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PRODUCT DEMAND FORECASTING: A SOLUTION TO DETERMINE RAW MATERIAL NEEDS FOR COCONUT OIL AGROINDUSTRY DEVELOPMENT

PERAMALAN PERMINTAAN PRODUK: SOLUSI UNTUK MENENTUKAN KEBUTUHAN BAHAN BAKU UNTUK PENGEMBANGAN AGROINDUSTRI MINYAK KELAPA

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ABSTRAK

Indonesia merupakan penghasil kelapa terbesar di dunia. Salah satu kabupaten penghasil kelapa terbesar di Indonesia adalah Kabupaten Indragiri Hilir, meskipun perkebunan kelapa di daerah ini sangat luas, namun pengembangan agroindustri kelapa di daerah ini masih rendah. Salah satu produk kelapa yang potensial adalah minyak kelapa karena banyak diminati di pasar luar negeri. Pengembangan agroindustri memerlukan penentuan kebutuhan bahan baku karena bertujuan untuk perencanaan kapasitas agroindustri. Penentuan bahan baku harus dimulai dengan peramalan permintaan karena dapat meningkatkan efisiensi dan penurunan penyimpanan bahan baku sehingga mengurangi pemborosan. Berdasarkan hal tersebut, penelitian ini bertujuan untuk meramalkan permintaan sebagai solusi untuk menentukan kebutuhan bahan baku dalam pengembangan agroindustri minyak kelapa. Penelitian ini menggunakan integrasi metode ARIMA dan mass balance. Hasil penelitian menunjukkan bahwa peramalan permintaan minyak kelapa dari tahun 2025 hingga 2030 adalah 556,749 ton/tahun, dengan kebutuhan bahan baku sebesar 4,259,130 ton/tahun. Penelitian ini dapat menjadi gambaran bagi petani dan agroindustri untuk mengembangkan agroindustri minyak kelapa.

Kata kunci: bahan baku, peramalan permintaan, minyak kelapa, pengembangan agroindustri

ABSTRACT

Indonesia is the world's largest coconut producer, with Indragiri Hilir being one of its major coconut-producing regencies. Despite the extensive coconut plantations in the region, the development of the coconut agroindustry remains underdeveloped. Coconut oil, a high-demand product in international markets, represents a significant opportunity for agroindustrial growth. Effective agroindustrial development requires accurate determination of raw material needs to plan production capacity and ensure efficient operation. Forecasting demand is a critical first step in this process, as it can enhance efficiency, reduce unnecessary raw material stockpiling, and minimise waste. This study aimed to forecast the demand for coconut oil, which is a crucial step for determining raw material requirements in the development of the coconut oil agroindustry. The research integrated ARIMA and mass balance methods. The findings indicated that coconut oil demand was projected to reach 556,749 tons per year from 2025 to 2030, with a corresponding raw material requirement of 4,259,130 tons per year. This study provides valuable insights for both farmer and agroindustry stakeholders in advancing the development of the coconut oil agroindustry.

Keywords: agroindustry development, coconut oil, demand forecasting, raw material

INTRODUCTION

Coconut trees (*Cocos nucifera* L.) are a highly valuable plant due to its extensive range of applications. Consequently, they are often referred to as the "tree of life", signifying that nearly every part of the plant can be utilized for various purposes (Deen *et al.,* 2021). Among their abundant derivatives, coconut oil is one of the most economically significant products, which is extracted from the coconut kernel. The oil has gained prominence as an essential vegetable oil due to its numerous health benefits (Wallace, 2019). The increasing global awareness of these health benefits has led to a rising international demand for coconut oil. Moreover, Indonesian coconut oil holds a strong comparative advantage in the global market with a high revealed comparative advantage value reaching 0.94 and 0.99 (Yulhar and Darwanto, 2019; Purba *et al.*, 2021; Xia and Dewi, 2022). Given that the coconut oil has a surge demand in the international trade landscape, further development of the coconut agroindustry is imperative to enhance competitiveness and maximize economic benefits.

The development of the coconut agroindustry is crucial for Indonesia, particularly in Indragiri Hilir Regency, which is the largest coconut-producing region in the country (Wardah and Yani,

*Coressponding Author

2022; Wardah *et al.,* 2023). Despite the extensive coconut plantations in this area, there are clear and significant constraints which lead to the loss of significant economic opportunities (Wardah *et al.,* 2020). In Indragiri Hilir, the total coconut plantation area reaches 440,821 hectares, accounting for 12% of the national coconut plantation area (Murtius, 2024). The advancement of the coconut agroindustry in this region has the potential to create employment opportunities, thereby increasing farmers' incomes and ultimately contributing to national economic growth. Therefore, the development of the coconut agroindustry in the area is a critical step towards achieving sustainable economic growth.

