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Losses in Each Stage of Rice Harvest and Postharvest

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ABSTRACT

Indonesia ranks second in the world for high food loss and waste levels, totaling 300 kg per capita per year. Most of these losses occur during harvesting and post-harvest stages before the produce reaches the consumer. This research aimed to determine the correlation between these stages and production loss. The research was conducted using a descriptive quantitative method in Sungai Besar Village, Ketapang Regency, from November 2022 to February 2023. The respondents in this study were 89 farmers in the village. The results showed that each stage, including the harvesting and post-harvest stages, was correlated to yield loss. The yield loss at each stage varied greatly and is affected by several factors, including harvest age, harvesting methods, tools, rice varieties, threshing mechanisms, threshing delays, drying duration, drying medium size, grain cleaning, raw grain materials, maturity level, and milling machines. The percentage of yield loss ranges from 2 to 4.46% (in the harvesting and threshing stages), 0.52 to 1.55% (in the drying stage), and 1 to 2,5% (in the milling stage).

Keywords: rice, food loss, harvester, post-harvest

INTRODUCTION

Indonesia is included in the category of countries with a high level of food loss and food waste (FLW), which is the 2nd in the world with 300 kg per capita per year where this figure is dominated by losses at the harvest and post-harvest stages (Economist Intelligence Uni 2017). From 2000-2009, the generation of FLW in Indonesia reached 23–48 million tons/year, causing economic losses of Rp213–551 trillion rupiah/year or equivalent to 4–5% of Indonesia's GDP/year (Bappenas 2021). The percentage of food loss over 20 years tends to decrease, from 61% in 2000 to 45% in 2019, with an average of 56%. Meanwhile, the percentage of food waste over the past 20 years tends to increase, from 39% to 55% within the same period, with an average of 44% (Figure 1).

Harvest and post-harvest losses are a global problem in developing, underdeveloped, and developed countries. However, the value of losses in developed countries is lower than losses in developing countries (Figure 2). Most countries with high food production need adequate modern production technology (HLPE 2014). Harvest and post-harvest losses lead to food being spilled, spoiled, experiencing abnormal deterioration in quality such as bruising or wilting, or lost before reaching consumers, because of which about one out of every four calories grown to feed people is ultimately not consumed by humans (Lipinski *et al*. 2013). Most countries with high food production do not have adequate modern production technology. Harvest and post-harvest losses lead to food being spilled, spoiled, subjected to abnormal deterioration in quality such as bruising or wilting, or lost before reaching consumers; consequently, about one out of every four calories grown to feed people is ultimately not consumed by humans.

The high loss rate in developing countries is not only caused by the low availability of adequate production technology but also by human resources, which are less able to adapt to the available technology. So even though it has been provided, farmers who are used to traditional farming methods prefer to stick to this method (FAO 2011). Based on Global Food Security Index (GFSI) data, Indonesia's food security condition in 2021 was declared weaker than the previous year because Indonesia's food security index score in 2020 reached 61.4 while in 2021, the index dropped to 59.2. Through this index, Indonesia's food security in 2021 is ranked 69th out of 113 countries. Reducing crop and post-harvest decline is a critical way to increase food availability without additional production resources, which in developing countries can contribute to rural development and poverty alleviation by improving agribusiness livelihoods (Hodges *et al.* 2011). Crop losses of various countries in Asia are presented in Table 1.

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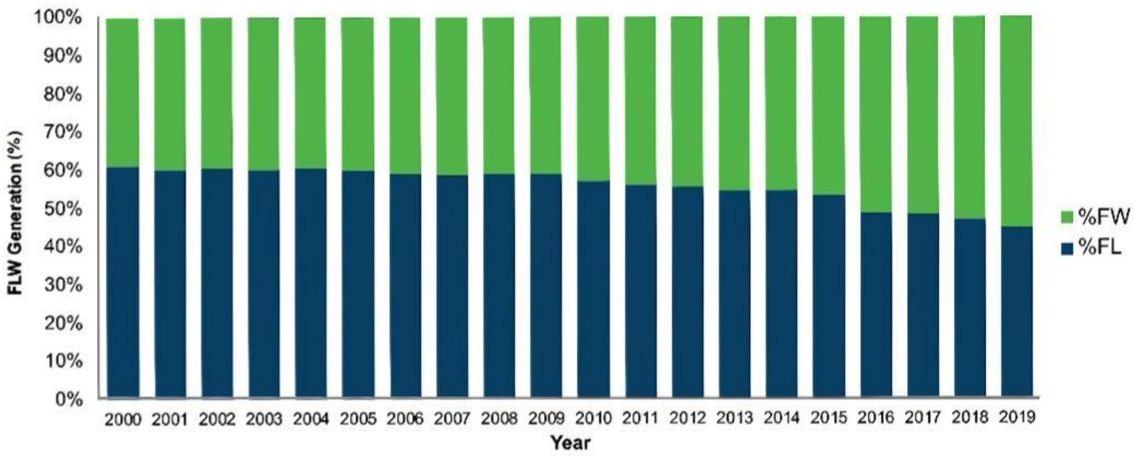

Figure 1 Percentage of food loss (FL) and food waste (FW) compared to total FLW in 2000−2019.

