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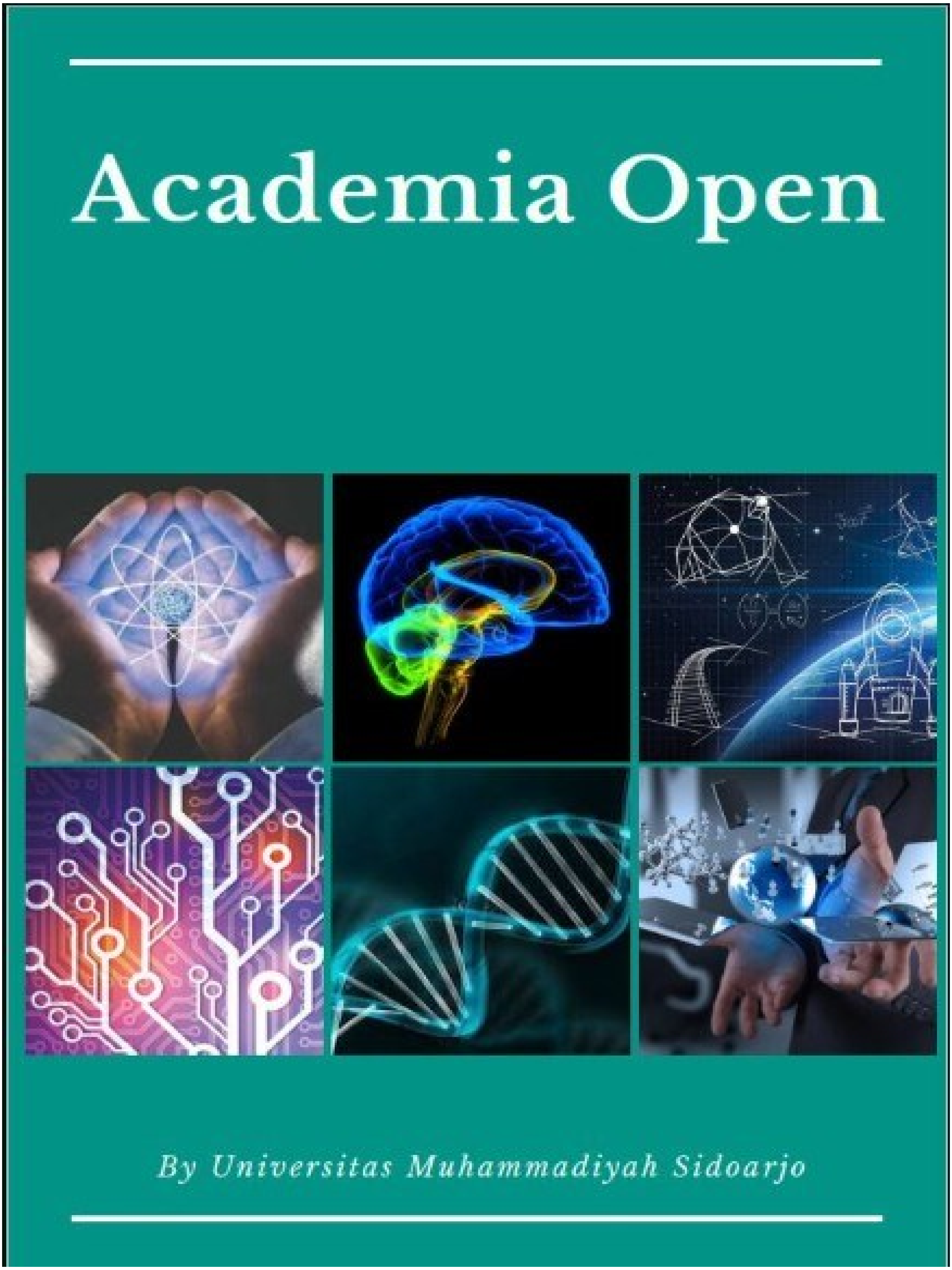

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Constrained Inventory Optimization Using Lagrange Multiplier in Animal Feed Production