Considering the importance of agroindustry development, it is essential to determine raw material requirements before proceeding with such development, as this is crucial for defining the capacity of the agroindustry (Suryaningrat, 2016; Sazvar *et al.,* 2021; Santosa *et al.,* 2022). Accurate calculations of raw material needs ensure sufficient availability for production, thereby reducing the risk of operational delays caused by raw material shortages. Agroindustry that can accurately forecast raw material requirements and secure a reliable supply chain will gain a competitive and sustainable advantage in an increasingly dynamic global market (Hofmann, 2018; Xiao *et al.,* 2021; Czajka *et al.,* 2022; García-Ten *et al.,* 2024). To response this need, determination of raw material demand should begin with forecasting product demand. Accurate demand forecasting enhances efficiency, strengthens production capabilities, and optimises supply chains by aligning production facilities with raw material needs. This alignment reduces excess inventory and waste caused by inaccurate capacity planning (Seyedan dan Mafakheri, 2020). Another reason is that the accurately forecasted demand is essential for optimising and managing future production in a cost-effective manner, playing a pivotal role in monitoring supply chains.

The integration of product demand forecasting with determination of raw material requirements is a contemporary issue, as research on coconut oil demand forecasting has declined over the past five years. However, copious studies have been conducted on the production of coconut oil-based biodiesel (Budhwani, 2019; Helmiyati, 2019; Rathore, 2019; Thushari, 2019; Yusuff, 2019; Rajasekar, 2020; Thushari 2020; Bambase 2021; Lugo-Méndez 2021; Dey *et al.* 2023), the effects and processes of coconut oil production (Jayawardena, 2020, 2021; Karagounis, 2019; Malaeb, 2020; Neelakantan, 2020; Ng, 2021; Nitbani, 2022; Pupala *et al.*, 2019; Rabail, 2021; Ramesh, 2021; Saleel, 2022; Santos, 2019; Teng, 2020; Woolley, 2020), and phase-change materials (Saleel, 2019; Saraç, 2019; Alqahtani, 2020; Safira, 2020). Aligning demand forecasting with raw material needs plays a crucial role in monitoring the supply chain and its integration with other trading capacities. This makes it one of the most important aspects that businesses can leverage for long-term sustainability, while promoting the advancement of effective and successful agro-industrial development. Therefore, this study fills the research gap regarding product demand forecasting for raw material determination in the development of the coconut oil agroindustry, supporting the broader growth of the agroindustry sector.

The commonly used demand forecasting methods are based on traditional time series, but they still require model structure information that requires more significant data (Rendon-Sanchez & de Menezes, 2019). In this case, creating a reliable demand determination method to provide superior and more accurate estimates is fundamental. A common technique for estimating strategies is conventional time setting, but it still entails structural data that employ more critical information. In this approach, producing reliable demand estimation is crucial to provide and more precise and enhanced figures. Nevertheless, forecasting methods, particularly Autoregressive Integrated Moving Average (ARIMA), must be fundamentally applied. Its implementation in specific domains remains limited, indicating a research gap and providing opportunities for further studies to improve forecasting accuracy and support better decision-making in forecasting coconut oil product demand (Fattah *et al.*, 2018; Karmy, 2019; Seyedan, 2020).

Additionally, ARIMA approach presented by Box and Jenkins (1976) is well known as the Box-Jenkins strategy (Fattah *et al.,* 2018; Kumar *et al.,* 2021; Mishra *et al.,* 2021). The method is typically applied in a stationary form, though it can also be used in non-stationary form. However, separation operations or other significant transformations must be performed to address the non-stationarity of the method (Noureen, 2019). Furthermore, the results of product demand forecasting need to be integrated with raw material requirements determination for the development of the coconut oil agroindustry. The mass balance method can be employed as it is a widely recognised tool for calculating raw material needs in agro-industrial development. This method benefits the agroindustry sector by involving all inputs, outputs, and losses to balance the mass entering and exiting the system (Chiaraluce *et al.*, 2023; Yahya *et al.*, 2023). The method presented in this study results in the cutting-edge integration of the ARIMA strategy with mass balance.

