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*Full Length Research Paper*

# Post harvest losses of rice from harvesting to milling in Ghana

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**Estimation of postharvest losses of rice (*Oriza sativa*) from harvesting to milling was carried out in Ejisu Juabeng District of Ghana to provide basic information important regarding the losses. Harvesting losses were higher (2.93%) in sickle-harvesting than in panicle harvesting method (1.39%). Threshing losses were also higher (6.14%) in the 'bambam' in the bag beating method (2.45%). Harvesting losses ranged between 4.07 and 12.05% at farmer's fields. Storage and drying losses were 7.02 and 1.66% respectively. SB30 milling machine was more efficient and produced 67.3% head grains compared to SB10 (50%) and the locally manufactured machine (47.3%).**

**Key words:** Rice, postharvest losses, milling, grain quality.

## INTRODUCTION

Rice (*Oriza* spp) is after wheat, the most widely cultivated cereal in the world and it is the most important food crop for almost half of the world's population (IRRI, 2009a). It is estimated that rice sustains the livelihood for 100 million people and its production has employed more than 20 million farmers in Africa (WARDA, 2005). According to Harris and Lindblad (1978) postharvest losses comprise all changes in the ability, wholesomeness or quality of food that prevents it from being consumed by people. Postharvest losses can occur during any of the stages in the postharvest operations.

Whatever the source, postharvest losses represent more than just a loss of food as it ripples through the factors (including land, water, labour, seeds, time and fertilizer). The wastes indicate that postharvest food loss translates not just into human hunger and minimizing the revenue of farmers but into tremendous environmental waste as well (Earthtrend, 2001).

The steady increase in population and a corresponding increase in demand for food have led to increased rice imports in Sub-Saharan Africa. Between 1989 and 1996 Ghana was reported to be only 15.1% self-sufficient in rice production after dropping from 48.3% between 1970 and 1974 (Oteng and SantAnna, 1999). According to WARDA (2007) Ghana was below 25% self-sufficiency in rice production. This means that Ghana still require huge imports to augment the difference in local demand. According to Manful and Fofona (2010) as well as Aidoo (1993), quantitative postharvest losses of rice in Sub-Saharan Africa are estimated to be between 10 to 22% while qualitative losses could be as high as 50%. Reducing postharvest losses could help in reducing rice imports with its accompanied economic losses. However, there is insufficient data on postharvest losses of rice in Ghana with regards to what, where and why the losses occur in the production system. For effective reduction in losses it is important to estimate the losses and the stages at which they occur. This study therefore aimed at assessing the postharvest losses that occur in rice in Ghana from harvesting to milling with the aim of providing information for reducing postharvest losses and ultimately increasing rice supplies without increasing acreages under cultivation or imports. This study provides critical assessment of what, where and why losses occur, and what could be done to reduce such losses.

## MATERIALS AND METHODS

### Experimental site

The research was conducted at *Nobewam* and *Besease* in the Ejisu-Juabeng District in the Ashanti Region of Ghana between 2009 and 2010.

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### Experimental procedure

The experiment was done in two phases: A survey and a field work.

#### *Survey*

The survey on farmers' perception and knowledge of postharvest losses of rice was conducted at Besease in the Ejisu Juabeng District of the Ashanti Region of Ghana. A semi structured questionnaire aimed at investigating some rice farmer's perception about postharvest losses of rice was administered to thirty rice farmers in "Besease" a rice farming community in the Ashanti region of Ghana. Information on farmers' perception of postharvest losses and methods of reducing such losses was collected. Other important information collected included the causes of postharvest losses, the estimation of postharvest losses.

#### *Field experiment*

Two rice varieties, Nerica 1 and Nerica 2, commonly grown by farmers were grown for assessment. For each variety, an area of 4 x 5 m was demarcated for cultivation. There were three replications per variety. Cultural practices carried out on the field included land clearing, ploughing, retovation, raising nursery for seedlings and transplanting. At maturity the crops were, harvested, threshed, dried, stored and milled to determine the postharvest losses that were involved at each stage.

### Experimental design

A 2 x 2 RCBD was used comprising 2 varieties (Nerica 1 and Nerica 2) and 2 harvesting methods (panicle and sickle) for determining harvesting losses. The experimental design for milling yield was 2 x 3 CRD comprising 2 varieties and 3 milling machines.

