Calculation of raw material inventory using Silver Meal Heuristic

Calculation of raw material inventory using Silver Meal Heuristic is done by using demand forecasting data with the smallest error value. The data is re-analyzed to determine the optimal supply with minimal cost. The main equation used is as follows [5]:

\[
\frac{\text{TRC(T)}}{T} = \frac{C + Ph}{T} \sum_{k=1}^{T} (k-1)Rk
\]

Where:

- \( \text{TRC(T)} \) = total relevant costs in period T
- \( C \) = ordering cost per period
- \( T \) = time in certain period
- \( Ph \) = holding cost per period
- \( Rk \) = demand average in period k
2.4. Calculation of safety stock and reorder point

Safety stock calculations are carried out to determine the minimum quantity of raw material inventory. Safety stock is an additional inventory to prevent possible shortages of raw materials. The calculation of safety stock can be done with the following equation Error! Reference source not found.:

\[ SS = k\sqrt{LT(\sigma d^2)} \]  

Where:
- \( SS \) = safety stock
- \( k \) = safety factor
- \( LT \) = lead time
- \( \sigma d \) = standard deviation

The reorder point calculation is done to determine the reorder level of raw materials. The reorder point calculation can be done with the following equation [6]:

\[ ROP = d \times L + SS \]  

Where:
- \( ROP \) = reorder point
- \( d \) = demand per unit time
- \( L \) = lead time
- \( SS \) = safety stock

2.5. Comparison between Silver Meal Heuristic method and company method

The data obtained will be analyzed by comparing the performance of inventory control using the Silver Meal Heuristic method with the inventory control implemented by the company.

3. Results and Discussion

3.1. Result of product demand forecasting

Demand forecasting is based on past sales data. In this study, the sales data used were from June 2018 to May 2020. Figure 1 shows product sales decreased drastically in the period 4-7 or in June 2018 and in the period 49-52 or in June 2019. This happened because in that month there was an Eid al-Fitr holiday which caused production to stop. Based on the sales data, there was a decrease and an increase in the same period, thus forming a seasonal pattern. Besides, product sales have also increased at each period so that the pattern that is formed is a seasonal pattern with a trend. Seasonal time series are often based on data collected every month [7]. This pattern has an increase in data from year to year which has the nature of decreasing and increasing at the same time every year.

![Figure 1. Sales of frozen processed shrimp (June 2018 – May 2020).](image)
The methods used to forecast demand include multiplicative decomposition, additive decomposition, moving average, single exponential smoothing, and double exponential smoothing. These methods are included in the time series model [9]. The selection of the forecasting method is based on the smallest error value in which the error value categories used include mean absolute percentage error (MAPE), Mean Absolute Deviation (MAD), and Mean Squared Deviation (MSD). Comparison of MAPE, MAD, and MSD error values can be seen in Table 1.

### Table 1. Comparison of forecasting error values.

| Forecasting method                  | MAPE (%) | MAD   | MSD               |
|-------------------------------------|----------|-------|-------------------|
| Multiplicative decomposition        | 28       | 15845 | 706800228         |
| Additive decomposition              | 20       | 10245 | 483088248         |
| Moving average                      | 23       | 15479 | 456651704         |
| Single exponential smoothing        | 28       | 16883 | 639273075         |
| Double exponential smoothing        | 22       | 11463 | 493403519         |

Table 1 shows that the additive decomposition method has the smallest error value compared to the others so that this method was chosen to forecast demand. Forecasting results can be seen in Table 2.

### Table 2. Demand forecasting results using additive decomposition.

| Month-Year  | Period | Sales  | Month-Year  | Period | Sales  |
|-------------|--------|--------|-------------|--------|--------|
| June 2020   | 1      | 35,199 | December 2020 | 1      | 151,370|
|             | 2      | 93,598 |             | 2      | 154,002|
|             | 3      | 94,415 |             | 3      | 155,613|
|             | 4      | 94,515 |             | 4      | 152,834|
| July 2020   | 1      | 158,910| January 2021 | 1      | 165,215|
|             | 2      | 158,499|             | 2      | 171,174|
|             | 3      | 159,146|             | 3      | 169,431|
|             | 4      | 159,077|             | 4      | 167,154|
| August 2020 | 1      | 154,423| February 2021 | 1      | 146,410|
|             | 2      | 151,834|             | 2      | 149,241|
|             | 3      | 154,756|             | 3      | 150,127|
|             | 4      | 154,198|             | 4      | 149,712|
| September 2020 | 1     | 157,055| March 2021  | 1      | 149,789|
|             | 2      | 156,949|             | 2      | 146,281|
|             | 3      | 156,786|             | 3      | 149,408|
|             | 4      | 156,594|             | 4      | 150,015|
| October 2020 | 1     | 180,261| April 2021  | 1      | 166,669|
|             | 2      | 178,583|             | 2      | 170,768|
|             | 3      | 178,213|             | 3      | 166,298|
|             | 4      | 177,979|             | 4      | 169,903|
| November 2020 | 1    | 141,663| May 2021    | 1      | 175,710|
|             | 2      | 143,120|             | 2      | 175,318|
|             | 3      | 143,619|             | 3      | 179,190|
|             | 4      | 143,503|             | 4      | 166,288|
3.2. Raw material requirement
The raw materials used and the amount of raw material needed to produce 1 pack of processed frozen shrimp can be explained using the Bill of Material (BOM) tree. BOM tree can be seen in Figure 2. Based on the BOM tree, it can be seen that there are 5 raw materials, namely plastic, shrimp, pre-dust flour, breaded flour, and bread crumb. The number of units from BOM and the results of demand forecasting will be used to calculate the needs of each raw material in the period June 2020 - May 2021.

