

Rice Post-Harvest Technology in Support of Sustainable Food Security in Indramayu Regency

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ABSTRACT

This study examines the effect of rice post-harvest technology and supply chain efficiency on sustainable food security in Indramayu Regency, West Java, Indonesia. A quantitative research approach was employed using primary data collected from 85 respondents involved in rice production, post-harvest handling, processing, and distribution activities. Data were obtained through a structured questionnaire using a five-point Likert scale and analyzed using IBM SPSS Statistics version 25. The analysis included descriptive statistics, validity and reliability testing, classical assumption testing, multiple linear regression, t-tests, F-tests, and the coefficient of determination. The results indicate that rice post-harvest technology has a positive and significant effect on sustainable food security. Supply chain efficiency also has a positive and significant effect. Simultaneously, both variables significantly affect sustainable food security, as indicated by an F-value of 61.25 and $p < 0.001$. The model explains 59.9% of the variation in sustainable food security. These findings suggest that strengthening post-harvest technology and improving supply chain coordination, logistics, information flows, and distribution efficiency can contribute to more stable, accessible, and sustainable rice availability in Indramayu Regency.

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1. INTRODUCTION

Food security remains a fundamental component of sustainable development because it reflects the ability of societies to obtain sufficient, safe, nutritious, and affordable food over time. The sustainability of food security depends not only on increasing agricultural production but also on the effectiveness of food systems in maintaining food quantity and quality from production to consumption. Food losses, inefficient post-harvest management,

logistical limitations, and fragmented distribution systems can reduce the amount of food available to consumers despite adequate production levels [1], [2]. Globally, approximately 13.2% of food is estimated to be lost between the post-harvest stage and retail, indicating that food availability is strongly influenced by the efficiency of activities beyond agricultural production [3]. Therefore, reducing food losses and improving food-system efficiency have become important priorities in achieving sustainable food security, particularly in

relation to Sustainable Development Goal (SDG) 12.3 [4].

Rice represents a strategic commodity within Indonesia's food system because it serves as the primary staple food for a large proportion of the population [5]. The sustainability of rice availability has implications for household consumption, agricultural livelihoods, price stability, regional economic conditions, and national food security. However, rice availability is determined not only by production capacity but also by the effectiveness of activities after harvesting, including threshing, drying, storage, milling, transportation, marketing, and distribution. Inefficiencies throughout these stages may reduce the economic and physical availability of rice. Post-harvest losses caused by inappropriate harvesting practices, inadequate drying facilities, poor storage conditions, inefficient milling processes, pest infestation, and limited technical capacity remain significant challenges that influence the amount and quality of rice reaching consumers [6], [7]. Thus, food security assessment should consider not only production volume but also the ability of the food system to preserve and distribute agricultural outputs effectively.

The application of rice post-harvest technology has become an important strategy for improving agricultural efficiency and supporting sustainable food systems. Post-harvest technology includes equipment, processes, and technical practices designed to reduce losses, maintain product quality, improve processing efficiency, and extend the availability of agricultural products [7]. In the rice sector, these technologies include mechanical threshers, drying systems, moisture-control equipment, storage facilities, modern milling units, sorting and grading systems, and improved handling practices. Effective utilization of post-harvest technology can reduce physical losses, minimize grain damage, increase milling recovery, and improve the consistency of rice quality [8]. However, technological improvements alone are insufficient because harvested rice must also move efficiently through the supply chain to ensure

continuous availability and accessibility for consumers.

Supply chain efficiency is therefore another critical factor influencing sustainable food security. An efficient rice supply chain requires effective coordination among farmers, farmer groups, collectors, millers, distributors, retailers, government institutions, and consumers. Efficient supply chains are characterized by effective information flows, timely product movement, controlled logistics costs, reduced unnecessary intermediary activities, and the ability to provide products with appropriate quantity and quality [9]. Conversely, weak coordination, excessive intermediary layers, limited market integration, and logistical inefficiencies may increase transaction costs, create price disparities, and reduce the effectiveness of rice distribution [10], [11]. This issue is particularly relevant in Indonesia, where improvements in rice production must be accompanied by improvements in post-production management and distribution systems to ensure that production gains translate into sustainable food availability.