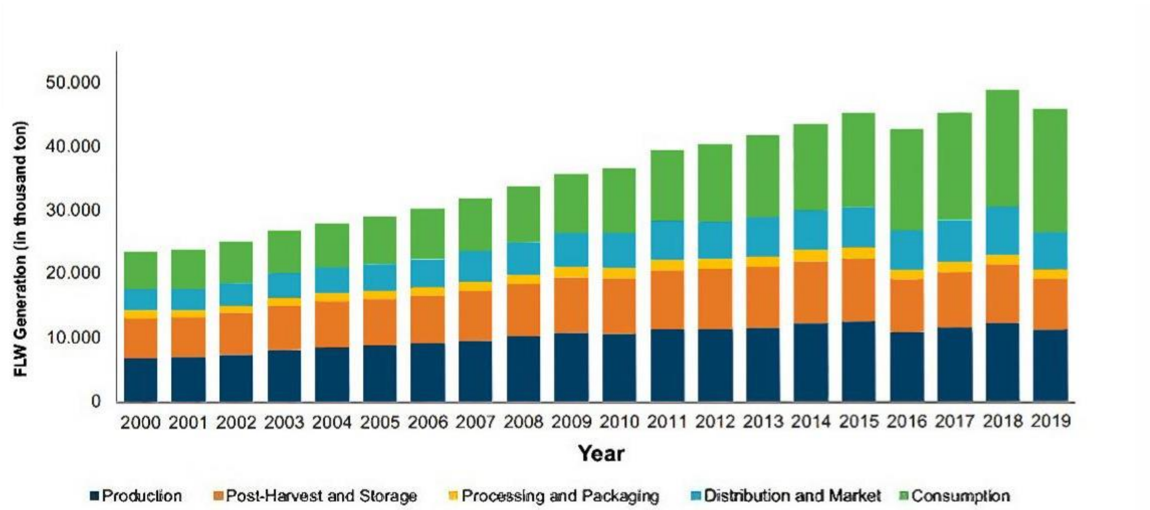

Figure 2 Food loss and waste in Indonesia in 2000−2019 in food supply chain stages (in 1000 ton).

Table 1 Crop losses in several countries in Asia

Country	Harvest losses	Justification
India	Quantitative loss: 2,88-3.60%	(Jha *et al.* 2015; Sarkar *et al.* 2013; Veerangouda *et al.* 2010)
China	Quantitative loss: 1,23-5,5%	(Gao *et al.* 2016; Grolleaud 2002; Li *et al.* 1991; Qu *et* 2021b, 2021a)
Bangladesh	Quantitative loss: 1,61-6,95%	(Alam *et al.* 2018; Bala *et al.*,2010; Begum and Hossai 2012; Greeley 1982; Hasan *et al.*,2019; Nath *et al.* 201
Iran	Quantitative loss" 2,26-2,58% Qualitative loss: 0,47-2,44%	(Alizadeh and Bagheri 2009)
Myanmar	Quantitative loss: 16-28,2% (rainy season), 0,9-9,3% (dry season)	(Grolleaud 2002; Gummert *et al.* 2020)
Thailand	Quantitative loss: 1,1-9,3%	(Grolleaud 2002)
Democratic Republic of Timor-Leste	Quantitative loss: 10,15% Economic loss: USD 9100	(FAO 2018)

The number of food losses from different countries varies widely. The estimated number of food losses is high and, of course, very economically, socially, and environmentally detrimental. The losses in Egypt due to combined harvesting machines are smaller than those due to manual harvesting and threshing (Badawi 2001). Comparable results were found in Bangladesh (Hasan *et al.* 2019), Myanmar (Gummert *et al.* 2020), Dominican Republic (Boxall *et al.* 1981), and Thailand (Groleaud 2002). However, some findings are contradictory. Amusat *et al.* (2016) found that mechanical operations led to higher losses in Nigeria's three stages of harvesting, raking, and winking. In particular, the threshing losses due to mechanical threshing are more than twice as much as manual threshing. This is consistent with the findings of a questionnaire survey by Bavasaraja *et al.* (2007). Several studies in China, including two field trials (Huang *et al*. 2018; Li *et al.* 1991), a farmer survey (Qu *et al.* 2021b), and a three-year survey study by the Center for International Development Research (Groleaud 2002) showed that these losses due to combined harvesting were higher than the total losses due to segmented harvesting. In reducing food loss, it is necessary to conduct analysis at each stage of harvesting and post-harvest because the technology to be chosen to control food loss must be suitable for the location to be chosen where the technology does not conflict both technically, economically, and socially with the local community (Nugraha 2012).

In considering these factors, it is essential to analyze the correlation between each harvesting stage and post-harvest *food loss* in one of the villages in Ketapang Regency. This study aimed to find the correlation between the harvest and post-harvest stages with the shrinkage rate to determine appropriate and efficient solutions.

METHODS

This study used secondary and primary data with a quantitative approach, which was quantitative descriptive. Secondary data was gathered from the Food Agriculture Organizer (FAO), the Central Statistics Agency (BPS), the Ministry of Agriculture, national and international Institutions, thesis, scientific journals, books, and other sources from previous research, as well as primary data obtained from interviews with members of farmer groups. Data processing was used to measure the correlation between each stage and the level of crop loss using the Spearman Rank Test through SPSS. The research location was in Sungai Besar Village, Ketapang Regency, which was selected based on considerations. The study population comprised 25 rice farmer groups in the village, with 830 farmer group members. The sample size was 89 respondents, determined using the Slovin formula. The variables consisted of two: X was the stage related to yield loss (harvesting, threshing, drying, and milling stages), and variable *Y* was the yield loss. The stages were (1) measurement of total loss, (2) analysis of the correlation of each stage to loss, and (3) Spearman rank analysis.

Measurement of Total Loss

The loss for each stage (*Y*) is calculated from the difference between the amount of rice in the previous stage and the next stage. The conversion rate used in this study at each stage referred to the source of agricultural extension worker (PPL) in South Matan Hilir District, namely the 15% conversion of the drying stage and the 30% conversion of the milling stage.

