An overview of reducing rice yield loss to improve national food security

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Abstract. Concerning national food security, rice has a significant role as a staple food, although it is not the only source of carbohydrates. The government made various efforts to meet the sufficiency of rice. So far, the fulfilment of rice still relies on increasing production and productivity. Another potential way to raise the availability of rice is by reducing the losses along the supply chain. This paper examines the rice yield loss related to supply chain activities, magnitudes, and factors affecting yield loss. The study uses the literature review method. The study results show that rice yield loss can occur in almost all supply chain activities, such as harvesting, threshing, drying, storage, milling, and distribution. The amount of yield loss varies considerably among supply chain activities and across the rice centre region. Modern agricultural tools and machinery, especially combine harvesters, can reduce yield losses. Factors affecting yield loss include land area, harvest time, varieties, tools and techniques of harvesting, threshing equipment, and season. The study results recommend that success in reducing yield loss could be achieved by using more modern agricultural tools and machinery and implementing good handling practices (GHP), supported by good agriculture practices (GAP) and good distribution processing (GDP).

1 Introduction

Indonesia, a growing nation, continues to struggle with food challenges, particularly the problem of supplying food due to the country's rapid population growth [1]. Food security is posited as a top priority in development because food is the most basic need and plays a role in the national economy [2]. Concerning food in Indonesia, rice is very strategic because it is the population's staple food. Indeed, not only in Indonesia but more than half of the world's population consumes rice, and about 90% of this commodity is produced and consumed in Asia [3]. Due to the strategic role of rice in Indonesia, various policies and programs have been directed at increasing rice production to meet the population's needs. Apart from that, harmonisation is carried out with international trade policies so that rice prices can accommodate the appeals of producers (farmers) and consumers [4].

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The government consistently continues to encourage increased production to meet rice availability. Theoretically, there are two sources of production growth: an increase in harvested area and productivity [5]. Another study mentions two ways to increase food (rice) availability, i.e., increasing production and reducing food loss [6]. Food loss refers to food spilt, spoils, or experiencing an unusual decline in quality, such as bruising or wilting, or being lost in some other way before it reaches the customer [7]. Another definition of food loss is loss at or near the farm and supply chain, i.e., throughout harvesting, storage, or transport [8].

BAPPENAS study, as reported by Yananto et al. [9], revealed that Indonesia's food loss and waste (FLW) in 2000–2019 was 115–184 kg/capita/year. The handling and prevention of FLW by 25% for rice cases can potentially increase the availability of rice by 4 kg/capita/year for the population or over 2 kg/capita/year for the world population [9,10]. Regarding sectors and types of food, the most considerable incidence occurs in food crops, i.e., grains category, including rice. It indicates the potential to increase rice availability by reducing losses along the supply chain. Therefore, defining rice supply chain activity to identify potential yield loss is essential. Several studies have identified yield losses at the harvest, threshing, drying, milling, and distribution stages [6,11]. Apart from that, it is also necessary to know the causes of rice loss. A previous study states that land area, harvest time, farmer behaviour, varieties, harvesting tools and methods, threshing equipment, and season will influence crop yield losses [12].

The government's role in providing food for the community is compulsory. Regarding food loss, the government has the authority to implement policies and regulations that can help reduce losses. On the one hand, reducing losses prevents the waste of resources, such as water, land, labour, and others, for rice production. On the other hand, it can increase the availability of rice, which is expected to strengthen national food resilience. Thus, reducing food loss and waste is crucial to food security [13]. A holistic policy is required to reduce food losses at every stage of food production and distribution [10].

Based on the description mentioned above, this paper aims to (1) identify the stage of loss in the supply chain, (2) assess the factors affecting rice yield loss, and (3) recognise policies/programs to reduce rice/food losses. By knowing the three aspects, a more complete picture of rice loss can be obtained to formulate more appropriate recommendations to improve the availability of rice.