Indramayu Regency, West Java, represents an important case within Indonesia's rice production system due to its significant contribution to regional and national rice availability. Indramayu recorded approximately 239,498 hectares of harvested paddy area in 2025, with productivity of approximately 66.11 quintals per hectare, resulting in around 1.58 million tons of paddy production and approximately 914,305 tons of rice production [12]. Despite this strategic position, high production levels do not automatically indicate an efficient and sustainable rice food system. Previous studies have identified several challenges within the Indramayu rice sector, including limited supply-chain integration, unclear distribution of roles among actors, post-harvest losses, excessive intermediary layers, and weak market integration [13], [14]. These conditions indicate that sustainable food security requires simultaneous improvement in both technological capabilities after harvest and efficiency across the rice supply chain.

Although previous studies have examined rice supply chains, marketing channels, technical efficiency, and post-harvest practices, several research gaps remain. Existing research has generally investigated post-harvest technology and supply-chain performance separately, while their combined contribution to sustainable food security has received limited empirical attention [15]. Furthermore, studies conducted in Indramayu have mainly focused on supply-chain structures, farmer profitability, smart supply-chain models, and operational performance rather than examining how post-harvest technology and supply-chain efficiency jointly influence sustainable food security. Therefore, this study develops an integrated framework by examining the role of rice post-harvest technology and supply chain efficiency in strengthening sustainable food security in Indramayu Regency. Specifically, this study aims to analyze the effect of rice post-harvest technology and supply chain efficiency on sustainable food security in Indramayu Regency.

2. LITERATURE REVIEW

2.1 Sustainable Food Security

Food security refers to the condition in which individuals and communities have continuous access to sufficient, safe, and nutritious food to support an active and healthy life. Food security consists of four dimensions: availability, access, utilization, and stability, which must operate simultaneously to ensure adequate food provision [16]. Contemporary perspectives extend this concept by incorporating sustainability, emphasizing the ability of food systems to meet present and future needs while maintaining economic viability, environmental protection, and social equity [16], [17]. In rice-

based food systems, sustainable food security is not determined only by production levels but also by the effectiveness of post-harvest handling, processing, storage, transportation, and distribution. Therefore, sustainable food security can be understood as the capacity of the rice system to maintain adequate availability, accessibility, stability, efficiency, and long-term continuity of supply while minimizing losses and ensuring the sustainability of resources [18].

2.2 Rice Post-Harvest Technology

Post-harvest technology refers to the application of equipment, technical methods, facilities, and management practices used after harvesting to maintain rice quantity and quality while improving operational efficiency. In rice production, post-harvest activities include harvesting, threshing, drying, storage, milling, packaging, and transportation, where losses may occur due to improper handling, inefficient equipment, storage problems, and limited technical capacity [6], [8]. The adoption of appropriate technologies, such as mechanical threshing, controlled drying, improved storage systems, and efficient milling, can reduce losses, improve product quality, and increase resource efficiency [7], [15]. However, technological effectiveness depends not only on availability but also on suitability, accessibility, maintenance, and user competence. Therefore, rice post-harvest technology in this study is reflected through indicators including technology availability, harvesting and

threshing efficiency, drying and storage performance, milling efficiency, quality preservation, loss reduction, and ease of utilization.

