Effect of different threshing methods on the physical characteristics of two varieties of paddy rice

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Abstract: As part of the efforts to reduce the postharvest losses (quantity and quality) of rice, this study was carried out to ascertain the effects of three threshing methods: (stone, bambam (wooden box), and combine harvester) on two varieties of rice: AGRA and Jasmine 85. The experimental design was a 2×3 factorial experiment in Completely Randomized Design (CRD) with three replications. At the end of the study, the result of the parameters measured shows combine harvester threshing method recorded the highest dockage level (0.41%) while bambam produced the cleanest grains with dockage level of 0.22%. Percent immature grains produced by AGRA (1.02%) was significantly higher than that of Jasmine 85 (0.61%). Threshing by the stone method produced the highest amount of fissured grains (3.8%) whiles combine harvester produced the least (3.14%) fissured grains. In the germination test, Jasmine 85 (86.11%) were geminated significantly better than AGRA (63.88%). In terms of grain weight, Jasmine recorded a higher weight (25.783g) than AGRA (25.197g), suggesting a higher carbohydrate stored in Jasmine 85. It could be concluded that different varieties have different internal and external properties hence respond differently to a postharvest treatment.

1. Introduction
Rice belongs to the grass family Poacaea in which there are more than 10,000 species of grasses distributed among 600 genera. It has its place in the genus Oryza among which lies two domesticated species (Sativa and Glaberrima) [1]. The two species of rice have recently been crossed, producing a promising hybrid. The rice plant grows between 0.4 and 0.5 meters high and matures within 3-6 months, depending on the cultivar or variety [2].

The Alliance for Green Revolution in Africa (AGRA) sponsored the development of the AGRA rice in Ghana with registration number IR841 through a varietal development program. The project aimed at developing quality rice varieties for the Ghanaian market was commenced in 2009 by a team of rice breeders from the Center for Scientific and Industrial Research (CSIR), Accra, and Tono Irrigation Project, Tono [3]. On the other hand, Jasmine 85, which traces its origin back to Thailand, was introduced into Ghana in 1998 by the Savana Agricultural Research Institute (SARI), Ghana. This variety was chosen because of the characteristics it possessed, especially its aroma, grain size, and grain length [4].

Rice in Ghana is cultivated under three different ecologies: low-land rain-fed ecology (78 percent of production), upland rain-fed ecology (6 percent of production), and irrigated ecology (16 percent of production).
production) [5]. Most farmers in Ghana, especially those in the southern part, practice the sickle kind of harvesting, and the reaping of the harvested rice is usually done by women [6]. Mechanized rice harvesting is practiced in the northern sector of the country where combine harvesters are used. Harvesting of paddy too late often results in grain lost through shattering or cracking during threshing. Cracked grains do not germinate, and they also break during milling [7]. [8] also stated that harvesting of grains too early also results in grain lot with a lot of immature grains. These immature rice kernels are very slender and chalky and contribute excessive amounts of bran and broken grains during milling. Threshing rice can be carried out either manually or mechanically. Manual threshing comes in different forms, such as hitting the panicle of rice against objects such as stones, drums wooden boxes bambam, etc., sometimes humans and animals are made to trample on the harvested panicles in other to loosen the paddy grain from the panicle. Although this threshing method is proven to be cheaper, it is also associated with both quantitative and qualitative losses between 20-30% [9],[10]. According to [11], threshing methods significantly affect percentage quantity and quality loss of rice regardless of variety.

In recent times, rice has become a major staple in Ghana with a per capita consumption of 25kg/year, but most of the consumption is met by imports [12]. Ghana, in 2009, imported over 350,000 tonnes of rice worth 600 million US dollars, representing over 60% of demand [13]. [14] disclosed that rice is the second most important cereal in Ghana after maize, and its consumption is expected to keep increasing. On a global scale, it serves as food for more than half of the world’s population and could be envisaged as food for the future.

Rice grain consists of 75-80% starch, 12% water, and 7% protein with a full complement of amino acids. Its protein is highly digestible with excellent biological value and protein efficiency ratio owing to the presence of higher concentration (4%) of lysine. [15] raised points such as poor postharvest handling, non-availability, and the generally perceived poor quality of local rice as the reasons for the low patronage of the locally produced rice. In harmony with the points raised above, [16] reported that Ghanaian consumers’ preference for imported rice to the locally produced one is based on the absence of foreign material, better grain quality, ease of cooking, and fragrance. In addition to enhancing the patronage of the local rice, good quality seed is also capable of boosting yield between 5-20% [9]. [8] also reported that the low quality of the grain, leading to the rejection of the locally produced rice, could be attributed to inefficient manual threshing of rice used by small scale farmers. The main objective of this study, therefore, was to identify the effect of three threshing methods on the physical characteristics of two varieties of paddy rice.