The integration is able to generate a comprehensive approach that can effectively calculate raw material requirements and generate more accurate demand forecasts. The combination of demand forecasting and raw material requirements determination provides a foundation for more informed decision-making, which can reduce waste, enhance supply chain efficiency, and increase the competitiveness of the coconut oil agroindustry in the global market. This approach has been scarcely applied in previous research, particularly within the context of the coconut oil agroindustry. Therefore, this integration model can serve as one of the most relevant and contemporary approaches to support strategic planning in the agroindustry. As outlined in the background above, this study aims to forecast the demand for coconut oil products in order to find solutions for raw material determination for agroindustrial development by integrating the ARIMA method with mass balance.

RESEARCH AND METHODS

Research Framework

This study aims to forecast product demand to provide solutions on determination of raw material needs for development of coconut oil agroindustry. In this work, ARIMA method was integrated with the mass balance (Figure 1).

Data Collection

Primary and secondary sources were used to collect qualitative and quantitative data, as presented in Table 1.

Model Development of Coconut Oil Product Demand Forecasting

ARIMA could provide a picture that portrays a given time arrangement based on values that can be utilized to figure out future values. The modelling steps by ARIMA are as follows:

1. Checking the data stationarity.
2. Checking the differencing proof in ARIMA.
3. Constructing ARIMA model by ACF and PACF plots

The Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) tests are essential tools in time series analysis, primarily used to identify patterns and dependencies in data.

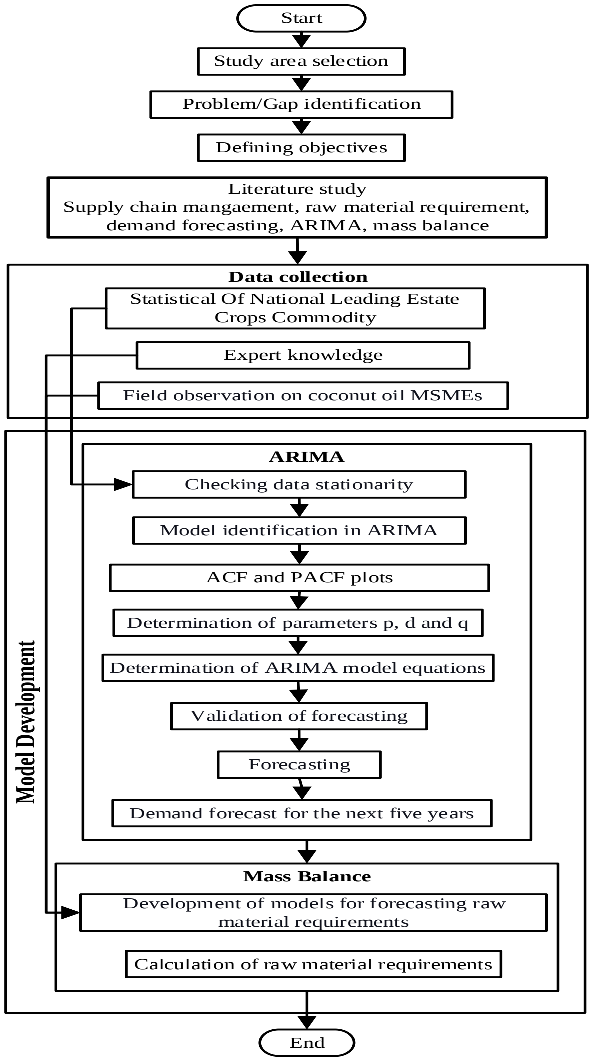

Figure 1. Framework and stages of research

Table 1. Data specification and collection procedures

No	Data	Type	Sources	Data retrieval	Analysis
1	Location of research area	Secondary Primary	Reports and journals Experts	Field survey and Interviews	Analysis
2	Demand for coconut oil products	Secondary	Reports	Statistical Report	Analysis
3	Demand Forecasting Coconut Oil	Secondary	Reports	Statistical Report	ARIMA
4	Development of models for forecasting raw material requirements	Primary	Field observation on coconut oil MSMEs Experts	Interviews	Mass Balance
5	Calculation of raw material requirements	Primary	Product demand forecasting results	Demand Forecasting Coconut Oil	Development of a model from a mass balance

