Inventories Analysis of Animal Feed Raw Materials by Using the Silver Meal Method and Wagner within Algorithm (Case Study of PT. XYZ Makassar)

S Asmal1*, I Setiawan1, N Ikasari1, and Y Adriani1

1Department of Industrial Engineering, Faculty of Engineering, Hasanuddin University, Makassar, Indonesia
*Email: saptasmal@yahoo.com

Abstract. PT. XYZ Indonesia is a national company engaged in animal feed production. through the Production Planning Inventory Control (PPIC) department has implemented the Material Requirement Planning (MRP) system for inventory control but in the implementation of the company's MRP system, the PPIC department only considers the quantity of raw materials that can meet demand without regard to the issue of lot size inventory efficiency, so that the cost of raw material inventory is high. The purpose of this research is to compare the cost of procuring raw materials that have been carried out by the company with the cost of procuring raw materials using the silver meal method and Wagner Within algorithm. From the results of research and analysis conducted a comparison between the methods used by the company with the lot size silver meal method and Wagner Within algorithm in order to obtain the total inventory cost of raw materials in 2016, where yellow corn and rice bran raw materials have the same inventory costs between the methods used by the company, the silver meal method and the Wagner Within algorithm method are Rp. 1,080,000 so they do not have cost savings. As for the inventory of lime stone raw materials, it is more optimal to use the silver meal method and Wagner Within algorithm with a total inventory cost of Rp. 606,394 and can save costs by 35.08%.

1. Introduction
In a manufacturing industry, the availability of raw materials becomes very important to support production activities [1]. The process of procuring raw materials and their availability can support the smooth production process. Inventory Control section in this case plays an important role in controlling raw material inventory, therefore a good analysis is needed in determining the quantity and time of ordering raw materials. Determination of quantity and good order time will not interfere with the smooth production and can minimize the total inventory cost.

According to [2] inventory is a general term that indicates everything or organizational resources that are stored in anticipation of fulfilling demand. Without inventory, the entrepreneur will be faced with the risk that his company will not be able to meet the demands of its customers. Therefore, inventory has a meaning and a very important role in the company. Meanwhile, according to [3] states that, the final goal of inventory management is to minimize costs in changing inventory levels.
In this study will be discussed about the supply of raw materials at PT. XYZ Makassar Branch where the product produced is animal feed. This company produces many types of animal feed products ranging from feed broilers, breeders, hobbies and others. The types of feed produced are in the form of pellets (granules) and crumble (fine grains). To produce these products, PT. XYZ Makassar Branch requires a diverse supply of raw materials such as Yellow corn, Rice bran, Lime stone, and others. The marketing area of PT. XYZ Makassar Branch is Kalimantan and eastern Indonesia. With this wide marketing area, the supply of raw materials is very important especially for limited materials and can only be imported from outside the region or from abroad. The business risks are availability and fluctuation of raw material prices. So far, PT. XYZ Makassar Branch through the PPIC department implements the MRP system for inventory control which starts from forecasting demand. The forecasting process carried out by the company is the result of coordination between the marketing department who knows the market conditions with the PPIC department. Forecast by the company is not able to describe the actual condition of the product demand. Inaccurate calculation of forecasts can cause a lack of raw material stock in warehouses that will cause losses that disrupt the production process and also result in loss of opportunity to earn profits if it turns out that the demand for the actual conditions exceeds the demand predicted and also the excess raw material stock which causes high holding costs.

In implementing the company's MRP system, the PPIC department only considers the quantity of raw materials that can meet demand without regard to the issue of lot size inventory efficiency. In addition the company also has never evaluated and compared the existing inventory system with other methods. From the description above, the researcher is interested in conducting a study of controlling the supply of animal feed raw materials in the company by using the method of comparing the cost of procuring raw materials that have been carried out by the company with the cost of procuring raw materials using the silver meal method and the Wagner Within algorithm for the company.

2. Study Literature

**Material Requirement Planning (MRP)**

MRP system is a system of planning and scheduling material requirements that require several stages of the process. The production plan for the final product is translated into raw material requirements by calculating the waiting time so that it can be determined when and how much raw material must be ordered for the product to be made [2].

To implement MRP, basically there are four basic prerequisites that must be met, namely:

1. Availability of master production schedule.
   The master production schedule is a detailed plan about the amount of goods to be produced at several time units in the planning horizon. The master production schedule is a cost optimization that takes into account the capacity available in the demand forecast to achieve production which will minimize the total production cost.