2. Materials and methods

The harvesting and threshing of the rice were done in Aveyime, Volta Region of Ghana. The measurement of the physical characteristics was carried out in the laboratory at the Department of Horticulture, Kwame Nkrumah University of Science and Technology (KNUST).

2.1 Sourcing of samples

Paddy samples (AGRA & Jasmine 85) were collected from the paddy field in Aveyime, Volta region of Ghana. After the rice had reached physiological maturity with a moisture content of 20-22%, part of the field was harvested using combine harvester and the other harvested part using the man-powered sickle method. The sickle harvested paddy was threshed using two threshing methods: bambam and stone. The paddy was dried to an acceptable moisture content of 12-14%. Samples were transported to the Laboratory of the Department of Horticulture, KNUST Kumasi, for analyses.

2.2 Experimental design

The design of the experiment was 2×3 factorial arrangement in a Completely Randomized Design (CRD) in three replications. The factors were 2 varieties (Jasmine 85 and AGRA), and 3 threshing methods
(combine harvester, *bambam*, stone). Bambam served as the control because it is the conventional method used by most farmers in Ghana. Rice samples were redistributed zip lock bags, 108 bags in all were used.

2.3 Measurement of Parameters

All parameters were measured following standards given by the International Rice Research Institute [17].

2.3.1 Dockage. A 100g paddy was randomly collected from each sample. Stones, weeds, and other extraneous materials were carefully sorted out. The weight of the extraneous materials was weighed, and the percent of dockage computed using equation (1)

\[
\text{Dockage\%} = \frac{\text{weight of dockage}}{\text{weight of 100g sample}} \times 100
\]

2.3.2 Immatured grains. The number of immature grains in the sample was determined by randomly collecting 25 grams of paddy from the sample, then all grains that met the IRRI description for immature grains (very slender and flat) were carefully sorted out. The immature grains were then weighed and the percentage determined using equation (2)

\[
\text{Immature grain \%} = \frac{\text{weight of immature grains}}{\text{weight of the 100g sample}} \times 100
\]

2.3.3 Fissure. One hundred paddy grains were randomly drawn from each sample and were scanned with a fissure detecting camera. The X-ray camera displays the internal condition of the grains out of which the percentage of fissured grains was determined by using equation (3)

\[
\text{Fissured grains\%} = \frac{\text{No of fissured grains}}{\text{100 grains}} \times 100
\]

2.3.4 Length to width ratio (grain shape). Ten paddy grains were collected at random from each sample, and the dimensions were measured to obtain the average length and width using a digital caliper. Data obtained were interpreted based on the scale prescribed by [17]. The paddy shape was obtained using equation (4)

\[
\text{Length to width ratio} = \frac{\text{average paddy length (mm)}}{\text{average paddy width (mm)}} \times 100
\]

| Length | Shape   | L/W ratio |
|--------|---------|-----------|
| 1      | Slender | Over 3.0  |
| 3      | Medium  | 2.1-3.0   |
| 5      | Bold    | 1.1-2.0   |
| 9      | Round   | 1.0 or less|

2.3.5 1000 grain weight. Seeds were randomly drawn from the various samples and fed into an electronic grain counter (Countamatic electronic grain counter), which discharged the seeds through an outlet as the counts appear digitally on a screen attached to the device. A thousand seeds were counted from each sample and weighed using an electronic balance.

2.3.6 Germination test. Paddy was randomly drawn from each sample and carefully dehulled by hand to ensure that the embryo is not removed by the mechanical threshing process. The dehulling served as a means
of enhancing early germination. The seeds were placed in a petri dish with a wet filter paper; each dish carried twenty seeds with their respective labels on the covers.

\[
\text{Germination} \% = \frac{\text{No of seeds germinated}}{\text{total No of seeds planted}} \times 100 \text{………………………………………………………….(5)}
\]

2.3.7 Moisture test. This was carried out using the oven (Quincy 20GC Hydraulic Gravity), the temperature was set at 130 °C and weighed paddy samples kept inside for 16 hours after which final weight of samples was taken. The moisture content of paddy was computed on a wet basis using equation (6)

\[
\text{M.C}_{wb} = \frac{\text{mf} - \text{mi}}{\text{mi}} \times 100 \text{………………(6)}
\]

Where,

- \( \text{mi} \) = initial weight
- \( \text{mf} \) = final weight
- \( \text{wb} \) = wet basis

2.4 Data Analysis

Data obtained were subjected to analysis of variance (ANOVA) using Statistix Software Version 10, and means were separated using the Least Significant Difference (LSD) at 5% (P < 0.05).