Analysis of the Correlation of Each Stage to Loss

- **Preparation of respondents' answers**

The analysis of the correlation between each stage and the loss began with preparing respondents' answers. As shown in Table 2, 17 indicators were used as questions to respondents.

1. Score calculation for each stage

Each question had 3 answer options with a score of 1–3. Then, each stage was divided into 3 categories (low, intermediate, and high). Therefore, the formula for calculating the score interval is as follows:

$$\text{Interval} = \frac{\text{(The highest score x Number of indicator)} - \text{(The lowest score x Number of Indicator)}}{\text{(Number of Category)}}$$

a) Harvesting stage (*X*1)

In the harvesting stage, four indicators were used as questionnaire questions (Table 2), giving the intervals:

$$\text{Interval} = \frac{\text{(The highest score x Number of indicator)} - \text{(The lowest score x Number of Indicator)}}{\text{(Number of Category)}}$$

$$= \frac{(3 \text{ x } 4)\text{-}(1 \text{ x } 4)}{(3)}$$

$$= \frac{12-4}{3} = 2.66$$

The score interval at each category level was 2.66, so the score interval is shown in Table 3.

b) Threshing stage

In the threshing stage, four indicators were used as questionnaire questions (Table 2), giving an interval:

$$\text{Interval} = \frac{\text{(The highest score x Number of Indicator)}-\text{(The lowest score x Number of Indicator)}}{\text{(Number of Category)}}$$

$$= \frac{(3 \text{ x } 4)\text{-}(1 \text{ x } 4)}{(3)}$$

$$= \frac{12-4}{3} = 2.66$$

The score interval at each category level is 2.66 (Table 4).

Table 2 Variable measurement

Variable	Sub-variable	Indicator	Sub Indicator	Parameter	Score	Justification
Harvest stage (X1)	Harvest age	Harvesting based on the description of the variety used	a. Based on the calculation of days according to the provisions b. Visually, the grain in panicles is yellow or golden yellow around 90-95% c. In the dry season, the moisture content of grain ranges from 22%-23%, and during the rainy season it ranges from 24%-26%.	a. 3 is done b. 2 is done c. 1 is done	3 2 1	David (2019)
	Harvest system	Implement a harvesting system that can reduce yield loss	a. Harvesting is carried out in groups b. Blocking system c. Individual or group systems	a. Do point a b. Do point b c. Do point c	3 2 1	David (2019)
	Harvest tools	Use of new technologies	a. Harvesting is done using a combine harvester machine b. Harvesting is done using a stripper or reaper machine c. Harvesting is done manually	a. Do point a b. Do point b c. Do point c	3 2 1	David (2019)
		The technology used is still in good condition	a. Technology is still in very good condition and working optimally b. There are several components of technology that are not good so that the results are not optimal c. Technologies used in poor conditions	a. Point a is met b. Point b is met c. Point c tis met	3 2 1	David (2019)
Threshing stage (X2)	Rice variety	Use of government-released varieties (certified)	a. Varieties used according to cultivation techniques b. The varieties used are in accordance with the local environmental conditions c. The variety used has a thresher resistance	a. 3 is met b. 2 is met c. 1 is met	3 2 1	Hasbullah and Dewi (2009)
	Threshing mechanism	Use of threshing machine	a. Threshing using the combine harvester machine b. Thresher with a power thresher or pedal model power thresher c. Threshing manually	a. Do point a b. Do point b c. Do point c	3 2 1	Hasbullah and Dewi (2009)
		Threshing machine in good condition	a. Technology is still in very good condition and working optimally b. There are several components of technology that are not good so that the results are not optimal c. Technologies used in poor conditions	a. Do point a b. Do point b c. Do point c	3 2 1	Hasbullah and Dewi (2009)
	Threshing delay	Does not delay threshing after harvesting	a. Immediately threshing after harvest b. Do not delay threshing for more than 2 days	a. 1 is done b. Never do	3 2 1	Hasbullah and Dewi (2009)
Drying stage (X3)	Drying media	Good use of drying media	a. The size of the drying medium used is according to the amount of grain being dried b. The drying media used is still in good condition	a. 2 is met b. 1 is met c. Never met	3 2 1	Herawati (2008)
	Drying delay	Immediately dried after threshing	a. Not delaying drying for more than 3 days b. Drying is carried out for a minimum of 2 days (6 hours/day)	a. 2 is done b. 1 is done c. Never do	3 2 1	Herawati (2008)
	Drying thickness	Drying thickness less than 2 cm	a. Drying thickness less than 2 cm b. Drying time adjusts the thickness of the rice c. Routinely flipping rice	a. 3 is done b. 2 is done c. 1 is done	3 2 1	Herawati (2008)
	Weather	Drying when the weather is favorable	a. The drying is carried out directly under the hot sun b. Do not dry on wet/moist ground due to rain c. Do not dry when the weather is shady	a. 3 is done b. 2 is done c. 1 is done	3 2 1	Herawati (2008)
	Grain cleaning	Separating damaged grain	a. Separation is carried out using a thresher machine b. Separation is carried out using a fan c. Separation is done manually	a. Do point a b. Do point b c. Do point c	3 2 1	Herawati (2008)
\		The grain separator or machine is still in good condition	a. Technology is still in very good condition and working optimally b. There are several components of technology that are not good so that the results are not optimal c. Technologies used in poor conditions	a. Do point a b. Do point b c. Do point c	3 2 1	Herawati (2008)
Milling stage (X4)	Grain raw material	Always watch out for foreign objects or damaged grain	a. Always watch out for foreign objects or damaged grain b. Do not mill if there are foreign objects or damaged grain	a. 2 is done b. 1 is done c. Never done	3 2 1	Sarjo et al (2018); Umar (2011)
	Degree of maturity	Note the interaction between the combination of drying time length and milling frequency	a. Milling the dried grain with a drying time of about 20 hours b. Milling frequency is at least 2 times	a. Do point a b. Do point b c. Do point c	3 2 1	Sarjo et al (2018); Umar (2011)
	Types and configurations of milling machines	Using good types and types of machines	a. Use minimal milling with double-phase machine type b. The completeness of the series of rice milling systems (drive motor, breaking machine, husk breaking machine, head rice milling machine, grain separation machine, crystallization machine). c. The series of rice milling systems is in good condition	a. 3 is met b. 2 is met c. 1 is met	3 2 1	Sarjo et al (2018); Umar (2011)