![Figure 2. BOM tree of frozen processed shrimp.](image)

3.3. Results of inventory cost calculation by the company
Raw material inventory control is implemented by the company by placing orders at constant time intervals. The ordering frequency for shrimp is once a week, while the ordering frequency of other raw materials is different, such as pre-dust flour and bread crumb, ordered once a week, while breaded flour and plastic were ordered once every 2 weeks. The order is made when the company has received information on the number of requests. The quantity for ordering and safety stock of each raw material is based on the average product demand of 152,250 packs/week. Table 3 shows that the inventory cost charged to the company in the period June 2020 to May 2021 was IDR 263,730,918.63.

![Table 3. Inventory cost calculation by the company.](image)

*Average demand for frozen processed shrimp = 152,250 packs*
3.4. Results of inventory cost calculation using Silver Meal Heuristic method
Silver Meal Heuristic calculation shows the optimal order period and order amount so that it has a minimum total cost per period. Based on the calculation, the summary of the total inventory cost of each raw material using the Silver Meal Heuristic method can be seen in Table 4. Table 4 shows that the total cost of inventory using the Silver Meal Heuristic Method was IDR 71,240,442.

| Raw material   | Ordering cost (IDR) | Holding cost (IDR) | Total cost of inventory (IDR) |
|----------------|---------------------|--------------------|-----------------------------|
| Shrimp         | 80,251,917          | 18,735,432         | 98,987,349                  |
| Predust flour  | 3,941,350           | 8,210,040          | 12,151,390                  |
| Breaded flour  | 3,500,274           | 4,720,773          | 8,221,047                   |
| Bread crumb    | 7,346,076           | 4,895,642          | 12,241,718                  |
| Plastic        | 24,860,257          | 17,689,139         | 42,549,396                  |
| **Total**      | **119,899,875**     | **54,251,026**     | **174,150,901**             |

3.5. Results of safety stock and reorder point calculation
The lead time for raw materials in the company varies, among others, shrimp has a lead time of 7 days, while pre-dust flour, breaded flour, bread flour, and HDPE plastics have a lead time of 14 days. In the calculation of safety stock, it is necessary to ensure that the time unit used must be the same as the time unit from the standard deviation [10]. The service level value used in the company is 95%. The value of safety stock and reorder point for each raw material can be seen in Table 5.

The costs borne by the company to hold a safety stock of each raw material each year are IDR 35,573,784 for shrimp, IDR 2,590,796 for pre-dust flour, IDR 5,183,380 for breaded flour, IDR 2,593,408 for bread crumbs, and IDR 3,529,943 for plastics.

| Raw material   | Lead time (week) | Demand average per week | Safety stock | Reorder point | Unit |
|----------------|------------------|-------------------------|--------------|---------------|------|
| Shrimp         | 1                | 76,362,65625            | 21,221       | 97,583.66     | kg   |
| Pre-dust flour | 2                | 4,581.75                | 1,800        | 10,963.52     | kg   |
| Breaded flour  | 2                | 15,272.53               | 6,002        | 36,547.06     | kg   |
| Bread crumb    | 2                | 33,599.57               | 13,205       | 80,404.14     | kg   |
| Plastic        | 2                | 152,725.31              | 60,023       | 365,474       | pcs  |

3.6. Comparison result of inventory control
The comparison of the total inventory cost calculation carried out by the company and the calculation of the total inventory cost with the Silver Meal Heuristic can be seen in Table 6. Based on Table 6, the total savings that can be made using the Silver Meal Heuristic method is IDR 40,108,706 or 15%. The savings made with this method are related to the ordering frequency. Ordering costs calculated using the Silver Meal Heuristic are smaller than the ordering cost made by the company so that there is a cost savings of IDR 29,044,910. Holding costs calculated using the Silver Meal Heuristic also get smaller compared to the holding cost made by the company where the difference is IDR 11,063,796. The ordering frequency also shows a different result. In ordering raw materials using the Silver Meal Heuristic method, it shows lower results.

The factor that most influences the calculation of the total cost of inventory is the ordering cost so that it will affect the ordering period. The higher the ordering period, the higher the total cost of inventory and vice versa [11]. Therefore, the silver meal heuristic method shows better results than that...
of the company because the Silver Meal Heuristic method combines several ordering periods in one period to get a lower order frequency.

**Table 6.** Comparison of total inventory costs.

| Raw material     | SMH+ SS (IDR)   | Company+SS (IDR) | Savings        | Cost (IDR) | %  |
|------------------|----------------|------------------|----------------|------------|----|
| Shrimp           | 134,561,133    | 168,753,651      | 34,192,517     | 20         |
| Predust flour    | 14,742,186     | 21,480,002       | 6,737,815      | 31         |
| Breaded flour    | 13,404,427     | 25,720,860       | 12,316,432     | 48         |
| Bread crumb      | 14,835,125     | 16,834,431       | 1,999,306      | 12         |
| Plastics         | 46,079,339     | 30,941,973       | (-15,137,366)  | (-39)      |
| Total            | 223,622,212    | 263,730,918      | 40,108,706     | 15         |

4. Conclusions
The company controls inventory by placing constant orders, which is once a week for shrimp and breaded flour, while other raw materials every 2 weeks. By using the Silver Meal Heuristic method, the company can find out the time of ordering raw materials where the order quantity shows smaller results for raw materials of shrimp, pre-dust flour, breaded flour, and HDPE plastic than that of the company. Besides, the total inventory cost using the Silver Meal Heuristic method is also smaller than the total inventory cost applied by the company.

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