### Postharvest studies

#### *Determination of harvesting losses*

The rice plots were divided into quadrants (5 x 5 m) and skilled harvesters were allowed to harvest as per farmer practice using panicle and sickle harvesting methods. Left over rice grains on the harvested plots (both on the ground and on unharvested standing plants) were thoroughly collected, cleaned, dried, weighed and stored in a cloth bag. Percentages of harvesting losses were determined using the method described by Badawi (2003). For farmers' grown fields (5), harvesting was done using sickle. The weight of paddy rice left on the field per quadrant was determined and losses estimated using the formula:

Harvesting losses = left over paddy/ Total harvested paddy x 100

### Determination of threshing losses

Two different types of threshing methods as practiced by farmers were used bag-beating (panicle) and bambam (sickle). Panicle harvested rice were put in a bag and beaten with stick to separate the grains from the stalks. Rice harvested with sickle was threshed using the "bam bam" a locally made wooden box with a tarpaulin beneath. In the bambam method, the rice stems were held and the stems together with the panicles on them and beaten against an inner side of the box. Removed grains were allowed to drop onto the tarpaulin beneath the box. After threshing, all the rice grains that fell out and was found outside the wooden box as well as the bags were collected, cleaned, dried and weighed and all the rice grains remaining on the stalks after the beating were also collected, cleaned, dried and weighed. Threshing losses were also assessed on five different farmers' fields using the bag a beating method (panicles). Threshing losses were estimated using the formula:

Threshing losses = [Weight of left over grains/ Total weight of collected grains] x 100.

### Determination of Weight losses during storage

Two rice varieties (Nerica 1 and Nerica 2) were harvested, threshed, dried, weighed and stored in rice bags for 60 days in a well ventilated room at room temperature after which they were weighed at the end of the storage. At the end of the 60 day period, the pre-weighed bags of rice were reweighed. Storage losses were calculated using the formula:

By weight = [(Initial weight of paddy rice - Final weight of paddy rice)/ Initial weight of paddy rice] x 100.

### Milling yield and milled rice quality

The performance of three different milling machines (One-pass type mill - SB30, SB10 and Engelberg type mill - locally made). Each machine was used to mill 25 kg of Nerica 1 and Nerica 2 paddy. Milling was done in triplicates. The resulting rice, bran and husk from each milling machine were collected and weighed. Milling yield was determined according to the procedure of IRRI (2009b) using the formula:

Milling yield = [Weight of white rice/ Weight of paddy] x 100.

The grains after milling were subjected to head grain count to determine which of the milling machines produce more breakages. Ten grams (10 g) of milled rice from each sample was taken. Head grains (unbroken grains) were separated from the broken grains and weighed. The percentages of broken and unbroken grains from each machine were determined as described by the method described by IRRI (2009):

Percentage of Head rice = (Weight of whole grains/ Weight of paddy sample) x 100
Percentage of Broken rice = (Weight of broken grains/ Weight of paddy sample) x 100

### Statistical analysis

The Statistical Package for Social Sciences (SPSS) version 17 was used to analyze the responses on farmer's perception of postharvest losses. Analysis of variance (ANOVA) was performed on experiment data collected using GENSTAT Discovery Edition 3 and separation of treatment means was done using the LSD at 5% level of significance.