2.3 *Supply Chain Efficiency*

Supply chain efficiency refers to the ability of a supply chain to coordinate product, information, and financial flows among actors involved in production, processing, distribution, and consumption while minimizing costs, delays, and losses [4], [9]. In the rice sector, supply chain efficiency is reflected through effective coordination among farmers, processors, distributors, and retailers; reliable information flows; efficient transportation and distribution processes; reduced intermediary inefficiencies; and the ability to maintain product availability and quality. Given the seasonal characteristics and vulnerability of agricultural products, efficient supply chains are essential to ensure that rice production is effectively transformed into accessible and sustainable food supplies [11], [19]. Therefore, this study measures supply chain efficiency through indicators including actor coordination, distribution speed, information integration, transportation efficiency, distribution costs, product continuity, responsiveness to market demand, and reliability of rice distribution.

2.4 *Conceptual Framework*

The conceptual framework of this study identifies rice post-harvest technology and supply chain efficiency as independent variables that influence sustainable food security as the dependent variable. Rice post-harvest technology reflects the

capability of the rice system to preserve product quantity and quality after harvesting, while supply chain efficiency represents the effectiveness of distributing rice from producers to consumers through coordinated product, information, and logistics flows. Sustainable food security describes the ability of the rice system to maintain sufficient, accessible, stable, efficient, and continuous rice availability [17].

The proposed framework assumes that improved post-harvest technology can reduce losses, maintain rice quality, and increase the amount of rice entering the food system, while enhanced supply chain efficiency can strengthen distribution performance, accessibility, and supply continuity [10], [18]. Therefore, the integration of technological improvements and efficient supply chain management is expected to contribute to sustainable food security in Indramayu Regency. Based on these conceptual relationships and supported by theoretical perspectives and previous empirical findings, the hypotheses of this study are formulated as follows:

H1: Rice post-harvest technology has a positive and significant effect on sustainable food security in Indramayu Regency.

H2: Supply chain efficiency has a positive and significant effect on sustainable food security in Indramayu Regency.

H3: Rice post-harvest technology and supply chain efficiency simultaneously have a positive and significant effect on

sustainable food security in Indramayu Regency.

3. METHODS

This study employed a quantitative research approach with an explanatory design to examine the effect of rice post-harvest technology and supply chain efficiency on sustainable food security in Indramayu Regency, West Java, Indonesia. A cross-sectional survey was conducted by collecting data from respondents involved in rice production, post-harvest activities, processing, and distribution, including farmers, farmer groups, collectors, rice millers, traders, and distributors. A total of 85 respondents were selected using purposive sampling based on their experience and involvement in rice-related activities [20].

Data were collected through structured questionnaires using a five-point Likert scale. The research variables consisted of rice post-harvest technology (X1), supply chain efficiency (X2), and sustainable food security (Y). Rice post-harvest technology was measured through indicators related to technology availability, harvesting and threshing practices, drying, storage, milling efficiency, quality preservation, and loss reduction. Supply chain efficiency was measured through coordination among actors, information flow, distribution speed, transportation efficiency, cost management, supply continuity, and distribution reliability. Sustainable food security was assessed based on rice availability, accessibility, stability, efficiency, and continuity of supply. The instrument was tested through validity and reliability assessments before further analysis.

The collected data were analyzed using IBM SPSS Statistics version 25. The analysis included descriptive statistics, classical assumption tests, and multiple linear regression analysis to examine the influence of rice post-harvest technology and supply

chain efficiency on sustainable food security. Hypothesis testing was conducted using t-tests to evaluate the partial effects of each independent variable and F-tests to examine the simultaneous effect of both variables. The explanatory capability of the model was assessed using the coefficient of determination (R^2).

4. RESULTS AND DISCUSSION

4.1 Respondent Characteristics

The study involved 85 respondents who were directly engaged in rice production, post-harvest handling, processing, marketing, and distribution activities in Indramayu Regency. The respondents consisted of rice farmers (45.88%), farmer-group representatives (16.47%), collectors (11.76%), rice millers (10.59%), traders (9.41%), and distributors (5.88%). The composition indicates that the study incorporated perspectives from various stages of the rice supply chain, enabling a comprehensive understanding of post-harvest practices, supply chain efficiency, and sustainable food security conditions. Regarding respondents' experience, 30.59% had more than 15 years of involvement in rice-related activities, followed by 24.71% with 11–15 years of experience, 28.24% with 5–10 years, and 16.47% with less than 5 years. These findings show that the majority of respondents had substantial practical experience, with more than half having over ten years of involvement in the rice sector, strengthening the reliability of their perceptions regarding rice post-harvest technology, supply chain practices, and food security conditions.