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Abstract

General Background: Raw material inventory control is critical in manufacturing because excessive stock can create warehouse overcapacity, higher holding costs, and inefficient procurement decisions. **Specific Background:** Animal feed production requires animal-based raw materials with limited warehouse capacity, making optimal multi-item ordering essential for cost efficiency and storage utilization. **Knowledge Gap:** Previous inventory studies have rarely applied the Lagrange Multiplier method to animal-based raw material control in the animal feed industry while explicitly considering warehouse capacity constraints. **Aims:** This study aimed to optimize raw material inventory control by determining order quantities that minimize total inventory cost under limited storage capacity. **Results:** Using quantitative inventory calculations, the conventional method produced a total inventory cost of IDR 1,166,757,379. The EOQ approach still exceeded the available warehouse capacity, indicating that unconstrained optimization was not feasible. The Lagrange Multiplier method produced optimal order quantities of 173.99 tons for material A, 225.16 tons for material B, and 111.45 tons for material C. The resulting storage requirement was 2,393.03 m³, within the available 2,393.46 m³ capacity. Total inventory cost decreased to IDR 894,288,924, producing 26.8% cost savings. **Novelty:** This study applies constrained Lagrange Multiplier optimization to multi-item animal-based raw material inventory. **Implications:** The findings support more efficient purchasing, capacity-based ordering, warehouse utilization, and inventory cost control.

Highlights:

-
- EOQ exceeded the available storage limit.
- Proposed ordering quantities fit within warehouse capacity.
  Total spending declined by 26.8%.

Keywords: Inventory, EOQ, Lagrange Multiplier, Raw Material Control.

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Introduction

Raw materials are the primary components in product manufacturing; therefore, companies prepare raw material budgets to plan material requirements over a specific production period [1]. The procurement and management of raw materials also play a crucial role in determining a company's success [2]. Inventory, particularly raw materials, holds a vital role in supporting operational activities in both trading and manufacturing companies, as it ensures the continuity of production and distribution processes [3]. Consequently, every stage from selecting high-quality raw materials to ensuring proper storage conditions, must be carefully managed, as it directly affects the quality of materials used in the production process [4]. Inventory management itself is a series of activities aimed at controlling the availability of raw materials, work-in-process, and finished goods to meet company requirements in terms of quantity, timing, and cost efficiency [5]. As an agrarian country, the agricultural and livestock sectors are among the main drivers of national economic growth [6]. The livestock subsector significantly contributes to Indonesia's GDP while also reflecting the country's food security, which continues to improve alongside increasing demand and greater nutritional awareness [7]. Based on data from the Central Statistics Agency (Badan Pusat Statistik) Agricultural Census 2023, there are approximately 12.19 million livestock farming households in Indonesia, highlighting its importance as a source of income and food security. To support this development, the availability of high-quality animal feed is essential; therefore, efficient feed inventory management is required to enhance productivity and ensure the sustainability of livestock businesses [8].

In line with this, PT XYZ, as an agri-food company, must maintain the quality of its feed products by utilizing animal-based raw materials as a source of essential amino acids, consisting of materials A, B, and C. However, the company faces inventory control issues, particularly overstock conditions reaching 22.93% above warehouse capacity, which leads to increased storage costs. This condition indicates that the existing inventory control system has not been optimized, especially in accommodating warehouse capacity constraints. To address this issue, this study employs the Lagrange Multiplier method, which is capable of optimizing objective functions while considering constraints without requiring explicit parameter separation. This method is widely used in solving complex optimization problems involving limited resources [9]. Its ability to handle constrained problems efficiently makes it highly effective for solving technical problems and complex differential equations [10]. Previous studies have demonstrated the effectiveness of the Lagrange Multiplier method in optimizing inventory costs. A study on inventory control for perishable goods showed that this method resulted in a lower minimum cost compared to the company's existing approach [11]. Another study found that the application of the Lagrange Multiplier method achieved cost savings of up to 63.5%, equivalent to IDR 3,237,127,932,948.96 [12]. However, prior research has rarely discussed its application in the animal feed industry, particularly in the management of animal-based raw materials and by considering warehouse capacity constraints. Therefore, this study proposes a multi-item inventory control approach using the Lagrange Multiplier method to optimize order quantities and minimize total inventory costs, thereby improving the company's operational efficiency.