The ACF measures the correlation between the time series and the lagged values, which is meaningful for detecting seasonality, trends, or dependencies. A slowly decreasing or sinusoidal ACF pattern often indicates an autoregressive (AR) process, while a sharp cut-off suggests a moving average (MA) process. On the other hand, the PACF isolates the direct impact of a specific lag by removing the influence of intermediate lags, making it useful for determining the order of an AR process. In ARIMA modeling, the ACF helps in selecting the MA (q) component, whereas the PACF helps in selecting the AR (p) component. By analyzing these plots, one can make informed decisions about the appropriate time series model to use for forecasting

4. Deciding parameters p, d, and q

Box and Jenkin presented ARIMA (p, d, q) demonstration in 1976, which can be applied to determine non-seasonal stationary time arrangements. The ARIMA demonstration is expressed by p, d, q, which denote the number of Auto-Regression (AR) term, Moving Normal (MA), and separation required to create the time arrangement stationary, respectively. Auto Relapse is the relapse of a variable on itself to forecast the required variable. It relates the design of one time period with that of the past period. MA may be a regression-like show that employs the blunder related to the estimation at the final step to figure out the variable at the other step. The following is the general equation of the p-order AR shown in conditions and the q-order MA is demonstrated in equation 1 and 2.

$$yt = C + \varphi 1y\ t-1 + \varphi 2yt-2 + \cdots + \varphi p + yt-p+\mathcal{E}t \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$yt = C + \mathcal{E}t + \theta 1\mathcal{E}t-1 + \theta 2\ \mathcal{E}t-2 + \cdots + \theta q\ \mathcal{E}t-q \quad \ldots\ldots\ldots\ldots \quad (2)$$

The ARIMA demonstration is built by combining AR demonstrate (equation (1)), integration (I), and MA demonstrate (Condition (2)). Integration (I) is the separation inverter that delivers scores. The generalized ARIMA demonstrated it is numerically spoken to, as in equation 3.

$$yt = C+ \varphi 1y+\varphi pyt-p +\cdots +\varphi nyt-n + \theta 1\mathcal{E}t-1 +\theta q\ \mathcal{E}t-q+\mathcal{E}t \quad \ldots\ldots\ldots\ldots \quad (3)$$

Where C is the caught, φi(i = 1, 2 ... p) is the auto-regressive demonstrate parameter, θ1(i = 1, 2 ... p) is the moving standard show parameter, it is the current time arrangement value, it-1, yt2 ... Yt-p are past values and is the arbitrary blunder or residual term for day t and is given by the equation 4.

$$t = yt - yt-1 \quad \ldots\ldots\ldots\ldots \quad (4)$$

5. Determination of ARIMA model equations.
6. Validation of forecasting.
7. Forecasting.
   The best model can be used to forecast demand for coconut oil.
8. Generating forecasts for the following years.

Model Development of Raw Material Requirement Determination

Observation is needed for the coconut oil raw material requirement model to obtain the appropriate coconut oil yield so that the product demand forecast forecasts the raw material requirements. The stages of coconut oil production are arranged according to relevant literature and validated through field observations in existing small and medium industries (MSMEs) of coconut oils in Indragiri Hilir Regency and expert interviews. The primary product production process includes coconut splitting, coconut drying, and pressing, as shown in Figure 2. The development of the raw material requirement model is obtained from the processing stages. The following are the stages of model development:

Splitting

Old coconuts with good quality and without damage or fungus were selected and grouped into two parts using a machete or coconut-splitting cutting tool. The coconut-splitting process begins by hitting the middle of the shell until it separates into two parts.

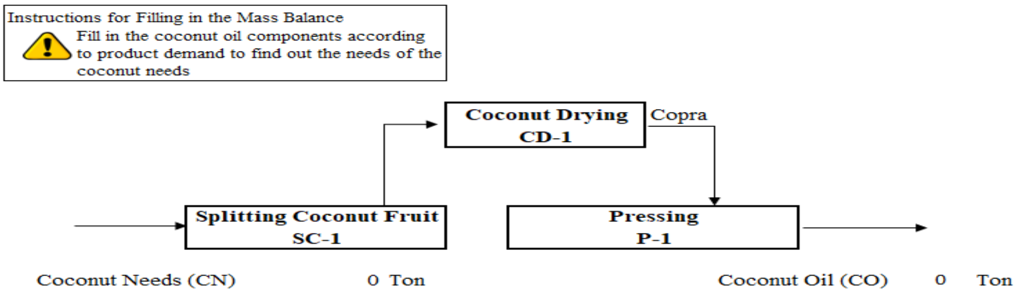

Figure 2. The primary process of making coconut oil

In one coconut fruit weighing 1 kilogram, the coconut meat (CM) is estimated to 0.28 kilograms.