## RESULTS AND DISCUSSION

### Survey - Farmers' perception of postharvest losses of rice

Farmers' experience of postharvest losses varied. Ninety

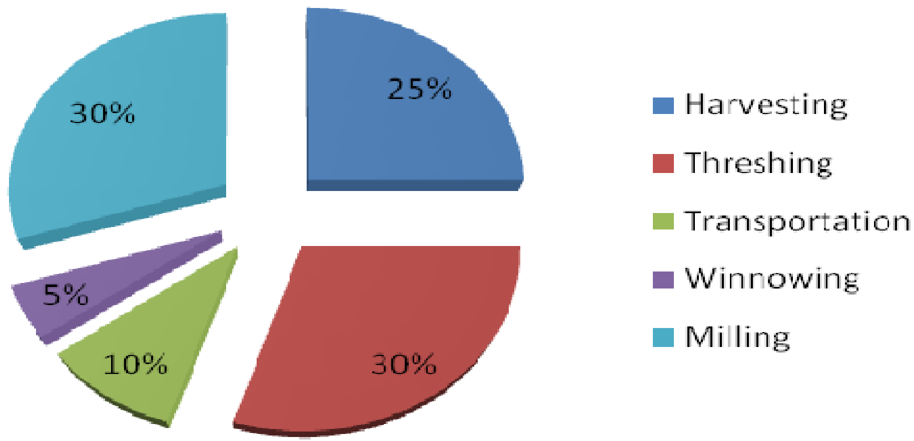


**Figure 1.** Stages at which most postharvest losses occur.

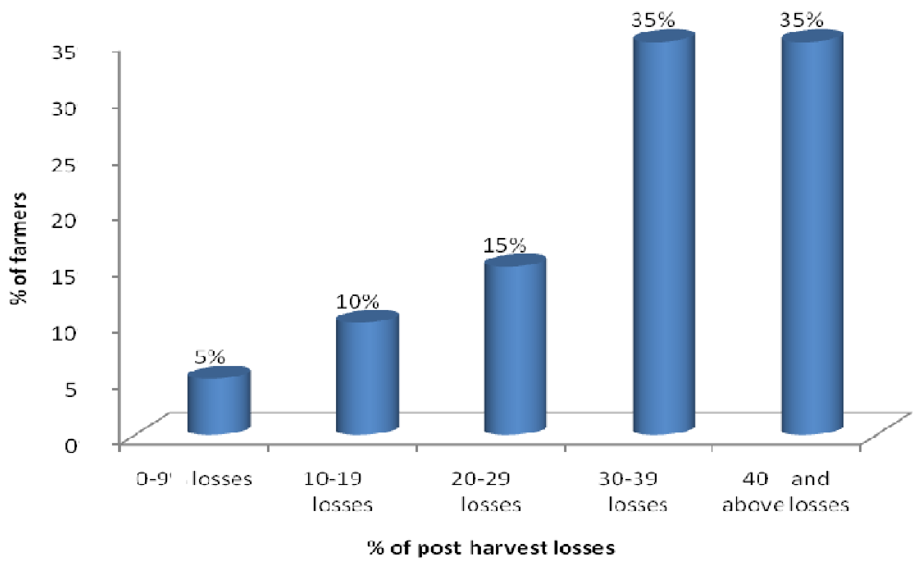


**Figure 2.** Perception of farmers on postharvest losses in rice from harvesting to milling.

five percent (95%) of the respondents reported that they had experienced postharvest losses of rice whilst the remaining 5% indicated they had not. According to the farmers, most postharvest losses in rice production occured from harvesting to milling and accure also at threshing and milling stages.

Thirty percent (30%) of the respondents indicated that the highest losses occur during threshing while another 30% reported that the highest losses were at milling. The results also showed that 25% of the farmers experienced the highest postharvest losses at the harvesting stage, 10% of farmers at the transportation stage and the remaining 5% at the winnowing stage as shown in Figure 1. The farmers also reported that the causes of losses were flooding of rice fields during harvesting when there were heavy rains, insufficient availability of postharvest machinery, other reported causes included rice shattering at harvesting, rice paddy getting mouldy during drying as well as rice grain breakage during milling.

As to how much is lost during the entire production chain, there were varying responses Thirty five percent (35%) of the respondents reported that they incur a total postharvest losses of 40% and above, 35% indicated that losses ranged between 30 and 39%, while 15% reported 20 to 29% losses (Figure 1). The remaining 15% of the farmers lost between 0 and 19% of their produce. These loss figures were unacceptable to majority (90%) of the respondents. However, the remaining 10% considered the such losses as normal (Figure 2). From the responses, it is obvious that the perceived losses were unacceptably high. The implication is that the rice farmers lose huge amounts since 70% of the rice farmers

**Table 1.** Harvesting losses in of Nerica 1 and Nerica 2 rice varieties using two kind of harvesting methods: Panicle and sickle.

| Treatments variety | Total weight of harvested rice (g) | Harvesting losses (g) | Harvest weight loss (%) |
|---|---|---|---|
| Nerica 1 | 6688 | 132 | 2.19 |
| Nerica 2 | 6926 | 148 | 2.13 |
| Panicle | 6430 | 83 | 1.39 |
| Sickle | 7184 | 196 | 2.93 |
| Lsd | 1692.4 | 59.7 | 1.338 |
| Nerica 1 x Panicle | 6450 | 66 | 1.13 |
| Nerica 1 x Sickle | 6925 | 197 | 3.25 |
| Nerica 2 x Panicle | 6409 | 100 | 1.64 |
| Nerica 2 x Sickle | 7443 | 195 | 2.62 |
| Lsd | 2393.4 | 84.4 | 1.89 |
| CV (%) | 21.8 | 11.4 | 32.3 |