Method

This study applies data collection methods consisting of both primary and secondary data. Primary data were collected through structured interviews to gain an understanding of current procurement procedures, storage policies, and the applied cost structure. In addition, direct observations were conducted in the warehouse area to examine space utilization, material handling processes, and storage system arrangements. This study uses a quantitative approach with the Lagrange Multiplier method to determine optimal order quantities.

The research instruments used in this study include interview guidelines, observation sheets, and company documents related to raw material inventory data, such as purchasing data, inventory costs, and warehouse capacity, with data covering the period from January to December 2025.

The research steps are as follows:

1. The study begins with the preparation stage, followed by field study and literature review to understand the company's actual conditions and theoretical foundations.

2. The next step involves problem identification and formulation, setting research objectives, and collecting relevant data.

3. The data are then processed through calculations of warehouse capacity, inventory costs using the company's method, Economic Order Quantity (EOQ), and the Lagrange Multiplier method to obtain an optimal solution and determine the best method. Calculating storage space requirements using the formula :

$$\sum_{i=1}^{n} Wi\ Qi \leq W \tag{1}$$

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4. Calculating ordering and holding costs using the formula :

$$TC_p = (\text{Frekuensi Pemesanan x Biaya Pemesanan}) + \left(\frac{Q}{2}\right) \times \text{Presentase Biaya Simpan x Harga Beli)} \quad (2)$$

5. Determining optimal order quantities using the Lagrange Multiplier method with warehouse capacity constraints. Where the first step is calculating the order quantity using the Lagrange Multiplier method, by applying the following formula :

$$Q^*_{Li} = \frac{\text{Kapasitas Maksimal Gudang}}{\text{Hasil Perhitungan Ukuran Pemesanan dengan EOQ}} \; x \; Q^*_i \quad (3)$$

Then, it is followed by calculating the total inventory cost using the following formula :

$$TC\ Q^*_{Li} = \Sigma^n_{1i=1}\left(\frac{D_i}{Q^*_{Li}} \text{ x Biaya Pesan}\right) + \Sigma^n_{1i=1}\left(\frac{Q^*_{Li}}{2} \text{ x Harga Bahan Baku x Presentase Biaya Simpan}\right) \quad (4)$$

6. Comparing total inventory costs between the conventional method and the proposed method.
7. Furthermore, forecasting is conducted using the method with the smallest Mean Absolute Deviation (MAD), followed by validation using the Moving Range Chart (MRC).
8. The next step uses the forecasting results for inventory control calculations, followed by analysis to draw conclusions and provide recommendations.

Result and Discussion

A. Data collection

The data used in this study is data for the January-December 2025 period. Data on the purchase of raw materials for animals A, animals B and animals C can be seen in table 1 below:

Table 1. Purchase Data of Animal Raw Materials A, Animal B and Animal C

No.	Purchase Data of Animal Raw Materials A, B and C (Ton)			
	Moon	**Ingredient A**	**Ingredient B**	**Material C**
1.	January	1.474,81	1.601,40	409,05
2.	February	1.519,06	1.665,46	425,41
3.	March	1.592,80	1.649,44	413,14
4.	April	1.401,07	1.569,37	421,32
5.	May	1.533,81	1.681,47	400,86
6.	June	1.430,57	1.649,44	417,23
7.	July	1.519,06	1.569,37	400,86
8.	August	1.401,07	1.553,36	417,23
9.	September	1.533,81	1.633,43	396,77
10.	October	1.386,32	1.521,33	417,23
11.	November	1.519,06	1.569,37	392,68
12.	December	1.386,32	1.473,29	396,77
	Total	**17.697,76**	**19.136,76**	**4.908,55**

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The price data for raw materials for animals A, animals B and animals C can be seen in table 2 below:

Table 2. Purchase Data of Animal Raw Materials A, Animal B and Animal C

No.	Material Price	
	Jenis	**Purchase Price per Ton**
1.	Animal Material A	IDR 8,200,000
2.	Animal Ingredient B	IDR 7,000,000
3.	Animal Ingredients C	IDR 7,500,000

Data on storage costs and ordering costs for raw materials for animals A, animals B and animals C can be seen in table 3 below:

Table 3. Data on Order Costs and Storage Costs for Animal Raw Materials A, Animal B and Animal C

Booking Fee	Percentage of Storage Costs
IDR 2,470,000.00	15%

Data on raw material handling media, raw material handling dimensions, and raw material capacity per handling medium can be seen in the following Table 4:

Table 4. Warehouse Storage Capacity Data

Raw Material Storage Media	Raw Material Capacity per Handling Media (Pallet) / (Tons)	Raw Material Storage Dimensions (Wi) (m^3)
Pallet	1,44	6,75
Maximum Volume Storage Space Capacity (m^3)		**2,393.46 m3**

The data on the size of orders for raw materials for animal A, animal B and animal C are listed in table 5 below:

Table 5. Data on Storage Size of Raw Materials for Animals A, Animals B and *Animals C*

No.	Raw Material Type	Order Size (Tons)
1.	Animal Raw Material A	737.41
2.	Animal Raw Material B	800.70
3.	Animal Raw Material C	204,52

B. Calculation of Conventional Methods

Conventional method raw material inventory control is carried out by calculating the total storage space capacity and total inventory cost. The total storage space is calculated using the following formula:

Animal Raw Material A = Pallet Dimensions × (Order Quantity) / (Capacity per Pallet)

= 6,75 x 737,41 ton/ 1,44 ton

= 3.456,59 m^3

$$\sum_{i=1}^{n} Wi\ Qi \leq W \tag{5}$$

$$3.456{,}59\ m^3 + 3.753{,}29\ m^3 + 958{,}70\ m^3 \leq 2.393{,}46\ m^3$$
$$8.168.58\ m^3 \geq 2.393.46\ m^3$$

Based on calculations, the total capacity of 8,168.58 m^3 indicates that storage is not optimal because it exceeds the available capacity of 2,393.46 m^3 at PT XYZ. Furthermore, the total cost is calculated as follows:

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TCp = Total Booking Fee + Total Storage Fee
= IDR 111,720,000 + IDR 988,917,379
= IDR 1,166,757,379

Based on calculations, the total inventory cost by the company's method is IDR 1,166,757,379 at PT XYZ.

C. Calculation of Storage Space of EOQ and Lagrange Multiplier Methods

To control inventory, the first step is to calculate inventory without problems using the EOQ (Qi*) method. The Economic Order Quantity (EOQ) Multi-Item method is used in inventory management to help determine order quantities efficiently [13].

$$Q^* = \sqrt{\frac{2\ x\ Di\ x\ Ai}{\alpha\ x\ Ci}} \quad (6)$$

1. Animal Ingredient A

$$Qi^* = \sqrt{\frac{2\ x\ 17.697,76\ x\ 2.470.000}{15\%\ x\ 8.200.000}} = 266.60 \text{ ton}$$

2. Animal Ingredient B

$$Qi^* = \sqrt{\frac{2\ x\ 19.216,83\ x\ 2.470.000}{15\%\ x\ 7.000.000}} = 300.68 \text{ ton}$$

3. Animal Ingredients C

$$Qi^* = \sqrt{\frac{2\ x\ 4.908,55\ x\ 2.470.000}{15\%\ x\ 7.500.000}} = 146,812 \text{ ton}$$

The total new storage space can be calculated by applying *the Economic Order Quantity* (EOQ) method as follows.