2 Methodology

This paper uses the literature review method. Such a method aims to analyse and synthesise existing knowledge related to the research topic [14]. The stages in literature review consist of designing, conducting, analysing, and writing reviews [15]. Diverse previous studies published, such as international and national journals (28 articles), proceedings (2 articles), books (4), and thesis (1), are the primary sources for paper preparation and supplemented by other relevant documents (6).

3 Results and discussion

3.1 Potential rice losses along the supply chain

Food loss can occur in production (harvest), postharvest handling and storage, processing and packaging, and distribution and marketing. The results of the BAPPENAS study [9] show that yield losses of grain commodities at these stages of the supply chain were 6%, 7%, 3.5%, and 2%, respectively. Meanwhile, the global average total food loss of this commodity group

was about 14.6% [16]. Developing countries had a higher food loss rate than developed countries., at 16.0% and 12.6%, respectively. Food loss rates at production, postharvest, processing, and retailer levels were 5.8%, 6.3%, 4.0%, and 3.0%, respectively.) Furthermore, a study by Yananto et al. [9] showed that rice losses in Indonesia in 2018 reached about 1.2 million tons, equivalent to economic losses of IDR 11.2 trillion.

The main challenges in developing rice supply chains in Indonesia are the high rates of yield loss and low grain and rice quality during harvest and postharvest [17]. The following sections discuss rice loss along the supply chain.

3.1.1. Production (harvest) losses

Due to various limitations, rice farmers in Indonesia generally still use traditional sickles or jagged sickles for harvesting and threshing grain by slamming (*gebot*) or using pedal threshers. Rice harvest loss due to using jagged sickle and pedal thresher are 7.80% and 4.75%, respectively. On the other hand, the use of combine harvesters at harvest time produces a very low yield loss of 2.50%. Those results suggest that agricultural mechanisation is one aspect that plays a vital role in reducing rice yield losses. Several previous studies also revealed the low rice harvest loss associated with the use of combine harvesters, ranging from 2 to 4%, implying increased rice production and productivity [18–21].

Harvesting at optimum age is crucial to obtain good rice quality and reduce yield loss. The optimum age of harvest varies depending on the rice variety. The harvest age affects the percentage of head and broken rice [22]. Harvesting at the appropriate time can reduce the loss rate by 3.5% [23]. Delaying harvest can cause a hidden loss of dry matter, which results in lower yield and increased loss from grain and rice seed shattering after harvest. The harvest may be delayed in areas with a labour shortage for harvesting rice. Mechanisation can help ensure that the harvest occurs at the right time, preventing any yield loss due to delays.

3.1.2. Postharvest and storage losses

Postharvest loss is a significant contributor to food insecurity, and managing postharvest losses remains a substantial obstacle in implementing mitigation strategies throughout the value chain. The direct causes of postharvest losses are technology limitations, suboptimal storage space quality, poor packaging quality, and lack of GHP implementation [9]. These findings are supported by a previous study [24], which revealed that small-scale farmers suffer high postharvest losses due to inadequate knowledge, skills, and technology.

Most rice farmers traditionally dry their grain on tarps using solar energy in the yard or roadside. Although dryers can also be used, they are not widely available, causing only a few farmers to use them. Moreover, drying with the help of sunlight is cheaper and easier. However, drying rice grain in the sun results in a higher yield loss than using a flatbed dryer (2.98% vs. 2.30%) [22].

Improper postharvest handling practices can contribute to yield loss in addition to the type of tools and machines used. A study by Ruaw et al. [25] compared rice drying practices between farmers in Minahasa and a laboratory with the same method and found that, on average, farmers experienced a 2.19% lower yield.

Rice farmers store their harvest in the form of rice grains packed in sacks, which are then stored in empty places in their houses. When the rice grain is ready to be sold or consumed, the grain is taken out and milled into rice. However, this storage method has drawbacks, as rats often attack the grain, and sacks at the bottom of the pile can become damp and damaged. Farmers have employed various ways to minimise damage, such as using wooden pallets at the bottom of the storage area [26].