**Table 2.** Threshing losses of Nerica 1 and Nerica 2 rice varieties under two different threshing methods: Bambam and bag beating method.

| Treatments | Total weight of harvested rice | Threshing losses (g) | Threshing losses (%) |
|---|---|---|---|
| | **Varieties** | | |
| Nerica 1 | 6688 | 294 | 4.65 |
| Nerica 2 | 6926 | 288 | 3.94 |
| Threshing methods | | | |
| Bag beating (Panicle) | 6430 | 148 | 2.45 |
| Bambam (Sickle) | 7184 | 434 | 6.14 |
| Lsd | 1692.4 | 80.4 | 1.47 |
| | **Variety x Threshing method** | | |
| Nerica 1 Panicle | 6450 | 239 | 3.98 |
| Nerica 1 Sickle | 6925 | 349 | 5.33 |
| Nerica 2 Panicle | 6409 | 57 | 0.92 |
| Nerica 2 Sickle | 7443 | 519 | 6.96 |
| Lsd | 2393.4 | 113.6 | 2.1 |
| CV (%) | 21.8 | 11.2 | 12.8 |

reported losses of at least 30% and above. It is therefore important for stakeholders in the local rice industry to discuss this great losses to stimulate the growth of the industry and alleviate poverty among the farmers.

## Field studies - Harvesting losses

The results of harvesting losses of rice have been presented in Table 1. There was no significant difference between Nerica 1 and Nerica 2 with respect to harvesting losses. However, losses due to the methods of harvesting (panicle and sickle) were significantly different ($P < 0.05$) among the varieties. The use panicle harvesting method resulted in 1.39% grain loss. On the other hand, there was 2.94% loss when sickle harvesting method was used. This indicates that panicle harvesting should be the method of choice based on the figures for harvesting losses observed in this study.

The interaction between variety and method of harvesting impacted significantly on harvesting losses. Panicle harvesting of Nerica 1 showed the least harvesting loss of 1.13% while sickle harvesting of Nerica 1 resulted in the highest loss of 3.25%.

Generally, harvesting loss values of (1.13 to 3.25%) reported in this study falls far below than the 12.05% (Table 2) harvesting losses that were found on some farmers' fields during this study but falls within range (1 to 3%) reported for South East Asia (World Resources Institute, 1998). Even though panicle harvesting resulted in minimum postharvest losses when compared to sickle harvesting, harvesting by sickle method is twice faster

**Table 3.** Harvesting and threshing losses at farmer's fields.

| Parameter | Harvesting losses (g) | Threshing losses (g) | Total weight of harvested rice (g) | Harvesting losses (%) | Threshing losses (%) | Total losses (%) |
|---|---|---|---|---|---|---|
| Farmer 1 | 382 | 35 | 4837 | 7.91 | 0.73 | 8.65 |
| Farmer 2 | 135 | 50 | 1164 | 12.05 | 4.07 | 16.14 |
| Farmer 3 | 198 | 211 | 7773 | 2.60 | 3.00 | 5.60 |
| Farmer 4 | 299 | 144 | 3723 | 8.20 | 3.73 | 11.93 |
| Farmer 5 | 177 | 36 | 7124 | 3.03 | 0.53 | 3.57 |
| Lsd | 171.6 | 72.5 | 3421.5 | 5.44 | 1.95 | 4.57 |
| CV (%) | 39.6 | 43.4 | 38.2 | 44.2 | 44.5 | 27.4 |

and less laborious than panicle harvesting (Pingali and Hossain, 1998). Consequently, harvesting using panicle method on a large field might not be practical. The cost of the extra man hours, time spent as well as other extra resources spent on harvesting does not make the gain in panicle harvesting economical. Farmers therefore might still be better off harvesting with sickle in the absence of improved mechanized harvesting.

## Threshing losses

Sickle harvested rice from both Nerica 1 and Nerica 2 were threshed using the locally made wooden box commonly known in Ghana as "bambam" method. Since during panicle harvesting only the panicles are cut, the harvested rice does not come together with the stalks as in the case of sickle harvesting to enable threshing using the wooden box (bambam) method. Threshing for the panicle harvested rice was therefore done using the bag-beating method instead (Table 2).