Animal Raw Material A = Pallet Dimensions × (Order Quantity) / (Capacity per Pallet)
= 6,75 x 266.60 ton/ 1,44 ton
= 1.249,72 m^3

$$\sum_{i=1}^{n} Wi\ Qi \le W \quad (7)$$

$$1.249,72\ m^3 + 1.406,51\ m^3 + 688,18\ m^3 \le 2.393,46\ m^3$$
$$3.347,36\ m^3 \ge 2.393,46\ m^3$$

The calculation results show that the storage space requirement is 3,347.36 m^3, exceeding the available capacity of 2,393.46 m^3, so it is not optimal and needs to be optimized with the Lagrange Multiplier method.

After calculating the total inventory warehouse capacity using the *Economic Order Quantity* (EOQ) method, the next step is to calculate the inventory by considering the constraints using the *Lagrange Multiplier* method. The results of the calculation of inventory warehouse capacity without problems using the EOQ method, then the optimal order size (*QLi**) can be calculated as follows.

$$Q_{Li}^* = \frac{\text{Kapasitas Maksimal Gudang}}{\text{Hasil Perhitungan Ukuran Pemesanan dengan EOQ}}\ x\ Q_i^* \quad (8)$$

a. Animal Ingredient A

$$Q_{Li}^* = \frac{2.393,46}{3.347,36}\ x\ 266,60 = 190.63 \text{ tons}$$

b. Animal Ingredient B

$$Q_{Li}^* = \frac{2.393,46}{3.347,36}\ x\ 300,68 = 214.99 \text{ tons}$$

c. Animal Ingredients C

$$Q_{Li}^* = \frac{2.393,46}{3.347,36}\ x\ 146,81 = 104.97 \text{ tons}$$

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After the inventory calculation is carried out by considering the constraints using the Lagrange Multiplier method, it is continued with the calculation of the total storage space using the Lagrange Multiplier method.

Animal Raw Material A = Pallet Dimensions × (Order Quantity) / (Capacity per Pallet)

= 6,75 x 190,63 ton/ 1,44 ton

= 890,63 m^3

$$\sum_{i=1}^{n} Wi\ Qi \leq W \tag{9}$$

890,63 m^3 + 1.007,80 m^3 + 492,07 m^3 ≤ 2.393,64 m^3

2.390,50 m^3 ≤ 2.393,46 m^3

With the Lagrange Multiplier method, an optimal storage space of 2,390.50 m³ was obtained because it did not exceed the capacity of 2,393.64 m³, so that there was no overcapacity. After that, the total cost is calculated using the lagrange multiplier method.

TC Q^*_{Li} = Booking Fee + Storage Fee

$$= \Sigma_{1i=1}^{n} \left(\frac{D_i}{Q^*_{Li}} \text{ x Biaya Pesan}\right) + \Sigma_{1i=1}^{n} \left(\frac{Q^*_{Li}}{2} \text{ x Harga Bahan Baku x Percentage of Storage Cost }\right) \tag{10}$$

$$= \left(\begin{array}{l} \left(\frac{17.697,76}{190,63} \text{ x IDR } 2.470.000\right) + \left(\frac{190,79}{2} \text{ x } 15\% \text{ x IDR } 8.200.000\right) + \\ \left(\frac{19.216,83}{214,73} \text{ x IDR } 2.470.000\right) + \left(\frac{214,73}{2} \text{ x } 15\% \text{ x IDR } 7.000.000\right) + \\ \left(\frac{4.908,55}{105,06} \text{ x IDR } 2.470.000\right) + \left(\frac{105,06}{2} \text{ x } 15\% \text{ x IDR } 7.500.000\right) + \end{array} \right)$$

= IDR 345,716,326 + IDR 332,645,117 + IDR 174,530,222

= IDR 853,530,665

Thus, from the calculation of the total inventory cost using the Lagrange Multiplier method , the minimum total inventory cost is obtained which is IDR 853,530,665.

Table 6. Comparison of Total Inventory Costs of Conventional Methods with Lagrange Multiplier Methods

Conventional Methods	Metode *Lagrange Multiplier*	Total Cost Difference
IDR 1,166,757,379	IDR 853,530,665	IDR 312,865,714

Based on Table 4.10, the total inventory cost of the company method is IDR 1,166,757,379, while the Lagrange Multiplier method is IDR 853,530,665. The Lagrange Multiplier method is more optimal with savings of IDR 312,865,714 or 26.8% compared to the company method.