Milling is a process to convert grain into white rice. The rice grain milling process includes husk peeling, grain separation, polishing, packaging, and storage. Conventional mills cause higher losses (2.19%) than modified mills (0.19%) [22]. This finding shows that rice mills require modern technology to reduce losses. Many small mobile rice milling units (RMUs) operate in rice-producing centres, making it easier for farmers to mill their rice grains. However, although not significantly different in yield, mobile RMUs produce lower rice quality than large RMUs [27]. Another study [25] showed that the average loss due to milling in Minahasa was 2.12%.

During storage, rice can be vulnerable to pest damage. Pests attacking rice in storage are rice weevils, rats, and birds. Rice weevil (*Sitophilus oryzae* L.) is a type of insect that can damage rice supplies when stored in warehouses. Their attacks are very detrimental in terms of quantity and quality. They cause rice grains to have small holes and easily broken and crushed like flour, smell musty, and taste bad, making them inedible [28].

3.1.3 Distribution and marketing losses

During distribution and marketing, rice may experience losses due to suboptimal storage space quality, poor packaging quality, and lack of GHP implementation [9]. Rice losses during distribution occur due to scattering en route to marketing locations or during transportation from storage [29]. A study in Karawang district indicates an annual loss of about 7,180 tons of rice during distribution, valued at about IDR 67.89 billion/year [6].

3.2 Factor affecting rice yield loss

In rice farming, farmers' experience does not always guarantee the expected yield due to internal and external factors [30]. Rice yield loss can occur during harvesting, harvest handling, threshing, transportation, drying, milling, and storage [31]. Several factors that influence rice yield loss discussed include the scale of business or land area, rice varieties, agricultural tools and machinery, weather or season, harvest time and methods, and harvester behaviour.

3.2.1 Business scale or land area

There are three sources of rice yield growth: more advanced technological developments, increased technical efficiency, and economies of scale [32]. In other words, the size of the business or the area of land cultivated can influence rice yield losses. Farmers with land areas close to economic scale will be more efficient, use more advanced technology, and be able to reduce rice yield losses. A study by Hidayat et al. [12] showed that the significant yield loss of harvested rice per hectare (12.7%) was positively and significantly influenced by land area, rice harvest age, farmer behaviour, varieties, harvesting tools and methods, threshing tools, and weather conditions during the harvest season.

3.2.2 Varieties

A study by Alim et al. [33] revealed that the average loss rate during the harvest of superior rice varieties in Riau was 1.05%, which is lower than the national level (1.2%). The size of the rice yield loss is influenced by the variety, harvesting age, harvest method, and harvesting equipment used. Another study by Juniardi et al. [34] concerning the yield loss of the Situbagendit variety showed that the total loss of rice harvest and postharvest was 7.86%, including harvesting (0.24%), stacking (0.20%), collection (1.55%), threshing (0.89%),

drying (2.61%), and milling (2.37%). Factors affecting yield loss and postharvest rice were varieties, harvesting, threshing, drying, and milling technology. The results of the study [35] suggest that the Mekongga variety has the highest percentage of head rice (97%) with the lowest broken rice rate (2.8%).

3.2.3 Agricultural tools and machinery used

Harvesting techniques and technology are important direct causes of rice yield loss [9]. A study by Iswari [22] compared yield loss generated by several harvester tools and machines and revealed that modern harvesters caused lower yield loss than traditional ones. Variations in harvesting, threshing, drying, and milling technologies greatly affected the quantity and quality of grain and rice products and yield loss [17]. It was concluded that the advanced group had the highest efficiency and the lowest yield loss in agricultural tools and machinery typology.

Area of cultivation and financial sources are significant factors that positively influence farmers' adoption of agricultural tools and machinery [36]. Apart from the grain quality, technology and the sophistication of the rice milling tools affect the yield of dry unhusked grain (GKG) to rice and the level of yield loss [17].

3.2.4 Weather and season

The period from harvest until rice is available at the market varies depending on the season [17,31]. During the rainy season (MH), it is estimated to be 14–28 days. Meanwhile, in the first dry season (MK I), it is about 14–21 days; in the second dry season (MK II), it is about 7–14 days. The time between harvest and availability in the market determines the level of rice yield and yield loss. The difference between the rainy and dry seasons is determined by the availability of dryers, drying floors, weather or season, the supply of grain, and the smooth distribution of rice. Thus, the weather or season greatly influences rice yield and the level of rice yield loss.