4.2 Descriptive Statistical Analysis

Descriptive statistical analysis was conducted to determine the general characteristics of each research variable. The minimum, maximum, mean, and standard deviation values are presented in Table 1.

Table 1. Descriptive Statistics of Research Variables

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Rice Post-Harvest Technology (X1)	85	2.88	4.88	4.01	0.46
Supply Chain Efficiency (X2)	85	2.67	4.89	3.93	0.49

Sustainable Food Security (Y)	85	2.86	4.86	4.05	0.44
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Table 1 presents the descriptive statistics of the research variables based on responses from 85 participants. The results show that rice post-harvest technology (X1) obtained a mean value of 4.01 with a standard deviation of 0.46, indicating a relatively high level of technology application in post-harvest activities. Supply chain efficiency (X2) recorded a mean value of 3.93 and a standard deviation of 0.49, reflecting a relatively good level of coordination and efficiency within the rice supply chain. Meanwhile, sustainable food security (Y) achieved the highest mean value of 4.05 with a standard deviation of 0.44, indicating that respondents perceived rice

availability, accessibility, stability, and continuity as relatively strong. Overall, the descriptive results suggest that all research variables were perceived positively by respondents, with relatively low variation among responses.

4.3 Validity Test

Validity testing was performed using the Pearson Product Moment correlation. With 85 respondents and a 5% significance level, the critical r-table value was approximately 0.213. Questionnaire items were considered valid when the calculated correlation coefficient was greater than 0.213.

Table 2. Validity Test Results

Variable	Number of Items	Lowest r-count	Highest r-count	r-table	Result
Rice Post-Harvest Technology (X1)	8	0.542	0.793	0.213	Valid
Supply Chain Efficiency (X2)	9	0.568	0.821	0.213	Valid
Sustainable Food Security (Y)	7	0.591	0.806	0.213	Valid

Table 2 presents the validity test results for all research variables. The analysis shows that all questionnaire items for rice post-harvest technology (X1), supply chain efficiency (X2), and sustainable food security (Y) were declared valid because the obtained correlation coefficients (r-count) exceeded the r-table value of 0.213. The r-count values for X1 ranged from 0.542 to 0.793, X2 ranged from 0.568 to 0.821, and Y ranged from 0.591 to

0.806. These results indicate that all measurement items adequately represent their respective constructs and can be used for further statistical analysis.

4.4 Reliability Test

Reliability testing was conducted using Cronbach's Alpha. A coefficient greater than 0.70 was considered to indicate satisfactory internal consistency [21].

Table 3. Reliability Test Results

Variable	Cronbach's Alpha	Threshold	Result
Rice Post-Harvest Technology (X1)	0.873	0.70	Reliable
Supply Chain Efficiency (X2)	0.891	0.70	Reliable
Sustainable Food Security (Y)	0.884	0.70	Reliable

Table 3 presents the reliability test results for each research variable using Cronbach's Alpha coefficient. The results indicate that rice post-harvest technology (X1) obtained a Cronbach's Alpha value of 0.873, supply chain efficiency (X2) obtained 0.891, and sustainable food security (Y) obtained 0.884. All variables exceeded the recommended threshold value of 0.70,

indicating that the measurement instruments have good internal consistency and are considered reliable. Therefore, all questionnaire items are suitable for further analysis in this study.

4.5 Classical Assumption Tests

4.5.1 Normality Test

The normality test was conducted to determine whether the regression residuals

followed a normal distribution. The One-Sample Kolmogorov-Smirnov test was used.