3. Results and discussion

3.1 Dockage level

| Threshing methods | Varieties | Jasmine 85 | Mean |
|-------------------|-----------|------------|------|
| Combine           | AGRA      | 0.46\(^a\) | 0.37\(^ab\) | 0.41\(^a\) |
| Bam Bam           | 0.19\(^b\) | 0.24\(^ab\) | 0.22\(^b\) |
| Stone             | 0.35\(^ab\) | 0.23\(^ab\) | 0.29\(^ab\) |
| Mean              | 0.33\(^a\) | 0.28\(^a\) | 0.29\(^a\) |

LSD (5%) Interaction=0.2407 LSD (5%) Threshing M= 0.13 LSD (5%) Var. = 0.0902

The result from Table 2 showed no significant difference (P>0.05) in the scores recorded by the two varieties in their measure of dockage; meanwhile, combine threshing method recorded the highest significant (P<0.05) dockage level (0.41%) among the threshing methods against Bam Bam which recorded the lowest (0.22%). This observation could be attributed to the operating mechanism of the combine harvester: moving along the field ripping and threshing any standing plant indiscriminately. The constituents of the dockage from the combine were mainly broken straws of rice and other weeds that belong to the grass family. Stone threshing method produced the second-highest dockage percentage, the foreign materials found in the samples from stone included some seeds of other plants and small stones which suggest that the contamination took place during the collection of the threshed grains and perhaps the base collecting material on which the threshing was carried out was also not clean. Foreign matter in the grain, according to [18], could be included on the farm at the point of harvesting or the point of threshing; it also reduces milling recovery and quality of rice, and increases wear and tear on milling equipment.

3.2 Immatured grains

The result for immature grains from Table 3 showed that the percentage of immature grains is largely influenced by variety. AGRA recorded a significantly (P<0.05) higher percentage of immature grains
than Jasmine 85 (0.61%). This observation can be attributed to the low seedling vigour observed in AGRA during the germination test. [19] reported that vigorous seedlings are responsible for higher grain yield. [20] also stated that vigorous seedlings established their root and shoot systems quicker after germination so that they are able to imbibe, photosynthesize, and assimilate nutrients required for growth. Jasmine 85 recorded a higher seedling vigour from observation during the germination test hence producing more matured grains than AGRA.

### Table 3. Percentage (%) Immature grains of varieties resulting from the different threshing methods

| Threshing methods | Varieties   | Jasmine 85 | Mean |
|-------------------|-------------|------------|------|
|                   | AGRA        | 3.15ab     | 3.13a|
|                   | Bambam      | 3.13ab     | 3.14a|
|                   | Stone       | 3.14ab     | 3.15a|
|                   | Mean        | 3.14ab     | 3.15a|

LSD (5%) Interaction= 1.0055  LSD (5%) Threshing M = 0.5662  LSD (5%) Var. = 0.3767

3.3 Percentage germination.

### Table 4. Germination percentage of rice varieties

| Threshing methods | Varieties   | Jasmine 85 | Mean |
|-------------------|-------------|------------|------|
|                   | AGRA        | 3.15ab     | 3.13a|
|                   | Bambam      | 3.13ab     | 3.14a|
|                   | Stone       | 3.14ab     | 3.15a|
|                   | Mean        | 3.14ab     | 3.15a|

LSD (5%) Interaction= 1.0055  LSD (5%) Threshing M = 0.5662  LSD (5%) Var. = 0.3767

The results from the germination test in Table 4 suggest that the threshing methods applied did not cause any significant (P>0.05) effect on the germination percentage of the paddy. Jasmine 85 recorded the highest significant (P<0.05) percentage germination (86.11%) in terms of variety regardless of the threshing method used, whiles AGRA resulted in a lower germination percentage of 63.88%. This observation can also be attributed to the higher store of carbohydrates in the endosperm of Jasmine 85 than AGRA. A report by [19], which attributed germination ability to the store of carbohydrate in the seed, explains this observation. An observation of the two varieties of seed under a microscope during the fissure test showed the embryo of most AGRA seeds dislodged. This can also be a possible cause of the lower germination percentage recorded by AGRA.

### Table 5. Percentage of Fissured grain resulting from the various grain resulting from different threshing methods

| Threshing methods | Varieties   | Jasmine 85 | Mean |
|-------------------|-------------|------------|------|
|                   | AGRA        | 3.15ab     | 3.13a|
|                   | Bambam      | 3.13ab     | 3.14a|
|                   | Stone       | 3.14ab     | 3.15a|
|                   | Mean        | 3.14ab     | 3.15a|

LSD (5%) Interaction= 1.0055  LSD (5%) Threshing M = 0.5662  LSD (5%) Var. = 0.3767