Drying Coconut Into Copra

The coconut meat was arranged on a clean drying rack and covered with UV plastic, ensuring the drying location exposed to direct sunlight and protected from dust. The position of coconut meat was periodically rotated to ensure even drying, taking 2-3 days and depending on the intensity of sunlight. The copra (C) was estimated 0.222 kilograms from 1 coconut.

Pressing Copra Into Coconut Oil

Copra was pressed to extract oil by oil press machine. This machine used a high pressure to extract oil from copra, then crude coconut oil emerges. Calculating the mass balance of coconut oil begins with a validation mass balance as in equation 5, where C is copra, and CO is coconut oil, CM is copra meal. Based on equation 5 and field studies or real terms, the oil content (OC) in copra is 63%, and the extraction efficiency (EE) is 95%, so equation 6 is obtained. Conversely, 1 kilogram of copra requires 4.5 coconuts with an average weight of 1 kilogram of coconut, so equation 7 is obtained. Integration of equations 6 and 7, the coconut requirement (CN) is obtained as in equation 8.

$$C = CO + CM \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (5)$$
$$C = 1.7\ CO \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (6)$$
$$C\ (Kg) = 1/4.5\ CN\ (Kg) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (7)$$
$$CN\ (Ton/Year) = 7.65\ CO\ Ton/Year \quad \ldots\ldots.\ldots. \quad (8)$$

RESULTS AND DISCUSSIONS

Product Demand Forecasting

Demand forecasting is the most punctual arrangement demonstrated by capacity as input for stock control. The information within the demand determination shown in this research is coconut oil trade information collected from 1995 to 2021 as depicted in Figure 3. The graph clearly shows that the quantity of coconut oil exports fluctuated markedly over the years, meaning that the demand is not stationary. Data stationarity in the fluctuation can happen through the Box-Cox change. When the adjusted value or lambda (λ) is equal to 1, the information has stationarity in change at that point.

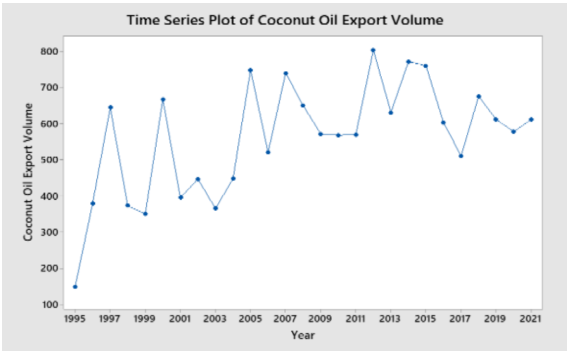

Figure 3. Data plot of coconut oil exports

In case of lambda (λ) not rising to 1, at that point, the information does not have stationarity in its fluctuation. Hence, a change must happen until the adjusted value in Box-Cox reaches 1. The information obtained from investigative information is in Figure 4. Figure 4 shows that the adjusted value (lambda) is 0.5, meaning that the change information is not stationary. The lambda value does not break even with 1, and information change is required. The information changes appear in Figure 5. The change 1 appeared in Figure 5 and appears to have an adjusted value of 1.00. This value shows that the requested information, as of now, has stationarity in its fluctuation.