Further, yield losses during the rainy season are higher due to falling plants during harvesting, grain harvesting and transportation activities disruption, and imperfect drying processes. In the dry season, yield losses from harvest and postharvest activities are about 7.9%, while in the rainy season, yield losses are about 9.4%.

3.2.5 Harvest time and harvester used

Determining the right harvest time can be seen as a critical point in the rice harvest process. Most farmers do it visually (70–80%) by looking at the panicle and leaf colours [37]. Most farmers use an ordinary scythe to harvest, and a few have used a combine harvester. In the current condition, farmers in rice production centres in Java Island and South Sulawesi province have used a combine harvester, which has been proven to be able to reduce yield losses to only about 4–6% from the previous 10–12% and increase grain yield and quality [17]. Further, the timing of harvest time is crucial since too early or late harvesting might increase losses. Postponing harvesting may result in significant loss due to shattering and prolonged exposure to natural occurrences, such as bird and other pest attacks [38].

According to Kariyasa and Suryana [39], higher losses in developing countries compared to developed countries are due to the limited availability of technology, facilities, and infrastructure, such as harvesting equipment, dryers, storage, and processing of agricultural products. Moreover, the poor road and transport infrastructure has led to higher yield loss rates. A previous study [9] has examined the direct causes and indirect drivers of FLW in

Indonesia at every stage of the supply chain. The causes and drivers of food loss associated with rice are presented in Table 1.

Table 1. Causes and drivers of food loss in various activities along the rice supply chain.

Supply chain stage	Direct cause	Indirect driver
Production	- Improper harvest time - Poor harvesting techniques - Technology limitations	- Limited access to capital - Lack of information - Limited infrastructure access - Inefficient supply chains - Market quality standards and consumer preferences
Postharvest and storage	- Technology limitations - Suboptimal storage space quality - Poor packaging quality - Lack of GHP implementation	- Limited access to capital - Lack of information - Limited infrastructure access - Inefficient supply chains - Market quality standards and consumer preferences
Distribution and marketing	- Suboptimal storage space quality - Poor packaging quality - Lack of GHP implementation	- Lack of information - Inefficient supply chains - Market quality standards and consumer preferences

Source: Adapted from Yananto et al. [9]

3.3 Policy and program to tackle food losses

Food loss is a global issue and problem that needs attention and solutions to reduce it. Food loss in developing countries is generally more significant than in developed countries. Most developing countries have high levels of food production not matched by adequate modern production technology. At the global level, the production loss in postharvest handling and storage activities reached 54%, while at the processing, distribution, and consumption levels, it reached 46% [40]. In general, food loss is caused by (i) inadequate technology and greater yield loss and (ii) poor road infrastructure. The incidence of floods or roads is challenging to pass, causing transportation and distribution of crops to consumers to be hampered and impacting the process of food damage [8].

The government, both at the level of ministries, agencies, and other institutions, should have a big share in efforts to reduce food loss. Several ministries/agencies with strategic positions in FLW handling are the Ministry of National Planning and Development, the Ministry of Agriculture, the Ministry of Environment and Forestry, the Ministry of Public Works and Public Housing, and the National Food Agency (NFA).

Policies to overcome the problem of food loss are carried out by optimising the use of technology according to stages in the food chain. In Indonesia, the strategy to reduce yield loss is through the application of good agriculture processing (GAP), good handling processing (GHP), and good distribution processing (GDP). In addition, efforts are also made to improve cultivation technology, extension, and infrastructure facilities and strengthen market access for the products produced. Many policies on applying technology in the harvesting and postharvest processes have been carried out, including agricultural mechanisation. For rice and other cereal commodities, it is carried out through combine harvesters, flatbed dryers, and the revitalisation of the rice milling unit (RMU) to increase the efficiency of processing products from grain into rice while reducing food shrinkage.