2. Product structure in the bill of material.
   Each product unit and component must have a clear and unique identification so that it is useful during computerization. The product structure contains information about the relationships between components in assembly. This information is important in determining the gross needs and net requirements of a component. Furthermore, the product structure also contains information about all units.

3. Clarity and accuracy of inventory records.
   The MRP system is based on the accuracy of the inventory held so that the decision to make or order goods at one time can be done as well as possible. For this reason, inventory levels of components and materials must always be observed. MRP is not possible without accurate inventory.

4. Lead time.
   Waiting time is the time needed from the time the unit order is made until the time the unit is received and ready for use, both the product unit that must be made by itself or the product units ordered from
outside the company. The MRP system can be implemented well if the waiting time for ordering is known.

**The Silver Meal Method**

The Silver-Meal method was developed by Edward Silver and Harlan Meal based on the cost period. Silver Meal is one of the heuristic methods, which is a method with an approach that is easy to use, and from repetition of work will get good results when compared with other heuristics. The Silver Meal method is used as a request as a basis for repetition of variables in subsequent periods, then the total demand is above the planning limit.

The criterion of the Silver-Meal technique is that the lot size chosen must be able to minimize the total cost per period. Requests for successive periods are accumulated into a lot size (tentative lot size) until the total carrying cost and setup cost of the lot divided by the number of periods involved increases. This method tries to find a minimum average cost for each period for a number of planned periods [4]. General formulas that can be used are as follows:

\[
K(m) = \frac{1}{m} (A + h + 2hD3 + \ldots + (m-1)h)
\]

Calculate \(K(m)\), \(m = 1, 2, 3, \ldots, m\), and stop the count if \(K(m+1) > K(m)\) Note:

- \(Dm\) = Demand in the month period (\(D1, D2, D3, \ldots, Dm\))
- \(K(m)\) = Average inventory cost per unit time
- \(m\) = Period
- \(A\) = Order cost
- \(h\) = Cost of saving each unit / period

This Silver Meal method is used for problems where the variation in demand from one time period to the next is quite high.

Simply stated, the steps in the calculation use the Silver Meal Method as follows:

- **Step I:**
  Calculating the total cost for ordering a first time period, also calculating the costs for ordering the first two time periods. If the second cost is higher than the first cost, then it is concluded that the order is made for the first time period. But, if the second fee is not greater than the first cost or the second fee is smaller than the first cost, then proceed to the calculation of the total cost for ordering the first three time periods. If this third fee is higher than the second cost, then the booking is concluded for the second time period. But if the third fee is not greater than the second fee or the third fee is smaller than the second fee, then proceed to the calculation of the total cost for ordering the first four time periods. And so on until the condition is obtained where the total cost for the next order is higher than the total cost for the previous order.

- **Step II:**
  If there are still time periods that have not been calculated, then step 1 is repeated for the remaining time periods.

It is generally seen that this method has longer calculations than the other lot sizing methods, but the researchers conclude that this method is closer to optimal. This is a common symptom in management science that the better a heuristic method, the longer and more expensive the calculation, but still simpler and cheaper than the method for finding the best solution.

**Wagner Within (AWW) Algorithm Method**

The Wagner-Within Algorithm method is an optimization based on a dynamic programming model [5]. The goal is to obtain an optimum ordering strategy for the entire schedule of net needs, by minimizing total procurement costs and savings costs. This algorithm was developed by Wagner and Within in 1958 to
provide the optimum solution for the problem of deterministic order sizes at a certain time period where the needs of all periods must be met. Number of orders and time of order remains.

This method uses two ways to determine the number of orders, the first by ordering adjusted to the number of economic orders (must be close to the number of economic orders) by communicating the demand every month until approaching the number of economic orders after that do a trial and error until getting the lowest cost. The second method uses Wagner-Within algorithm calculations.

The Wagner-Within algorithm obtains a maximum number of solutions to the data that minimizes the problem of dynamic order size over limited planning. Several theories are used to simplify the calculation by following the steps in the following procedure:

- **Step 1:**
  Calculate the total cost of the matrix variable for all alternative horizon bookings for the time being which consists of N periods. Total variable costs include ordering and holding costs. Describe CEZ as the total variable cost in periods c through e placing an order in period c which creates needs in periods c to e:

\[
ZCE = C + Hp \sum_{k=c}^{e} (Qce - Qct) \text{ For } 1 \leq c \leq e \leq N
\]

Where:
- C: Per-order Message Cost
- h: Save Cost
- P: Unit Purchase Cost

\[
Qce = \sum_{k=c}^{e} R_k
\]

- **Step 2:**
  Describe fe as the minimum cost in periods 1 through e, that the inventory level at the end of period e is zero. The algorithm starts with f0 and calculates f1, f2, fn on the order. Then fe is calculated in the order of the order upwards using the formula.

\[
Fe = \min (Zce + fc-1) \text{ for } c=1,2,\ldots, e
\]

In other words, because in each period all alternative bookings are combined and compared in the replacement strategy fe. The best (lowest cost) combination is like the fe strategy to meet the needs for periods 1 to e. So the value of fe is the optimal cost of the order schedule.