Table 3 Score category in harvest stage

Score	Category
4–6.66	Low
6.67–9.33	Intermediate
9.34–12	High

Table 4 Score category in threshing stage

Score	Category
4–6.66	Low
6.67–9.33	Intermediate
9.34–12	High

c. Drying stage

In the drying stage, six indicators were used as questionnaire questions (Table 2), giving the interval number:

$$\text{Interval} = \frac{(\text{The highest score x Number of Indicator})-(\text{The lowest score x Number of Indicator})}{(\text{Number of Category})}$$

$$= \frac{(3 \, x \, 6)-(1 \, x \, 6)}{(3)}$$

$$= \frac{18-6}{3} = 4$$

The score interval at each category level is 4 (Table 5).

4. Milling stage

At the milling stage, three indicators were used as questionnaire questions (Table 2), giving the interval number:

$$\text{Interval} = \frac{(\text{The highest score x Number of Indicator})-(\text{The lowest score x Number of Indicator})}{(\text{Number of Category})}$$

$$= \frac{(3 \, x \, 2)-(1 \, x \, 2)}{(3)}$$

$$= \frac{9-3}{3} = 2$$

The score interval at each category level is 2 (Table 6).

Spearman Rank Analysis

After measuring the *X* and *Y* variables, the correlation between them was calculated using Spearman Rank analysis.

RESULTS AND DISCUSSION

Levels of Harvest, Postharvest, and Distribution Stages

1. Harvest stage

The proportion lost during harvest is higher than at other stages (Basapa *et al.* 2007). Crop loss in 5 districts of West Kalimantan province ranges from 1.4–2.7% (David 2019). Loss of yield at harvest time can be affected by several factors, such as harvest age, harvesting tools, and methods (Nugraha and Tahir 2007). The results of the level of the harvest stage obtained from 89 respondents based on the indicators that have been determined can be seen in Table 7. Approximately 65% of respondents carried out the harvesting stage with a high-level category, meaning that the harvest carried out by the respondents was classified as good. The other 35% of respondents were classified as moderate or can be said to be quite good. The following section will explain the indicators that influenced the high and low levels of the harvest stage.

Table 5 Score category in drying stage

Score	Category
6–10	Low
11–14	Intermediate
15–18	High

Table 6 Score category in milling stage

Score	Category
3–4	Low
5–7	Intermediate
8–9	High

Table 7 Harvest stage levels

Criterion	Interval	Harvest stage indicators	
		Number of respondents	Percentage
High	9.34–12.00	58	65
Intermediate	6.67–9.33	31	35
Low	4.00–6.66	0	0

a. Harvest age

Studies in India estimated increased rice harvest losses due to delayed harvests. Regarding the total number harvested, harvest loss is the highest, at 1.92% in the middle of harvest, and the lowest at 1.74% in early harvest. This result implies that farmers suffer considerable losses due to improper determination of harvest age (Kumar and Kalita 2007). To determine when to harvest, of course, we must pay attention to the correct harvest age because harvesting plants before the optimal age can result in poor grain quality because of the high percentage of green seeds in the grain, and harvesting after ripening can increase the percentage of grain loss because it is easier to fall off at the time of cutting (David, 2019). In addition, crop delays also increase exposure to severe weather, temperature and relative humidity variations, decay, and pests (Kader 2011). The correct harvesting criteria are as follows. (1) Based on the calculation of days following the provisions of the variety used, (2) Visually, the grain in the panicles is yellowish around 90-95%, and (3) The moisture content of grain in the dry season is between 22–23%, and the moisture content of grain during the rainy season is between 24-26%. These three things must be done to get more optimal results. Based on the results of the study, the determination of moisture content is not carried out by farmers, so 90% of farmers determine the harvest from the calculation of the day and color of the rice, and the other 10% of farmers determine the harvest age only based on the color of the rice.

b. Harvesting system

The more harvesters, the greater the loss percentage because each harvester has the potential to cause crop loss (Setyono 2009). Harvesting with a cooperative system (the number of members as many as 50 people) will result in yield loss of up to 9.9%. At the same time, if there are 20 harvesters, the percentage of yield loss is only 4.39%, with the ability of harvesters to be 135 and 132.6 hours/person/ha, respectively (Nugraha *et al.* 1994). Ananto (2002) stated that team or group harvesting is easier to control, which will reduce the rate of harvest loss. Based on the study's results, it is known that 72% of respondents use a group system in harvesting so that farmers have their tasks. There are also 28% of farmers harvesting with a block system, commonly called labor exchange, which is harvesting conducted with a limited number of harvests, in which case the harvester does not get wages from the rice field owner.

c. Harvesting tools

Three harvesting tools commonly used by the community were combined harvester machines, power thresher tools, and manual tools such as sickles and small hand knives (*ani-ani*). Some studies state that a serrated sickle's loss rate is lower than that of a traditional scythe. Likewise, modern harvesting tools such as combined harvesting machines had a loss rate of 6%, paddy mover tools had a loss rate of 2%, and combined harvester tools had a loss rate of 2.55% (Iswari 2012). According to Molenaar (2020), one factor affecting the decline in rice production is the right technology. The more modern the harvesting tools farmers use in the area, the lower the yield loss (Hidayat *et al.* 2021). The study results showed that 94% of respondents used a combined harvester machine in harvesting and 6% used a reaper machine. Respondents stated that using modern agricultural tools and machinery, namely the combined machine, is beneficial for the community in farming, especially regarding time efficiency.