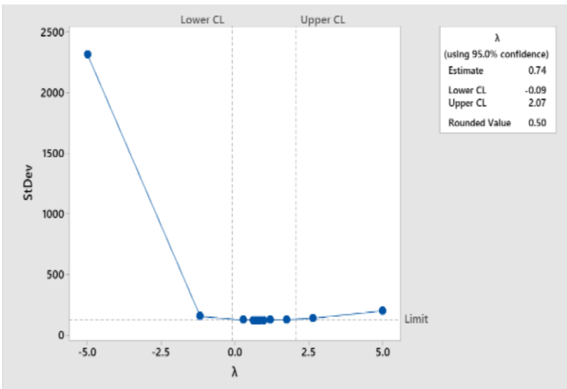

Figure 4. Box-cox output of coconut oil exports

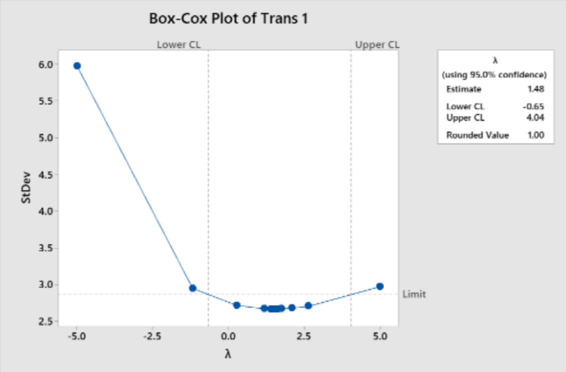

Figure 5. Box-cox output of coconut oil exports demand data at transformation 1

Checking the stationarity of the cruel (normal) is the following step. Utilize time arrangement graphs, autocorrelation work (ACF) plots, or fractional autocorrelation work (PACF) plots to test for stationarity within the cruel. If there are no slant components within the time arrangement plot, it can be concluded that the information has cruel stationarity. In the interim, it can be seen from the slack on the ACF plot for assessment utilizing the ACF plot. The standard information is stationary in case there is a quick decrease to approach zero after the moment or third slack. Figure 6 and Figure 7 are stationary charts since the blue line is inside the ruddy line, so it can be said that the information is stationary. In case the information is stationary, at that point, the ARIMA strategy calculation can proceed.

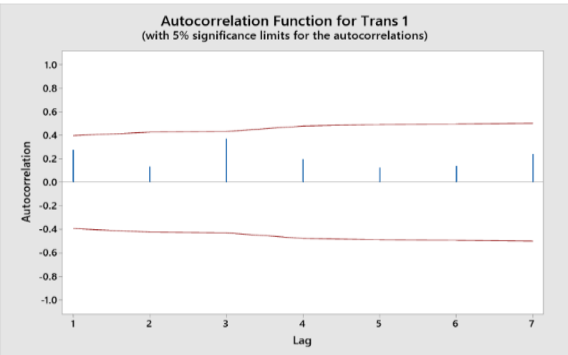

Figure 6. Graph output of the autocorrelation function of coconut oil exports demand data

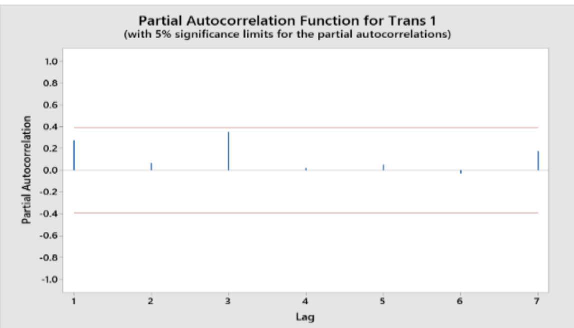

Figure. 7. Output graph of partial autocorrelation function for coconut oil exports

After stationary data are gained, ARIMA design is assessed, resulting in p value. Therefore, it can be said that the test comes about to have a critical impact. These scores will be tried exclusively, and mistake rates will be chosen. The estimation step is to get the evaluated coefficients from the chosen show. The results in Table 1 utilize the MINITAB 19 program to fill in future determining, and the blunder value for each ARIMA show can be seen. The ARIMA show was chosen based on the importance of the test. ARIMA determines the show chosen with the arrangement (0,0,1). Determining requests for the following a long time appears in Table 2. Table 2 shows that the demand forecast between 2025 and 2030 is the same for each year and this aligns with the result of research by Mishra *et al.* (2021). During the period, the estimated demand will be 556,749 tons/year, and from this prediction, the capacity of agroindustry can be estimated. The capacity should not exceed the demand forecast, reducing the stockpiling and cutting the waste.

Table 2. Forecasting demand for coconut oil

Year	Demand Forecasting (Ton/Year)
2025	556,749
2026	556,749
2027	556,749
2028	556,749
2029	556,749
2030	556,749

Test this leftover typicality test could be a prerequisite that's met to demonstrate that the estimates that come about are substantial and can be utilized. Leftover value is the contrast between figure information and genuine verifiable information. With a centrality level of 5%, the remaining test appears in Fandrappearst the information speculation with Ho: information is regularly dispersed, H1: information is not regularly conveyed, on the off chance that p-value < α, at that point dismiss Ho; if p-value > α, at that point acknowledge Ho. With a centrality level of 5% or 0.05, it can be seen that the p-value is 0.700 > 0.05 (α value), so Ho is acknowledged, which suggests the information is regularly dispersed. Value that demonstrates that the leftover value within the request estimating is ordinarily conveyed. Figure 8 shows that the leftover value is regularly disseminated since it appears to have a p-value of 0.700 > 0.05 (α value), so the estimating comes about can be utilized.