3.4 Fissure grains

### Table 5. Percentage of Fissured grain resulting from the various grain resulting from different threshing methods

The results from the germination test in Table 4 suggest that the threshing methods applied did not cause any significant (P>0.05) effect on the germination percentage of the paddy. Jasmine 85 recorded the highest significant (P<0.05) percentage germination (86.11%) in terms of variety regardless of the threshing method used, whiles AGRA resulted in a lower germination percentage of 63.88%. This observation can also be attributed to the higher store of carbohydrates in the endosperm of Jasmine 85 than AGRA. A report by [19], which attributed germination ability to the store of carbohydrate in the seed, explains this observation. An observation of the two varieties of seed under a microscope during the fissure test showed the embryo of most AGRA seeds dislodged. This can also be a possible cause of the lower germination percentage recorded by AGRA.
There was no significant difference (P>0.05) in the number of fissure grains produced by the two varieties. However, the three threshing methods recorded different quantities of fissured grains. The observation is in harmony with research by [11], which revealed that regardless of the variety used, threshing methods significantly affect quantitative and qualitative losses of rice. The Stone threshing method resulted in a significantly (P<0.05) higher fissure (3.80%) across the varieties, and this could be attributed to the mechanical impact of the hard surface of the stone. Combine threshing method recorded the least amount of fissured grains (3.14%). In a related study on fissure percentage of rice, [21] stated that conditions the rice field such as solar radiation and temperature, especially during periods of grain filling, also affect the fissure percentage of grains. The results revealed that prolong hours of sunshine during periods of grain filling increased the amount of fissured grains in all cultivars.

### 3.5 Moisture content of grains
The moisture content of the grains showed a significant (P<0.05) difference between the varieties, with only slight variations within a variety. AGRA variety recorded a significantly (P<0.05) higher mean moisture content (14.18%) than Jasmine 85 (13.7%). The consistency in moisture content recorded by the two varieties suggests that the observation could be attributed to varietal differences. The higher moisture content recorded by AGRA could be linked to the fact that it is a drought resistant variety. [3] mentioned drought resistance as one of the advantages that AGRA has over Jasmine 85. The bulky shape recorded by AGRA in the shape measurement could also be a contributing factor to its higher moisture retention capacity.

### 3.6 Grain length to width ratio (shape)

#### Table 6. Grain shape of the various varieties

| Threshing methods | Varieties      | Jasmine85 | Mean |
|-------------------|----------------|-----------|------|
| Combine           | AGRA 3.11*     | 3.36*     | 3.24*|
|                   | Jasmine85      | 3.10*     | 3.00*|
|                   | Mean 3.13*     | 3.26*     | 3.20*|
| LSD (5%) Interaction= 0.4 | LSD (5%) Var. = 0.1258 LSD (5%) Threshing M = 0.1891 |

The result from Table 6 showed no significant difference (P>0.05) in the grain shape when the different threshing methods were applied. However, the varieties showed a significant difference (P<0.05) in shape. Jasmine 85 recorded a significantly (P<0.05) higher score (3.31) for grain shape against AGRA, which recorded (3.11). Regardless of the statistical differences observed in the two varieties, they both fall in the same category in terms of shape; both varieties fell in slender grain category vis-à-vis the ISO standard for grain shape measurement (Table 1) [17].

### 3.7 Thousand grain weight

#### Table 7. Thousand-grain weight of various rice varieties

| Threshing methods | Varieties      | Jasmine 85 | Mean  |
|-------------------|----------------|------------|-------|
| Combine           | AGRA 25.150ab* | 25.470ab   | 25.310a |
The results of the thousand-grain weight from the study showed no significant difference (P˃0.05) within various threshing methods. This implies that the 1000 grain weight of the paddy is more dependent on a variety of crops than the threshing method employed. Jasmine 85 recorded the highest mean weight over AGRA; this could be attributed to the store of carbohydrate in the seed, which is also essential for better germination [19] reported that heavier seeds stand a better chance of germination than lighter seeds due to the store of carbohydrate in it. Apart from the insufficient store of carbohydrates, the lighter weight recorded by AGRA can also be attributed to the presence of many unfilled grains in the sample [22]. According to [23], 1000 grain weight is a more reliable index of rice yield compared to the number of grains per panicle or panicle per plant. Grain weight is directly influenced by grain shape, and this has a bearing on the commercialization of rice [24-26].

4.0 Conclusion
The percentage of fissured grains was highest in the stone threshing method, while the combine harvester method recorded the lowest. Though the dockage level in combine harvester was highest, it can still be considered as the best method since such quality issues associated with dockage can be amended later. Also, the difference in grain weight and shape of varieties suggests that grains should be treated differently during drying and other related postharvest activities. From the findings, it can be concluded that the suitability of the threshing method depends on the variety; hence such information must be considered during the design and construction of postharvest equipment. Further studies can be carried out on the milling and physicochemical properties of these rice varieties in order to derive conclusive results on the performance of the varieties and threshing methods. Also, similar research can be repeated using other varieties and threshing methods.

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