D. Forecasting Needs for the Upcoming Period

The initial stage of the Lagrange Multiplier method is to forecast the need based on historical data on the use of raw materials A, B, and C (January–December 2025) through pattern analysis with data plots.

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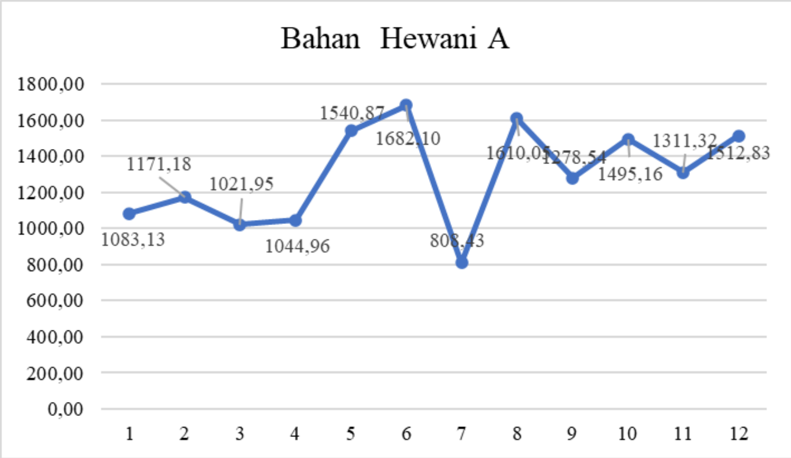

Figure 1. Animal Raw Material Data Plot A

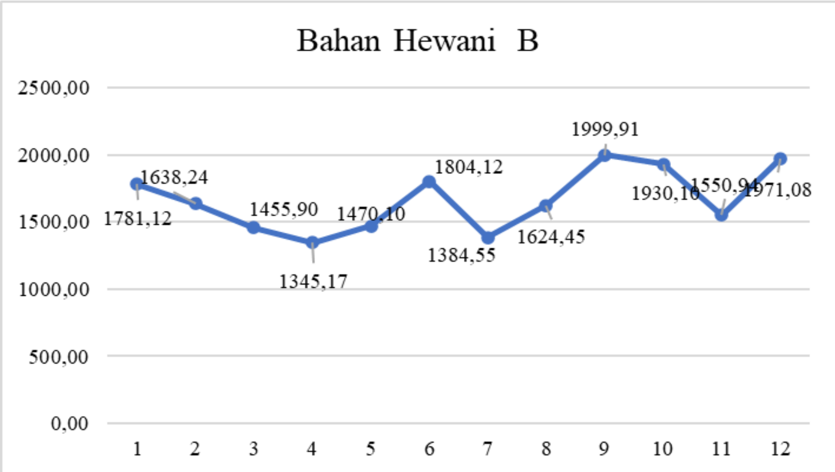

Figure 2. Animal Raw Material Data Plot B

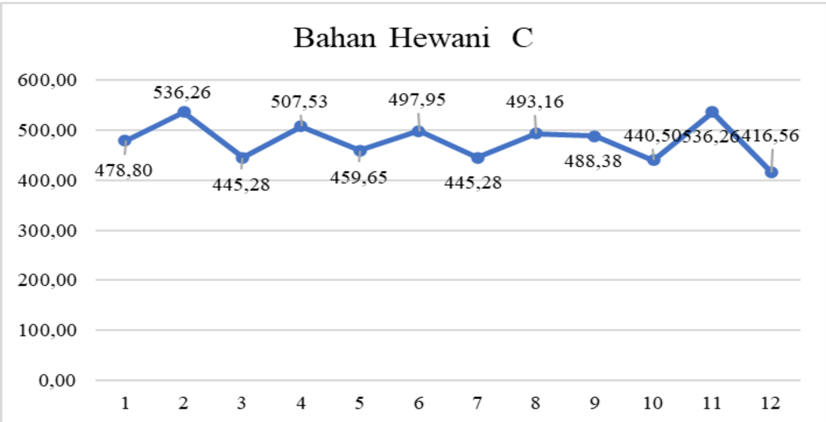

Figure 3. Animal Raw Material Data Plot C

Based on the results of the historical data plot of animal-based raw material purchases for the period January–December 2025, which shows a horizontal pattern. A horizontal data plot occurs when the data values fluctuate around

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a constant mean, remain stable, or are stationary around their average value [14]. Therefore, the appropriate forecasting methods are Single Exponential Smoothing, Moving Average, and Weighted Moving Average. Subsequently, the method with the smallest Mean Absolute Deviation (MAD) value is selected.