2. Threshing stage

Threshing is the process of separating the rice grains from the stalks, which can be done by combing the rice stalks, banging them against harder objects, or using tools. (Nugraha 2012). Research by Alizadeh and Bagheri (2009) showed that the threshing stage significantly affected the loss of broken and cracked rice and the percentage of broken rice after milling. Yield loss at the threshing stage can be seen from indicators in the threshing stage, such as rice varieties, threshing mechanisms, and threshing delays. The results of the level of the threshing stage obtained from 89 respondents based on the indicators that have been determined can be seen in Table 8. So, it is known that 90% of respondents carried out the threshing stage with a high category, meaning that the threshing carried out by the respondents was classified as good, and the other 10% of respondents carried out the threshing stage with a medium category or can be said to be quite good. The high and low levels of the threshing stage are affected by the indicators, which will be explained in the following sections.

a. Rice variety

Variety is one of the factors that affect the rate of loss (Suprihano *et al.* 2009). Based on the level of shedding, rice is categorized into 3 levels, namely easy to shed,

Table 8 Threshing stage levels

Criterion	Interval	Threshing Stage Indicator	
		Number of Respondents	Percentage
High	9.34–12	80	90
Intermediate	6.67–9.33	9	10
Low	4–6.66	0	0

Table 9 Percentage of grain fell and scattered of several rice varieties during rice cutting in the harvesting system

Variety	Moisture content at harvest time (%)	Loss of yield due to shedding (%)
IR64	s	6.4
Memberamo	21.8	6.5
Way Apo Buru	22.9	6.3
Cilamaya Muncul	23.8	5.1

Average observations in 3 locations (Bandung, Subang, and Karawang) (Setyono *et al.* 2001).

moderate, and resistant to shedding (Herawati 2008). The IR-64 variety should be more resistant to shedding than Memberamo and Way Apo Buru, but in this case, the loss rate due to shedding is almost the same (Table 9). It may be caused by excessive pressure during cutting or other factors (Herawati 2008). From the results of the study, 83% of respondents used the certified IR64 superior variety with a high level of fall resistance. In comparison, the other 17% of respondents used the superior varieties Inpari 30 and Inpari 32 with a medium level of fall resistance.

b. Threshing mechanism

Threshing can be done manually or mechanically. Research by Adjo and Hortegi (2021) in the Republic of Benin confirmed losses due to the use of manual threshing (4.5%) and threshing using BVPT 6CV (2.7%), BVPNT 6CV (2.6%), and BVPNT 15 HP (0.7%) machines. The difference in losses is that rice is scattered or spilled during threshing, either manually or mechanically, which causes losses (Qu *et al.* 2021). In addition, the lack of maximum rice pounding can cause much grain to be left on the straw and wasted. Satar *et al.* (2015) stated that using combined harvesting machines can overcome the labor shortage problem because the harvesting and threshing processes are carried out simultaneously. From the study results, 94% of respondents use a combined harvester machine, and 6% use a power thresher machine. The threshing machine used must also be in good condition so that the results obtained are optimal. As many as 17% of respondents used threshing machines in good condition, 7% used threshing machines in good condition, and 8% use threshing machines in poor condition. Like harvesting tools, the threshing machine was also not good because the respondent used the same machine as the harvester, the so-called combined harvester.

c. Delayed threshing

Postponing threshing will affect the amount of grain and rice produced. Astanto and Ananto (1999) postponed threshing in intervals of 2 days will cause a decrease in rice yield and increase grain shrinkage and rice shrinkage (Table 10). In addition to impacting grain quantity, delaying threshing can harm grain quality. Lesmayanti *et al.* (2013) said that the delay in threshing affects damaged grain or yellow grains, where the longer the delay in threshing, the higher the proportion of damaged grain or yellow grains. To get maximum results, respondents should (1) immediately thresh after harvest and (2) not delay threshing for more than 2 days. Both things must be done so that the grain is not damaged due to the delay in threshing. From the study's results, 96% of respondents immediately withdraw and do not postpone withdrawal for more than 2 days, while the other 4% of respondents still postpone withdrawal for more than 2 days.

3. Drying stage

Proper drying can minimize loss and maintain the quality of the grain. Wiset *et al.* (2001) said that the drying method greatly affects the percentage of head rice produced. The high moisture content in grain can allow insects to breed in the grain. Therefore, proper drying methods can prevent deterioration in grain quality and insect infestation (Ketut and Swastika 2012). Loss of yield at the drying stage can be seen from indicators such as drying medium, drying delay time, drying thickness, and weather. Table 11 illustrated that 70% of respondents conducted drying stages with a high category, which means the drying was good. Another 30% of respondents dried with a medium category, which is quite good. The

Table 10 Effect of long threshing delay on grain losses and rice yield

Delay length (days)	Rice yield (%)	Loss of grain (%)	Loss of rice (%)
0	63.9	0.0	0.0
2	63.8	0.3	0.2
4	60.5	0.6	3.4
6	57.1	1.1	6.7
8	56.3	1.9	7.7

Source: Astanto and Ananto (1999).