Even though the Nerica 2 variety had lower threshing losses (3.94%) compared to the Nerica 1 variety (4.65%), the difference was not significant. Threshing losses were higher (6.14%) in the sickle-harvested rice that used the "bambam" than in the panicle-harvested rice (2.45%) that used the bag beating method. This outcome is attributable to the different methods of harvesting (sickle or panicle) which dictated the threshing methods (bambam or bag-beating) that had to be used. The losses were lower in the bag beating method because very little grains dropped from the bag during threshing. However, in the "bambam" method, some grains scattered and were lost during threshing using the threshing box. Threshing in an enclosed room where escaping grains could be trapped on tarpaulin, may help reduce threshing losseswhich especially in the "bambam" method since scattered grains can be collected.

The interaction between variety and threshing method resulted in significant differences in the threshing losses. When the bag-beating method was used for threshing, Nerica 2 had significantly lower losses (0.92%) than Nerica 1 (3.98%). On the other hand when the bambam method was used there were no significant difference between threshing losses of Nerica 1 and Nerica 2. Generally the bambam method resulted in higher threshing losses (between 5.33 and 6.96%) than the bag beating method (between 0.92 and 3.98), regardless of the variety. These values are lower than the 4 to 6% threshing losses reported for South-East Asian countries (IRRI, 1997). These lower values (0.92 to 3.98%) contradict the perception of the rice farmers (30%) that the highest loss occur at threshing (Figure 1).

## Harvesting and threshing losses at five different farmers' fields

Five different rice farmers cultivating different rice varieties, mostly the Nericas and Sikamo rice varieties were also assessed for harvesting and threshing losses.

The results of the survey showed that harvesting losses ranged between 3.03 and 12.05% while threshing losses varied from 0.53 to 4.07% (Table 3). Total losses due to only harvesting and threshing losses at farmer's fields ranged between 5.60 and 16.14%. The differences in postharvest losses among the farmers were due to different level of skill of harvesting and threshing as well as poor weed control. During the study it was observed that the farmers' fields were engulfed in a lot of weeds. Poor weed control is known to interfere with effectiveness of harvesting (Al-Khatib, 1995).

## Weight losses during storage

There were weight losses in both varieties (Nerica 1 and Nerica 2) ranging between 6.19 and 9.35% (Table 4). The reduction in the weight could also be due to moisture losses from the grains during storage as well as pest and insect infestations. The storage losses observed were higher than the 2 to 6% reported for South East Asia (IRRI, 1997). Proper drying and pest control are important to minimize storage losses.

**Table 4.** Weight losses during storage losses of Nerica 1 and Nerica 2.

| Variety | Initial weight (g) | Final weight (g) | (%) Loss |
|---|---|---|---|
| Nerica 1 (Panicle harvest) | 6450 | 6053 | 6.07 |
| Nerica 1 (Sickle harvest) | 6925 | 6277 | 9.26 |
| Nerica 2 (Panicle harvest) | 6409 | 6019 | 5.97 |
| Nerica 2 (Sickle harvest) | 7443 | 6933 | 6.79 |
| Lsd | 3415.5 | 3088.0 | 3.29 |
| CV (%) | 26.6 | 25.9 | 24.9 |

**Table 5.** Total postharvest losses studied.

| Activity | Percentage losses |
|---|---|
| Harvesting losses | 3.03 to 12.05 |
| Threshing losses | 0.53 to 4.07 |
| Drying losses | 1.57 to1.76 |
| Total | 4.60 to 17.88 |

**Table 6.** Milling efficiency of different milling machines used by the farmers.

| Machine | Milling yield (%) | Bran weight (%) | Husk weight (%) |
|---|---|---|---|
| SB30 | 67.30 | 14.53 | 18.13 |
| SB10 | 66.0 | 17.87 | 16.13 |
| LLM | 63.33 | 36.67 | 0 |
| Lsd | 4.37 | 3.4 | 1.64 |
| CV (%) | 3.3 | 8.7 | 7.2 |

## Total postharvest losses of rice at harvesting, threshing and drying, operations

The total losses of rice in this study from harvesting to milling have been presented in Table 4 to 6. There were variations at each stage. Harvesting losses ranged between 3.03 and 12.05%. Threshing losses varied between 0.53 and 4.07% while drying losses ranged narrowly between 1.57 and 1.76%. Losses during storage varied between 5.97 and 9.26% (Table 5).