Table 7. Comparison of MAD and MAPE Values of Each Forecasting Method

Raw Material Type	*Single Exponential Smoothing*		*Moving Average*		*Weighted Moving Average*	
Fault Test	**MAD**	**MAP**	**MAD**	**MAP**	**MAD**	**MAP**
Animal Ingridient A	**228,18**	17,6%	280,08	22,3%	284,28	23,26
Animal Ingredient B	226,44	13,6%	**221,92**	13,1%	234,92	13,9%
Animal Ingredients C	**35,50**	7,5%	36,89	7,9%	39,5	8,4%

In testing the Mean Absolute Percentage Error (MAPE), a prediction value that is closer to the actual value indicates better method performance [15]. Based on the table, the Single Exponential Smoothing method is the best for materials A and C, while the Moving Average method is the best for material B (based on the lowest MAD value). The MAPE values show that material A is 17.6%, material B is 13.1%, and material C is 7.5%. Therefore, both methods are selected for forecasting the 2026 demand. The forecasting results are as follows.

Table 8. Forecast of Purchase of Animal Raw Materials A, B and C for January – December 2026

No.	**Raw Animals A, B AND C (Tons)**			
	Moon	**Ingredient A**	**Ingredient B**	**Material C**
1.	January	1.364	1.817	477
2.	February	1.364	1.817	477
3.	March	1.364	1.817	477
4.	April	1.364	1.817	477
5.	May	1.364	1.817	477
6.	June	1.364	1.817	477
7.	July	1.364	1.817	477
8.	August	1.364	1.817	477
9.	September	1.364	1.817	477
10.	October	1.364	1.817	477
11.	November	1.364	1.817	477
12.	December	1.364	1.817	477
Total		**16.368**	**21.804**	**5.724**

E. Calculation of Storage Space from EOQ Method Forecasting and Lagrange Multiplier Method

After the forecast results are known, then the calculation is carried out without problems using the EOQ (Qi*) method from the forecast results.

1. Animal Ingridient A

$$Qi^* = \sqrt{\frac{2 \; x \; 16.368 \; x \; 2.470.000}{15\% \; x \; 8.200.000}} = 247.49 \text{ ton}$$

2. Animal Ingredient B

$$Qi^* = \sqrt{\frac{2 \; x \; 21.804 \; x \; 2.470.000}{15\% \; x \; 7.000.000}} = 320.28 \text{ ton}$$

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3. Animal Ingredients C

$$Qi^* = \sqrt{\frac{2 \times 5.724 \times 1.470.000}{15\% \times 7.500.000}} = 158.53 \text{ ton}$$

Then the total storage capacity of new animal raw materials is calculated using the following EOQ method:

$$\sum_{i=1}^{n} Wi\ Qi \leq W \quad (11)$$

1.160,15 m3 + 1.501,34 m3 + 743,15 m3 ≤ 2.393,46 m3
3,404,64 m3 ≥ 2,393,46 m3

Based on the calculation results, the total storage space of 3,404.64 m³ exceeds the warehouse capacity of 2,393.46 m³, so it is not optimal and needs to be optimized using the Lagrange Multiplier method. After calculating warehouse capacity using the EOQ method, inventory optimization is then carried out by considering obstacles using the Lagrange Multiplier method.