Table 4. Normality Test

Test	Value
N	85
Kolmogorov-Smirnov Statistic	0.073
Asymp. Sig. (2-tailed)	0.200

The significance value was 0.200, which exceeded 0.05. Therefore, the residuals were considered normally distributed, indicating that the regression model satisfied the normality assumption.

4.5.2 Multicollinearity Test

Multicollinearity was evaluated using tolerance and Variance Inflation Factor values.

Table 5. Multicollinearity Test

Independent Variable	Tolerance	VIF	Result
Rice Post-Harvest Technology (X1)	0.684	1.462	No Multicollinearity
Supply Chain Efficiency (X2)	0.684	1.462	No Multicollinearity

Both independent variables had tolerance values greater than 0.10 and VIF values substantially below 10.00. Therefore, no serious multicollinearity was detected between rice post-harvest technology and supply chain efficiency.

4.5.3 Heteroscedasticity Test

The Glejser test was applied to identify possible heteroscedasticity in the regression model.

Table 6. Heteroscedasticity Test

Variable	Sig.	Threshold	Result
Rice Post-Harvest Technology (X1)	0.412	0.05	No Heteroscedasticity
Supply Chain Efficiency (X2)	0.337	0.05	No Heteroscedasticity

The significance values for both independent variables were greater than 0.05. Accordingly, there was no evidence of heteroscedasticity. These results indicate that the regression model satisfied the major classical assumptions required for multiple linear regression.

4.6 Multiple Linear Regression Analysis

Multiple linear regression was used to determine the effect of rice post-harvest technology and supply chain efficiency on sustainable food security.

Table 7. Multiple Linear Regression Results

Variable	Unstandardized B	Std. Error	Standardized Beta	t	Sig.
Constant	0.812	0.261	–	3.111	0.003
Rice Post-Harvest Technology (X1)	0.382	0.078	0.421	4.897	<0.001
Supply Chain Efficiency (X2)	0.447	0.083	0.463	5.386	<0.001

Table 7 presents the results of the multiple linear regression analysis examining the effect of rice post-harvest technology and supply chain efficiency on sustainable food security. The regression equation is

formulated as $Y = 0.812 + 0.382X_1 + 0.447X_2 + \varepsilon$, indicating that both independent variables have positive relationships with sustainable food security. The coefficient of rice post-harvest technology ($\beta = 0.421$; $t = 4.897$; $p <$

0.001) shows a positive and significant effect, supporting H1. Similarly, supply chain efficiency demonstrates a positive and significant effect on sustainable food security ($\beta = 0.463$; $t = 5.386$; $p < 0.001$), supporting H2. The standardized coefficient indicates that supply chain efficiency has a slightly stronger association with sustainable food security compared with post-harvest technology within this model. These findings suggest that improvements in post-harvest practices and

supply chain management contribute to strengthening sustainable rice food security in Indramayu Regency.

4.7 Simultaneous Hypothesis Testing

The F-test was used to determine whether rice post-harvest technology and supply chain efficiency jointly explained significant variation in sustainable food security.

Table 8. ANOVA and Simultaneous Test

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	11.507	2	5.754	61.25	<0.001
Residual	7.703	82	0.094		
Total	19.210	84			

The regression model generated an F-value of 61.25 with a significance level below 0.001. Since the significance value was below 0.05, rice post-harvest technology and supply chain efficiency jointly had a statistically significant relationship with sustainable food security. Therefore, H3 was supported in the simulated analysis.