The total loss estimate up to 18% observed in the field under experiment is similar to the report indicating 15% of the farmers (Figure 2) who mention total losses of ranged between 0 and 19%. The observed overall losses of up to 18% between harvesting and drying indicated that much is lost since that means a revenue loss of 18% of lost revenue, labor, man hours, food (rice), land as well as the other factors of production employed during production. All stakeholders should discuss these high losses. Capacity building inputs and machinery are crucial in redressing these losses. Implementation of appropriate safeguards should be encouraged (Balasubramanian et al., 2007) to reduce milling and threshing losses. According to Saunders et al. (1978), a reduction of 2% of postharvest losses in developing countries would provide at least 4 million metric tonnes equivalent to the annual caloric requirement of 10 million people.

## Milling efficiency of used machines

The results of the milling analysis have been presented in Table 6. The results showed that SB30 had marginally higher milling yield (67.32%) than SB10 (66%).

However, the differences between the milling yields of either the SB30 machine and the locally manufactured milling machine or that of the SB10 machine and the locally manufactured milling machine were significant. The locally manufactured milling machine had the lowest milling yield (63.33%). This implies that the locally manufactured milling machine was less efficient as it also resulted in higher percentage (52.7%) of broken grains (Table 6). This implies that the local machine produced less white rice per unit weight of paddy. This resulted in less recoverable rice and therefore less revenue. SB30 is

**Table 7.** Effect of milling machine type on grain breakages.

| Machine | Weight of broken grains (g) | Weight of unbroken grains (g) | Unbroken grains (%) | Broken grains (%) |
|---|---|---|---|---|
| (SB30) | 3.60 | 6.73 | 67.3 | 32.7 |
| (SB10) | 5.00 | 5.00 | 50.0 | 50.0 |
| (LMM) | 5.27 | 4.73 | 47.3 | 52.7 |
| Lsd | 1.37 | 1.30 | 13.00 | 13.01 |
| CV (%) | 14.8 | 11.8 | 11.8 | 14.8 |

therefore superior to both SB10 and the Local machine in terms of milling yield. In spite of the higher milling yield of SB30, it is still lower than the 67.5% (2010 data) considered to the lowest on record in the USA (Robinson, 2010). According to the author, this could lead to a shift to selling more broken grains, consequently mean lower prices. Norman and Otoo (2003) recommended that improved dehulling and whitening machines should be developed and tested for use in rice processing.

## Grain quality of rice from the three milling machines

There were significant differences (Table 7) between the milling machines to produce unbroken grains (head grains). The results showed that SB30 produced the highest (67.3%) percentage of unbroken grain, followed by SB10 (50%). The locally manufactured machine (LMM) produced the least (47.1%) percentage of unbroken rice grains after milling. The differences between SB30 and SB10 as well as between SB30 and LMM were significant. The performance of SB10 and the LMM were not significantly different from each other.

In the Bangladesh inspection standard for completely milled rice, the upper limit of broken grains was 12% for big broken and 4% for small broken aromatic rice (Afsar et al., 2001). On the other hand, in the United States of America, the upper limit of 25% is taken for the fourth grade rice (Schmidt, 2010).

Clearly, the levels of broken grains obtained in this study with SB30, SB10 and LMM were much higher than the internationally acceptable limits, although according to Sakurai et al. (2006) milling machines in Ghana are efficient. This indicates that rice milled using the SB30 machine falls below the international standard although it produced higher percentage of unbroken grains among the machines assessed. The results suggest that rice milled using the available milling machines in Ghana might not qualify even for the lowest grades in the international market (15% Japan, 25% USA). Accordingly the milling machines used in Ghana do not produce milled rice that falls in the acceptable grading standard of America and Japan. In this respect, Ghana milled rice might not compete very well with Japanese or American rice if they are all at the same market where unbroken grains is mostly demanded. Consequently, Ghanaian rice farmers might not get competitive prices for their rice on the international market.

## Conclusion

The study has highlighted the fact that rice farmers are aware of the postharvest losses involved in rice cultivation in Ghana. Harvesting losses were higher when the sickle method of harvesting was used, compared to the panicle harvesting method. Threshing losses were also higher in sickle harvesting where threshing was done by the “bambam” method. SB30 milling machine performed significantly better than SB10 and the local manufactured machines in terms of both milling yield and head grain quality. From the results obtained during this study, postharvest losses of rice during harvesting, threshing and drying ranged between 4.6 and 17.88%, with the exclusion of losses resulted from storage, transportation, winnowing and handling losses were not included.

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