1. Animal Ingredient A

$$Q^*_{Li} = \frac{2.393,46\ m^3}{3.404,64\ m^3} \times 247,49 \text{ Ton} = 173.99 \text{ ton}$$

2. Animal Ingredient B

$$Q^*_{Li} = \frac{2.393,46\ m^3}{3.404,64\ m^3} \times 320,28 \text{ Ton} = 225.16 \text{ ton}$$

3. Animal Ingredients C

$$Q^*_{Li} = \frac{2.393,46\ m^3}{3.404,64\ m^3} \times 158,53 \text{ Ton} = 111.45 \text{ ton}$$

The total storage capacity of new animal raw materials was calculated using the *following Lagrange Multiplier* method :

$$\sum_{i=1}^{n} Wi\ Qi \leq W \quad (12)$$

815,16 m3 + 1.055,44 m3 + 522,44 m³ ≤ 2.393,46 m3
2.393.03 m3 ≤ 2.393.46 m³

Based on the Lagrange Multiplier method, a total storage space of 2,393.03 m³ was obtained which did not exceed the warehouse capacity of 2,393.46 m³, so that conditions were optimal and there was no overcapacity. Then from the results of the calculation of the lagrange multiplier method, a calculation is made for the total cost, as follows:

TCQ^*_{Li} = Booking Fee + Storage Fee

$$= \Sigma_{1i=1}^{n} \left(\frac{D_i}{Q^*_{Li}} \text{ x Biaya Pesan}\right) + \Sigma_{1i=1}^{n} \left(\frac{Q^*_{Li}}{2} \text{ x Harga Bahan Baku x Percentage of Storage Cost}\right)$$

$$= \left(\begin{array}{l} \left(\frac{16.368}{173,99} \text{ x IDR } 2.470.000\right) + \left(\frac{173,99}{2} \text{ x } 15\% \text{ x IDR } 8.200.000\right) + \\ \left(\frac{21.804}{225,16} \text{ x IDR } 2.470.000\right) + \left(\frac{225,16}{2} \text{ x } 15\% \text{ x IDR } 7.000.000\right) + \\ \left(\frac{111,45}{198} \text{ x IDR } 1.470.000\right) + \left(\frac{111,45}{2} \text{ x } 15\% \text{ x IDR } 7.500.000\right) + \end{array} \right)$$

= IDR 347,257,956 + IDR 357,484,467 + IDR 189,546,501

= IDR 894,288,924

Thus, from the calculation of the total cost of inventory using the *Lagrange Multiplier* The minimum total inventory cost is IDR 894,288,924. The application of the Lagrange Multiplier method on animal raw materials A, B, and C is able to optimize the use of warehouse capacity and the number of orders, thereby reducing total inventory costs and becoming a more efficient approach.

Based on the difference in total inventory costs, the Lagrange Multiplier method is able to provide cost savings of 26.8% compared to the conventional method. These savings occur because the method produces more efficient order quantities that align with raw material requirements and warehouse capacity. Conceptually, the Lagrange Multiplier

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method is used to solve optimization problems with constraints, making it suitable for inventory control with limited warehouse capacity. The results of this study are consistent with inventory management theory, which states that optimal order quantities can minimize total costs, consisting of ordering and holding costs. In addition, the findings support previous studies that demonstrate the effectiveness of the Lagrange Multiplier method in optimizing inventory costs. This study also contributes by applying the method to multi-item inventory control of animal-based raw materials in the animal feed industry while considering warehouse capacity constraints, making the results both theoretically and practically relevant. Overall, the Lagrange Multiplier method not only reduces total inventory costs but also improves operational efficiency through more optimal inventory management.

Conclusion

This study concludes that the Lagrange Multiplier method is effective in optimizing inventory control of animal-based raw materials by considering warehouse capacity constraints. The Lagrange Multiplier method reduces total inventory costs to IDR 853,891,665 from IDR1,166,757,379, achieving a cost reduction of 26.8%, and determines the optimal order quantities. Therefore, its implementation can improve operational efficiency and reduce unnecessary costs within the conventional method. Then for further research, it is better to conduct further analysis related to other external factors that can affect the control of raw materials and can conduct further research using the latest methods as a further development of the Lagrange Multiplier method in inventory control.

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