- **Step 3:**
  The last sequence occurred in the period w and sufficient to satisfy requests w to n.
  \[f_e = Z_{w\cdot N} + f_{w-1}\]
  Prior to the last order sequence occurred in period v and sufficient to meet demand in periods v to w 1.
  \[f_{w-1} = Z_{v\cdot w-1} + f_{v-1}\]
  The first order occurred in period 1 and is sufficient to meet demand in periods 1 through u 1.
  \[f_{u-1} = Z_{1\cdot u-1} + f_o\]
3. Research Method
In planning the supply of raw materials, the company not only considers the quantity of raw materials that can meet demand, but must consider the problem of determining the size of the lot in order to produce an optimal order at a low cost. In calculating the lot size, there are various techniques which are divided into two major groups, namely the static lot sizing model and the dynamic lot sizing model. Where in static lot sizing there are several methods used, one of them is the Economic Order Quantity (EOQ) method. Whereas in dynamic lot sizing there are several methods used, including the Silver meal and AWW methods. For the level of demand with numbers up and down (random) dynamic lot sizing models are used, including the silver meal and AWW methods. The silver meal and AWW methods have not been widely used but can produce solutions that are close to optimal. After calculating the lot size of raw materials, it can be done planning raw material inventory.

![Figure 1. Schematic of a research framework](image-url)
4. Result and Discussion

Table 1. Product demand data for January - December 2015

| No. | month         | Broiler (Ton) | Breeder (Ton) | Hobby (Ton) |
|-----|---------------|---------------|---------------|-------------|
| 1   | January 2015  | 2,688.20      | 2,755.00      | 20.00       |
| 2   | February 2015 | 2,351.75      | 2,410.00      | 20.00       |
| 3   | March 2015    | 3,231.20      | 1,995.00      | 20.00       |
| 4   | April 2015    | 3,556.20      | 1,742.50      | 20.00       |
| 5   | Mei 2015      | 3,201.10      | 1,287.00      | 25.00       |
| 6   | June 2015     | 3,701.90      | 1,851.60      | 25.00       |
| 7   | July 2015     | 2,879.65      | 1,585.00      | 25.00       |
| 8   | August 2015   | 2,895.00      | 1,540.00      | 25.00       |
| 9   | September 2015| 3,000.00      | 1,940.00      | 30.00       |
| 10  | October 2015  | 3,495.00      | 70.00         | 35.00       |
| 11  | November 2015 | 3,164.60      | 470.00        | 30.00       |
| 12  | December 2015 | 3,077.50      | 705.00        | 35.00       |

The pattern of data on demand for broiler products from January 2015 to December 2015 presented in graphical form can be seen in Figure 2:

Figure 2. Pattern of Broiler feed product demand for January - December 2015

In Figure 2, it showed that the demand for Broiler feed products is random, where the shape of the data pattern cannot be known because the demand for broiler feed every month increases or decreases. The data patterns of demand for breeder feed products from January 2015 to December 2015 presented in graphical form can be seen in Figure 3:
In Figure 3 it showed that the demand for Breeder feed products is also random, it appears that there is a fluctuation in product demand every month. This can be seen in the month of June 2015 breeder feed demand increased and then decreased in July to August 2015 then in September 2015 demand again increased and decreased in October to November 2015 and increased again in December 2015.

While the pattern of demand data for Hobby feed products from January 2015 to December 2015 presented in graphical form can be seen in Figure 4.:

In Figure 4. The graph showed that the demand for Hobby feed products is random (random). This can be seen in May 2015 Hobby feed demand increased and demand remained / stable until August 2015 then again increased in September to October 2015 and again declined in November and increased again in December 2015.