Table 11 Drying stage level

Criterion	Interval	Drying indicator	
		Number of respondents	Percentage
High	11.68–15	60	67
Intermediate	8.34–11.67	29	33
Low	5–8.33	0	0

high and low levels of the drying stage are affected by the indicators, which will be explained in the following section.

a. Drying media

The most common drying technology used by rice farmers in Indonesia is drying on the roadside or agricultural land using drying media such as floors, tarpaulins, or mats. According to Ketut and Swastika (2012), such drying can result in more significant losses due to the large number of vehicles and animals passing by, as well as dust that flies kites or sudden rain. It must also be considered because the inappropriate size of the drying medium can cause more rice shrinkage. After all, it makes the rice more easily scattered (Nugraha 2012). For this reason, the drying media must meet the following requirements: (1) The size of the drying media used follows the amount of grain dried, and (2) The drying media used is still in good condition. Both things must be met so that the results obtained are more optimal. From the results of the study, farmers in Sungai Besar village use tarpaulins for drying, and 89% of respondents have adjusted the size of the tarpaulin to the amount of grain dried, and the tarpaulin used is still in good condition. Furthermore, 11% of other respondents still need to adjust the amount of grain to be dried with the area of the tarpaulin they have, and as a result, it will affect the thickness of the drying.

b. Length of drying delay

The longer the drying delay, the higher the yield loss rate and the damage to the grain. Piling wet rice for 3 days will cause grain damage of 1.66−3.11% (Rachmat *et al.* 2002). A drying delay will decrease the quality of grain and milled rice, characterized by the presence of yellow grains and germination (Umar and Alihamsyah 2014). To get maximum results, respondents should (1) immediately dry after threshing and (2) do not delay drying for more than 3 days. Both things must be done so that the grain does not suffer damage due to the delay in drying. From this study, 93% of respondents immediately dry after threshing, and 7% do not immediately dry after threshing due to the unfinished threshing process and limited workforce and drying media. Based on the interviews, there were no answers from farmers who deliberately delayed the drying process for more than 3 days unless the weather rained continuously. One farmer experienced delayed drying for more than 3 days, so the grain produced is not good because the grain begins to sprout (germinate).

c. Drying thickness

The higher the dr ying thickness, the more shrinkage will increase because the bottom grain cannot completely dry if it is not turned over regularly, so it can rot and cause shrinkage (Sary *et al.* 2018). Iswari (2012) said the optimal thickness for drying rice is 1-2 cm. For this reason, for the drying to be evenly distributed and the quality of the rice produced, what must be done are (1) drying with a drying thickness of less than 2 cm, (2) drying time adjusts the thickness of the rice, and (3) regularly turn the rice over.

Based on this study, 38% of respondents dried with a drying thickness of less than 2 cm; the drying time adjusts the thickness of the rice and routinely flips the rice. Furthermore, 46% of respondents carried out drying with a drying thickness of less than 2 cm, and the drying time adjusted the thickness of the rice. However, it did not routinely flip the rice due to the limitation of the energy possessed by the respondents, and 16% of other respondents dried by only adjusting the thickness and drying time.

d. Weather

Traditional drying, under sunlight, is still widely found in Indonesia. However, this traditional drying is often not possible due to unpredictable weather conditions that can cause the grain not to dry completely and cause damage such as rot, mold, germination, and yellowing of the grain. Hence, efforts to increase grain production in these conditions are in vain (Prasetyo *et al.* 2008). High levels of initial moisture content and unfavorable weather are challenging to overcome (Daulay 2005). For optimal drying, it is recommended to do the following: (1) dry directly under the bright sun, (2) do not dry on wet/moist ground due to rain, and (3) do not dry when the weather is shady. These three things should be done to get the desired level of rice maturity. The study showed that 14% of respondents dried under the bright sun and did not dry when the weather was shady and dry on dry soil (usually in asphalt/cemented areas). As many as 86% of other respondents were forced to dry on moist soil because they could not postpone drying until the soil was dry, and this drying was usually conducted in rice fields. Farmers in Sungai Besar Village did the drying by using the intensity of the sun's heat from 08.00 to 15.00. Drying with high heat intensity (scorching) was usually performed for 3 days if the sun-dried grain is less than 2 cm thick and 7 days if the dried grain is about 6-7 cm thick.

Table 12 Milling stage level

Criterion	Interval	Milling Indicator	
		Number of respondents	Percentage
High	8–9	11	12
Intermediate	5–7	67	8%
Low	3–4	1	1

e. Grain cleaning

Cleaning is done after drying. This cleaning aims to make the resulting grain yield of higher quality. This aeration can use a threshing machine, a fan, and, naturally, a winnowing basket (*nyiru*). David (2018) said that the high yield depreciation value at the time of threshing was mainly caused by the farmers' inaccuracy in cleaning the grain that had been dropped. In this study, 87% of respondents clean grain using threshing machines, 10% use fans, and 3% use *nyiru* by utilizing natural wind. According to the respondent, the use of fans and natural wind because the amount of grain to be cleaned is only a small amount.