Determination of Raw Material Requirements

Requirement determination is an essential step in creating the coconut oil agroindustry since the integration with other commerce capacities is one of the foremost vital arranging forms that a business can utilize for the long term. After the estimate is made, it will be coordinated with calculating crude fabric prerequisites with a mass adjustment utilizing equation 8. The estimating of raw material need is shown Table 3, presenting the amount of raw material needed to provide an overview of capacity planning for agroindustry development. In addition, if it meets all export shares, it can find out the number of raw materials needed so that it can plan which areas to meet the need for raw materials according to capacity planning for the development of the coconut oil agroindustry. In this study, the main target is product export because coconut oil is in great demand by the export share compared to the local market share. In terms of price, coconut oil is higher than other plant-oil products. Table 3 also provides farmers with an overview of the amount of coconut raw materials needed, and it enables them to expand the area of coconut planting land, corresponding to the demand.

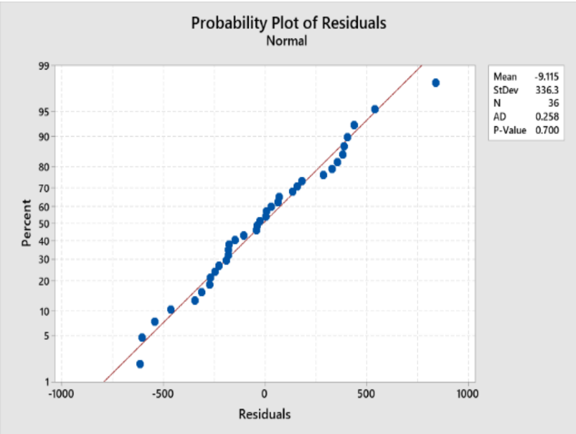

Figure. 8. Output from the probability plot of the residual test

Table 3. Raw materials requirement

Year	Demand Forecasting (Ton/Year)	C (Ton/Year)	CN (Ton/Year)
2025	556,749	930,241	4185,639
2026	556,749	930,241	4185,639
2027	556,749	930,241	4185,639
2028	556,749	930,241	4185,639
2029	556,749	930,241	4185,639
2030	556,749	930,241	4185,639

Managerial Implications

The model constructed from the integration of models and methods provides a significant contribution to science and is also expected to provide significant input and comparative studies for the government and agroindustry to develop the coconut oil agroindustry, especially in Indragiri Hilir Regency. In addition, it can provide information on forecasting demand for coconut oil products and raw material needs so that it can plan capacity simulations and supply chain designs according to the availability of raw materials if it is going to be developed in Indragiri Hilir Regency. In addition, agroindustry can provide an overview for farmers regarding the need for raw materials which aligns with the development of agroindustry. Furthermore, farmers can precisely determine the extension of their farming land when extra capacity is needed. The model integration is made by validating each model produced. The demand forecasting of product model results was validated using the residual normality test. In contrast, the raw material requirement model compares the amount of input with output. The development of this agroindustry has a tremendous economic impact that can increase added value and ensure market certainty and is expected to improve the welfare of farmers.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The development of integrated models and methods was successfully carried out. The resulting integration model is a product demand forecasting model and a raw material requirements determination model for developing the coconut oil agroindustry. At the same time, the integrated method is ARIMA combined with the mass balance method. The results of the forecasting for coconut oil product demand from 2025 to 2030 are 556,749 tons/year, with raw material requirements of 4,259,130 tons/year. The ARIMA method is validated by testing the residual normality, while the mass balance method is done by comparing the amount of input with output. The resulting model is expected to help provide an overview of the agroindustry and farmers to develop the coconut oil agroindustry. This overview is the determination of the capacity of the agroindustry to be developed based on the forecast of demand for coconut oil products, while for farmers regarding the raw material requirements needed by the agroindustry so that they can predict the area of land to be developed for coconut production.

Recommendations

The limitations of this study are the need for other resource requirements, such as the number of workers and the location of the agroindustry. This development is expected to make it easier. Based on this, it is necessary to include several criteria that are not considered in this model.

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