Product composition is used to determine the amount of raw materials contained in each product. In this research, three main raw materials are discussed, namely Yellow Corn, Rice Bran, Lime Stone. The composition used can be seen in Table 2:
Table 2. Composition of animal feed products

| Raw material | Feed Broiler (% use) | Breeder (% use) | Hobby (% use) |
|--------------|---------------------|-----------------|--------------|
| Yellow corn  | 55.17               | 63.98           | 47.27        |
| Rice bran    | 6.86                | 5.00            | 4.96         |
| Lime stone   | 3.00                | 4.50            | 5.00         |

source: PPIC Dept. PT. CPI Makassar

Inventory Costs applied by the Company PT. XYZ

a. Cost of ordering Yellow corn, Rice bran and Lime Stone raw materials

Cost of ordering raw materials at PT. Makassar CPI consists of telephone costs. For Yellow corn, Rice bran and Lime stone transportation costs are borne by the supplier. Data on ordering costs of Yellow corn, Rice bran, and Lime stone raw materials can be seen in Table 3:

Table 3. Cost of ordering Yellow corn, Rice bran and Lime stone raw materials During 2016 the company method

| Raw material | Booking Fee / month (Rp) | Order Frequency / year | Total Booking Fee (Rp) |
|--------------|--------------------------|------------------------|------------------------|
| Yellow corn  | 90,000                   | 12                     | 1,080,000              |
| Rice bran    | 90,000                   | 12                     | 1,080,000              |
| Lime stone   | 90,000                   | 4                      | 360,000                |
| Total        | 270,000                  | 28                     | 2,520,000              |

b. Cost of purchasing Yellow corn, Rice bran and Lime stone raw materials

High and low costs of purchasing raw materials is influenced by the order quantity. Where the purchase cost is multiplication of the order quantity with the price / ton of raw materials. Data on the cost of purchasing Yellow corn, Rice bran, and Lime stone raw materials can be seen in the Table 4:

Table 4. Cost of purchasing Yellow corn, Rice bran and Lime stone raw materials for the company 2016 method

| Raw material | Order Quantity (ton) | Price / ton (Rp) | Purchase cost |
|--------------|----------------------|------------------|---------------|
| Yellow corn  | 33,135               | 4,500,000        | 149,109,255,000|
| Rice bran    | 3,542                | 2,500,000        | 8,855,025,000  |
| Lime stone   | 1,008                | 500,000          | 504,025,000    |
| Total        | 37,685               | 7,500,000        | 158,468,305,000|

c. The cost of storing raw materials for Yellow corn, Rice bran and Lime stone.

Raw material storage costs consist of material handling / maintenance costs. Data on the cost of storing raw materials for Yellow corn, Rice bran, and Lime stone can be seen in the Table 5:

Table 5. The method of storing raw materials for Yellow corn, Rice bran, and Lime stone in 2016 is the company's method

| Raw material | Total Inventory (Rp) | Storage costs / ton (Rp) | Total storage costs / year (Rp) |
|--------------|----------------------|--------------------------|-------------------------------|
| Yellow corn  | 2,871                | 200                      | 574,204                       |
| Rice bran    | 0                    | 12,000                   | 0                             |
| Lime stone   | 0                    | 200                      | 574,204                       |
| Total        | 2,871                | Rp 32,200                | 574,204                       |
d. Inventory costs for Yellow corn, Rice bran and Lime stone.

Inventory costs of Yellow corn, Rice bran, and Lime stone raw materials with the company method in 2016 are the total of the total cost of ordering with the cost of storing raw materials in 2016. Data on inventory costs of Yellow corn, Rice bran, and Lime stone can be seen in Table 6:

Table 6. Cost of raw materials for Yellow corn, Rice bran and Lime stone in 2016 is the company’s method

| Raw material  | Order cost/year (Rp) | Holding cost/year (Rp) | Total inventory cost /year (Rp) |
|---------------|----------------------|------------------------|---------------------------------|
| Yellow corn   | 1,080,000            | 0                      | 1,080,000                       |
| Rice bran     | 1,080,000            | 0                      | 1,080,000                       |
| Lime stone    | 360,000              | 574,204                | 934,204                         |
| **Total**     | 2,520,000            | 574,204                | 3,094,204                       |

Comparative Analysis of Inventory Control Methods

Table 7. Comparison of the cost of ordering raw materials

| Raw material  | Company Method (Rp / year) | Silver meal method (Rp / year) | *Algoritma wagner within* method (Rp/year) |
|---------------|----------------------------|-------------------------------|----------------------------------|
| Yellow corn   | 1,080,000                  | 1,080,000                     | 1,080,000                       |
| Rice bran     | 1,080,000                  | 1,080,000                     | 1,080,000                       |
| Lime stone    | 360,000                    | 450,000                       | 450,000                         |