1. Milling stage

Milling is the last stage in the rice production process. The quality of the milling results is an essential factor in determining the rice price related to the rice's size and shape, the degree of whiteness, and the level of cleanliness of the rice (Arsyad and Maryam 2020). The yield loss at the milling stage can be seen from grain raw materials, degree of maturity, and machine type and configuration. The milling stage levels (Table 12) indicate that 12% of respondents carried out the milling stage with a high category, which means that the milling carried out was good, 87% of the respondents carried out milling with a medium category or can be said to be quite good, and another 1% of respondents carried out a milling stage with a low category or could be said to be less good. The high and low levels of the milling stage are affected by the indicators, which will be explained in the following section.

1. Grain raw materials

The purity of grain is the primary determinant of the physical quality of grain. The more foreign objects or empty or damaged grains are mixed, the lower the purity level of the grain (Pratiwiri 2006). The low grain purity level will affect the size of the milled rice yield (David 2019). For a good grain milling yield, the quality of raw materials must be considered by doing the following three things: (1) initial cleaning (aeration), (2) always pay attention to foreign objects or damaged grain, and (3) not milling if there are foreign objects in the grain. These three things must be done to get the desired grain raw materials. In this study, 96% of farmers always clean early, pay attention to foreign objects in the grain before milling and do not grind if there are foreign objects in the grain. Another 4% of respondents did not always pay attention to the raw materials of grain before rice is milled due to a lack of energy and time to carry out these activities.

a. Degree of maturity

The maturity level of grain can be seen from the moisture content of the grain, which is 13%-14% during the processing from grain to rice (Umar 2011). The proper maturity of the grain affects the yield obtained. The high and low levels of grain moisture content, where the moisture content of the grain is considered high if it is >14% or low if it is <14%, will affect the percentage of broken rice and groats (Indrasari *et al.* 2016). Attention should be paid to the interaction between the combination of drying time length and frequency to maximize yields, i.e., the higher the milling frequency, the better the rice produced. In this observation, 29% of respondents had a degree of grain maturity with a drying time of 20 hours and a milling frequency of two times, and 71% of farmers only did 2 times the milling frequency. Most farmers milled by drying for more than 20 hours.

b. Engine types and configuration

The completeness of the machine components will affect the final quality of the mill: the more complete the milling components, the better the quality and weight of the rice produced (Pratiwiri 2006). Conventional milling has 3 main components (drive motor, husk/husk breaker, and rice grinder). Rice produced using only 3 components has not met the quality set by SNI (Indonesian National Standard), due to a large amount of unmilled grain and the availability of foreign objects such as sand, stones, or grass seeds mixed in the rice, as well as a higher percentage of broken rice (Thahir *et al.* 2000). It needs to be improved by adding several components to produce good rice, such as the addition of grain cleaner before the grain is put into the husk breaking machine, as well as the addition of a grain separator after the grain passes through the husk breaker so that the unpeeled grain is separated from the husk broken rice. Then the husk-broken rice is put into the husk cracker (Tjahjoutomo *et al.* 2004). The average yield of milled and head rice in a simple rice mill with a husker-polisher (H-P) configuration was only 61.40% and 74.5%. In contrast, with a cleaner-husker-separator-polisher (CHSP) machine configuration, the milled and head rice yield increased to 66% and 84.6%. In addition, the set of components must also be in good condition to achieve the desired results (Budiharti *et al.* 2006). Therefore, for the type and configuration, it is preferable: (1) minimum milling with double phase type, (2) have complete milling machine components, and (3) the series of milling machine components is in good condition.

It was found that 75% of respondents met 2 criteria for a good milling machine and 25% of respondents met 1 criterion for a good milling machine. In Sungai Besar Village, there is only a medium rice mill with a double phase type where the rice milling machine is only equipped with 3 sets of components (drive motor, husk breaking machine, and shining machine). It resulted in mill yields reaching only 60–65%. According to respondents, the loss during milling was caused by various technical factors such as the presence of several milling tools that did not function properly and errors in the adjustment of the fan to suck and blow out the husks and bran, which caused much rice to be thrown along with the husks and bran.

The amount of yield loss at each stage

Table 13 presents the calculations conducted on respondent farmers, the number of yield losses in harvesting and post-harvest activities, and the results.

1. Harvesting and threshing stages

The amount of grain from the harvesting and threshing process by 89 respondents was 200,506 kg of fresh grain (GKP) from 146.5 ha. The total loss at the harvesting and threshing stage was 6,180 kg GKP, with an average 42 kg/ha loss. Based on this work, the percentage of yield loss at the harvesting and threshing stages is remarkably diverse, ranging from 2 to 4.46% of the harvest. It is due to the difference in harvesting and threshing technology used by the respondents, which, for respondents who have used the combined harvester, do not go through the collection or stacking stage at the time of harvest so that there is no loss at that stage.

1. Drying stage

At this stage, the total grain loss was 1,776 kg GKP, with an average loss of 12 kg/ha. Based on this study, the percentage of yield loss at the drying stage ranges from 0.52% to 1.55% of the crop yield. Losses at this stage were mostly due to improper drying treatment and the use of grain-cleaning machines.

2. Milling stage

At milling, the total loss of rice is 2,754 kg, with an average loss of 19 kg/ha. The percentage of yield loss at the milling stage ranges from 1 to 2.5%of the crop yield. The loss at this stage was primarily due to the treatment of the rice milling machine used.