The critical point of food loss at the harvest and postharvest stages at the farmer level occurs in harvesting, sorting and grading, packaging, and transportation activities[10]. At the wholesaler level, the tipping point is at the stage of handling sorting and packaging. At the stage of transportation from traders to consumers, weather aspects, environmental conditions, and transportation schedules become critical points for the intensity of food loss.

In Indonesia, by applying harvesting and postharvest technology, food loss for rice decreased from 20.92% to 11–13%. The strategy to implement harvest and postharvest technology and government policy intervention could be done by assisting postharvest and processing infrastructure and facilities, including in-store dryers and controlled atmosphere storage [41].

Government intervention is required to lower Indonesia's high food loss rate, particularly by helping with postharvest handling tools and equipment such as drying machines, storage warehouses, and silos. There are five policies of BAPPENAS [9] to handle food loss (also waste) as follows. (1) *Behaviour change*: focus on developing extension institutions in the regions, increasing the capacity of food workers, and educating consumers to increase knowledge about FLW and change behaviour. (2) *Improving food system support*: developing farmer corporations and providing infrastructure that supports the efficiency of the food production process, which also contributes to the reduction of FLW. (3) *Strengthening regulations and optimising funding*: optimising appropriate funding for food infrastructure improvement, developing FLW regulations at the national and regional levels, and strengthening coordination between institutions related to FLW issues. (4) *FLW utilisation*: encouraging the development of food distribution platforms, FLW management that supports the circular economy, and pilot development of city/district-scale FLW utilisation. (5) *Development of FLW study and data collection*: highlighting the need for integrated FLW generation data collection through the census and developing studies to complement FLW data in Indonesia.

Food loss reduction programs should cover the aspects of production, process, and distribution [42]. Efforts made include implementing good agriculture practices (GAP), good handling processing (GHP), and good distribution processing (GDP), improving cultivation technology, extension, improving infrastructure, and strengthening product market access. In addition, it must be accompanied by agricultural mechanisation, such as the use of combine harvesters, flatbed dryers, and RMU revitalisation.

4 Conclusions and policy recommendations

4.1 Conclusions

Fulfilling food needs, especially rice, is still challenging for the Indonesian government regarding national food security. The availability of rice so far has relied more on increasing production. Indeed, there is an alternative that can be done simultaneously with growing production, namely efforts to increase the availability of rice by reducing losses.

Indonesia still has significant rice loss. Production losses can occur during harvest, postharvest handling and storage, processing and packing, distribution, and marketing. Many factors affect food/rice losses, both direct and indirect. Poor harvesting techniques, technology limitations, suboptimal storage quality, packaging quality, and lack of GHP implementation are sources of rice losses. Technology improvements, infrastructure access, and social and economic aspects can enhance crop quality and reduce loss.

The strategy to reduce yield loss is through the application of good agriculture processing (GAP), good handling processing (GHP), and good distribution processing (GDP), which is carried out by optimising the use of technology according to stages in the food chain. There

are five policies to handle food loss and waste, i.e., (1) behaviour change, (2) improving food system support, (3) strengthening regulations and optimising funding, (4) FLW utilisation, and (5) development of FLW study & data collection.

4.2 Policy recommendations

Efforts to increase production and productivity must be balanced with a decrease in food loss to achieve national food security. Synergy must be carried out across ministries and institutions and involve other stakeholders, especially farmers and agricultural business actors, to reduce food loss. Policymakers should encourage innovation, research and development, and cross-sectoral and multi-stakeholder collaboration to reduce food loss effectively. Each ministry/institution is mandated to create a program for reducing food loss based on the main tasks and functions of the institution. Technological innovation related to variety, cultivation, harvesting, and postharvest must continue to be encouraged to reduce food loss. Implementing GAP and GHP can be a technology choice that should be massively encouraged to reduce food loss to increase revenue and business efficiency. It is required to intensify programs through socialisation and technical guidance to farmers on the importance and ways to reduce rice yield loss.

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