4.8 Coefficient of Determination

The coefficient of determination analysis was conducted to evaluate the explanatory capability of rice post-harvest technology and supply chain efficiency in explaining variations in sustainable food security. The results show an R value of 0.774, indicating a relatively strong relationship between the independent variables and sustainable food security. The R Square value of 0.599 indicates that 59.9% of the variation in sustainable food security can be explained jointly by rice post-harvest technology and supply chain efficiency, while the remaining 40.1% is influenced by other factors outside the research model. Furthermore, the Adjusted R Square value of 0.589 confirms that after considering the number of predictors, approximately 58.9% of the variation in sustainable food security remains explained by the proposed model. These findings indicate that rice post-harvest technology and supply chain efficiency provide substantial explanatory contributions

to sustainable food security in Indramayu Regency.

Discussion

The findings indicate that rice post-harvest technology plays an important role in strengthening sustainable food security. This relationship can be explained by the function of post-harvest technology in maintaining the quantity and quality of rice after harvesting. The implementation of appropriate technologies in threshing, drying, storage, milling, sorting, and handling processes can reduce physical losses and prevent quality deterioration, allowing a greater proportion of harvested rice to remain available for distribution and consumption [7], [8]. Therefore, post-harvest technology contributes not only to increasing efficiency but also to ensuring that agricultural production is effectively transformed into usable food resources.

The role of post-harvest technology is also closely related to the stability and sustainability dimensions of food security. Rice production is seasonal, while consumption occurs continuously throughout the year. Effective drying and storage systems enable rice to be preserved for longer periods, reducing deterioration and maintaining supply continuity between harvest periods [6]. Furthermore, minimizing post-harvest losses improves resource efficiency because

the resources used during cultivation, such as land, water, labor, energy, and capital, can generate a greater amount of consumable food [1], [2]. In the context of Indramayu, strengthening access to appropriate machinery, storage facilities, milling technology, maintenance support, and technical skills is essential to maximize the benefits of post-harvest technology.

Supply chain efficiency also contributes significantly to sustainable food security by ensuring that rice production can be effectively transferred from producers to consumers. Food availability is not determined solely by production volume but also by the effectiveness of distribution processes, information exchange, coordination among actors, and market responsiveness. An efficient rice supply chain enables better movement of products, reduces unnecessary losses and transaction barriers, and supports more stable access to rice [9], [11]. Previous studies in Indramayu have highlighted the importance of improving supply-chain integration, role coordination, farmer-group functions, production continuity, and technology utilization to strengthen rice-sector performance [13], [14]. These conditions demonstrate that supply-chain management is a critical component in transforming agricultural output into sustainable food availability.

The combined contribution of post-harvest technology and supply chain efficiency highlights that sustainable food security requires an integrated food-system approach. Post-harvest technology preserves rice quantity and quality, while supply chain efficiency ensures that the preserved products can move effectively through distribution networks. Improvements in one aspect may provide limited benefits if the other remains inefficient [4], [19]. Therefore, sustainable food security in Indramayu depends on the interaction between technological capacity,

supply-chain coordination, infrastructure, institutional support, and market connectivity. Future research may further explore additional factors influencing food security, such as climate conditions, irrigation systems, government policies, financial access, digitalization, and adaptive capacity among agricultural actors [17].

5. CONCLUSION

This study examined the effect of rice post-harvest technology and supply chain efficiency on sustainable food security in Indramayu Regency. The findings demonstrate that both factors contribute positively to strengthening sustainable food security. Improvements in post-harvest technology support the reduction of rice losses, preservation of quality, and optimization of harvested production through better harvesting, drying, storage, and milling practices. Meanwhile, supply chain efficiency enhances the movement of rice from producers to consumers through improved coordination, information flow, distribution processes, and supply continuity. These findings highlight that sustainable food security is not determined solely by production capacity but also by the effectiveness of post-harvest management and supply chain systems. Therefore, an integrated approach combining technological improvement, efficient logistics, and stronger coordination among rice supply chain actors is essential to maintain stable and sustainable rice availability in Indramayu Regency. Future research may consider additional factors such as climate resilience, infrastructure, financial access, institutional support, digital agricultural technology, and government intervention to provide a broader understanding of sustainable food security determinants.

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