Comparison of raw material inventory costs

Raw material inventory costs are the sum of ordering costs and storage costs so that the amount depends on the two components. The comparison of Yellow corn, Rice bran and Lime stone raw material inventory costs between the company method, the silver meal method and the Wagner Within algorithm can be seen in Table 8:

Table 8. Comparison of raw material inventory costs

| Raw material  | Company Method (Rp / year) | Silver meal method (Rp / year) | *Algoritma wagner within* method (Rp/year) |
|---------------|----------------------------|-------------------------------|----------------------------------|
| Yellow corn   | 1,080,000                  | 1,080,000                     | 1,080,000                       |
| Rice bran     | 1,080,000                  | 1,080,000                     | 1,080,000                       |
| Lime stone    | 934,204                    | 606,394                       | 606,394                         |

Table 9. Percentage of cost savings in controlling inventory of raw materials using the silver meal method, Wagner Algorithm within the company method

| Raw material  | Silver meal method (Rp / year) (%) | Company Method (Rp / year) (%) | *Algoritma wagner within* method (Rp/year) (%) |
|---------------|-----------------------------------|-------------------------------|----------------------------------|
| Yellow corn   | 0                                 | 0                             | 0                                |
| Rice bran     | 0                                 | 0                             | 0                                |
| Lime stone    | 35.08                             | 934,204                       | 606,394                         |
Based on Table 9 above, it can be seen that for Yellow corn and Rice bran raw materials have the same inventory costs between the methods used by the company with the silver meal method and Wagner Within algorithm method so that there is no cost difference while for Lime stone raw materials cost savings occur using the Silver meal method and Wagner Within algorithm method is 35.08% of the company's method. This proves that the Silver meal method and Wagner Within Algorithm method can be an alternative for companies in managing Lime stone raw material inventory policies whose demand fluctuates because this method can meet raw material requirements precisely and with minimum inventory costs.

5. Conclusion
Based on the results of data processing and analysis conducted, it can be concluded as follows:
The Silver meal method and Wagner Within Algorithm method, a lot size recommendation is obtained for ordering the three main raw materials. Where the total inventory of Yellow corn raw materials is 33,135.39 tons with an order frequency of 12 times a year. The total inventory of rice bran raw materials is 3,542.01 tons with a frequency of ordering 12 times a year. The total inventory of Lime stone raw materials is 2,746.31 tons with an order frequency of 5 times a year. Comparison of raw material inventory costs between the methods used by the company with the Silver meal method and Wagner Within algorithm as follows: a). Ordering costs for, Silver meal, and Wagner Algorithm within Rp 1,080,000 while for lime stone raw materials with the company method amounting to Rp 360,000 and using the Silver meal method, and Wagner within algorithm Rp. 450,000. b). The storage cost for Silver meal, and Wagner Algorithm within Rp. 0 while for lime stone raw materials, the company method is Rp. 574,204 and using the Silver meal method, and the Wagner Within algorithm. Rp. 156,394, c). Inventory costs for Silver meal, and Wagner Algorithm within Rp 1,080,000 while for lime stone raw materials the company method is Rp 934,204 and using the Silver meal method and Wagner Algorithm within Rp. 606,394. And from the calculation of inventory costs, that the exact lot size method of lime stone used is the Silver meal method and Wagner Within Algorithm method due to inventory cost savings of 35.08% compared to using the method used by the company.

Acknowledgment
Thank you for the engineering faculty of Hasanuddin University for providing funding assistance for this research activity through the Learning Based Education (LBE) program.

References
[1] Pramana, F. G. (2011). Application of ABC Analysis in Fabric Raw Material Inventory Control at PT. Batik Danar Hadi Surakarta Printing Division. Universitas Sebelas Maret. (in Bahasa)
[2] Handoko T. Hani. 1984. Basics of production management and operations First edition. Faculty of Economics, Gajah Mada University, Yogyakarta.
[3] Yamit Zulian. 2003. Production and Operations Management. Faculty of Economics, Gajah Mada University, Yogyakarta.
[4] Rangkuti, F. (2007). Inventory Management: Applications in the Business Field. Issue 2. Jakarta: PT. Raja Grafindo Persada
[5] Tersine, R. J., 1994, Principles of Inventory and Material Management, Edition, Englewood Cliffs, New Jersey: Prentice-Hall, Inc.,