3. Analysis of the Correlation between Harvest and Postharvest Stages on Yield Loss

a. Correlation between harvesting and threshing stages and yield loss

The outcome in Table 14 was based on each respondent's score, analyzed using SPSS. The value of Sig.(2-tailed) is 0.000, then the value of Sig.(2-tailed) is <0.05, meaning that there is a significant correlation between the stages of harvesting and threshing and loss of yield. The correlation coefficient is 0.697, meaning the correlation between variables is strong. The coefficient number has a negative value of –0.697, so the relationship between variables is in the opposite direction. Where the quality of the harvesting and threshing stages increases, the level of loss will also be smaller. It is in line with the results of the research that 88% of farmers who harvest and threshing well obtained

Table 13 Total yield loss

Stage	Total loss (kg)	Total loss (kg/ha)	Percentage of loss (%)
Harvesting & Threshing (fresh grain)	6.180	50–130	2–4.46
Drying (ready for milling)	1.776	12–40	0.52–1.55
Milling	2.754	21–73	1–2.5

Table 14 The correlation between harvesting and threshing stages and yield loss

Correlation				
			Harvesting and threshing stages	Yield loss
Spearman's rho	Harvesting & threshing stages	Correlation coefficient	1.000	–0.697**
		Sig. (2-tailed)	.	0.000
		N	89	89
	Yield loss	Correlation coefficient	–0.697**	1.000
		Sig. (2-tailed)	0.000	.
		N	89	89

lower losses (loss of 2–4.19%) than 12% of farmers who harvested and threshed in the medium category (loss of 2.55–4.46%). With this, the researchers agree that farmers' drying quality influences the loss rate of harvesting and threshing stages.

b. Correlation between drying stage and yield loss

The correlation between the drying stage and the yield loss is shown in Table 15. The value of Sig.(2-tailed) is 0.000 because the value of Sig.(2-tailed) <0.05, which means that there is a significant correlation between the stage of accompaniment and the loss of results. The coefficient above is 0.836, showing a strong correlation between the variables. The coefficient number has a negative value of –0.836, so the correlation between variables is in the opposite direction. Where the quality of the drying stage increases, yield loss will be lower. It is in line with the results of this study, namely, 67% of farmers who dried well had lower losses (0.52–1.12%) than 33% of farmers who did the drying in the intermediate category (loss of 0.80–1.55%). With this, the researchers agree that the loss rate of the drying stage is affected by the quality of drying carried out by farmers.

c. Correlation between milling stages and yield loss

The correlation between the milling stage and the yield loss (Table 16) explained that the value of Sig.(2–tailed) is 0.000 because the value is <0.05. This means that a significant correlation exists between the stage of accompaniment and the loss of results. The correlation coefficient is 0.902, which means that the level of correlation between variables is very strong. The coefficient number has a negative value of –0.902, so the correlation between variables is in the opposite direction. Where the milling stage's quality increases, the yield loss is lower. This is in line with the results of this study that 12% of farmers who milled well had lower losses (1–2%) than 87% of farmers who milled in the medium category (1–2.5%) and 1% of farmers with poor treatment had 3% loss. One farmer with a moderate treatment category had a loss of 2.5%, meaning that the loss is the same as that of a farmer with poor treatment. This is because the rice sack bond brought by the farmer came loose in the middle of the trip and made the rice scattered. Because the incident is not included in the research indicators, it cannot be considered for the treatment level. With this, the researchers agree that the loss rate of the milling stage is affected by the farmers' milling quality.

CONCLUSION

Based on the analysis results, the harvesting and post-harvest stages are significantly correlated with yield loss. So, this shows that the loss of yield depends on the stages of harvesting, post-harvest, where the better the quality of each stage is, the smaller the loss of yield obtained. Based on the test of yield loss with each stage, the harvesting and threshing stage is the stage with the highest loss rate, and the milling stage is the stage that has the strongest relationship with the loss rate that occurs in Sungai Besar Village, South Matan Hilir District, Ketapang Regency. The loss percentage at the harvesting and threshing stage ranges from 2% to 4.46%, with a total loss of 6,180 kg grain ready to be milled. Farmers can reduce losses by harvesting on time, reducing the use of harvesting personnel employing herds, using modern tools in good condition, reducing the

Table 15 The correlation between drying stages and yield loss

Correlation				
			Drying stage	Yield loss
Spearman's rho	Drying stage	Correlation coefficient	1.000	–0.836**
		Sig. (2-tailed)	.	0.000
		N	89	89
	Yield loss	Correlation coefficient	–0.836**	1.000
		Sig. (2-tailed)	0.000	.
		N	89	89

Table 16 The correlation between milling stages and yield loss

Correlation				
			Milling stage	Yield loss
Spearman's rho	Milling stage	Correlation coefficient	1.000	–0.902**
		Sig. (2-tailed)	.	0.000
		N	89	89
	Yield loss	Correlation coefficient	–0.902**	1.000
		Sig. (2-tailed)	0.000	.
		N	89	89

use of rice varieties that easily fall off, and reducing rice collection or postponement of the next stage.

The loss percentage at the drying stage ranged from 0.52% to 1.55%, with a total loss of 1,776 kg (fresh dry grain). Farmers can reduce losses by selecting drying media that can better accommodate rice, drying with a thickness of no more than 2 cm, paying attention to the weather during drying, and cleaning foreign objects mixed in the rice. The percentage of loss at the milling stage ranges from 1% to 2.5%, with a total loss of 2,754 kg. Efforts and strategic actions that farmers can take to reduce losses are paying attention to grain raw materials, paying attention to the degree of maturity of the grain, and choosing a more complete type and configuration of the milling machine and keeping it in good condition.

Government intervention is needed to reduce the loss rate in Sungai Besar Village, Ketapang Regency. The government's efforts and strategic actions to reduce yield loss include providing farmers with an understanding of *food loss*, strengthening their capacity and skills, utilizing appropriate technology according to the location, and recording the amount of *food loss* so that it can be used as a reference for improvement.

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