The Effect of Tempering on Strength Properties and Seed Coat Adhesion Strength in Sorghum and Millet

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ABSTRACT

The effect of tempering on seed coat adhesion strength and mechanical strength of sorghum and millet grain kernels was investigated at different tempering durations. Tempering reduced the kernel breaking strength and had significant effect on seed coat adhesion strength. Tempering the grain for 60 minutes at ambient temperature (20^0C) reduced the force required to break the grain kernel from 148.4 N to 120.9 N for Dionje (a hard endosperm sorghum variety), 86 .0 N to 36.4 N for Jumbo (a soft endosperm sorghum variety) and from 51.4 N to 31.0 N for millet. The amount of energy absorbed at the breaking point of the grain kernel decreased from 52.5 mJ to 37.0 mJ for Dionje, 18.9 mJ to 13.0 mJ for Jumbo and from 14.0 mJ to 5.3 mJ for millet within the same tempering duration. Deformation at break point increased with increasing tempering duration from 0.28mm to 0.46 mm for Dionje, 0.27 mm to 0.48 mm for Jumbo and from 0.21mm to 0.35 mm for millet. Tempering for 15 minutes reduced the seed coat adhesion strength per unit area by 87.6% for Dionje, 94.7% for Jumbo and 95.7% for millet compared to untempered grain. This indicated that tempering of sorghum and millet before dehulling could reduce both the dehulling time and losses incurred during the dehulling process leading to a substantial improvement in their dehulling efficiency.

KEY WORDS: Sorghum, millet, tempering, seed coat adhesion, and strength properties.

1.0 INTRODUCTION

Sorghum and millet are important food crops for millions of people living in the semi- arid Tropics of Asia and Africa (Hulse *et al.,* 1980, Laswai *et al.*, 1999). For human consumption these grains are usually dehulled to remove the seed coat, which is rich in fibre and anti-nutritional factors such as tannins and phytic acid. Removal of the seed coat results in reduction of crude fibre content, anti-nutritional factors and improvement in the appearance, texture, palatability and digestibility of products made from these grains. Most of sorghum and millet is consumed in the rural areas where the grain is dehulled using mostly pestle and mortar. To facilitate the removal of the seed coat, the grain is often tempered before being dehulled. So far, the effects of tempering on dehulling of sorghum and millet are not completely understood, but the addition of water or moistening of the grain cause the seed coat to soften and hence become more easily removed from the endosperm during the dehulling process. The extent of softening or loosening of the seed coat from the endosperm and the change of the mechanical properties of the grain due to tempering have not been fully studied. The knowledge of how tempering affect these two factors may be useful in designing of more efficient mechanical dehulling equipment to replace the tedious traditional methods and improve the performance of mechanical dehullers currently in market.

Several methods have been described to assess abrasion resistance and skin adhesion in fruits and vegetables such as in potato (Mohsennin, 1986; Muir and Bowden, 1994) and watermelon (Pulchaski and Brsewitz, 1996). However, unlike vegetables, very little information is available in literature on methods for measuring seed coat adhesion strength in grain. Ehiwe and Reichert (1987) studied the seed coat adhesion of cowpeas, pegion peas and mung beans by nicking the grain with a pocket knife and subjectively evaluating the degree to which the seed coat was attached to the cotyledons as loose, intermediate or tight. Such ratings only gave a rough idea on the adhesion strength of the seed coat to the cotyledons or endosperm, but did not give any quantitative measure of the adhesion strength. Phirke *et al.* (1995) designed and constructed a shear force measuring apparatus using a piezo-electric transducer, and measured the shear force required for the removal of pigeon pea seed coat, splitting the cotyledons and breaking raw and pre-treated (heated) pigeon peas. This was the first serious attempt at quantifying the seed coat adhesion strength in grain legumes. So far, there has been no attempt made to quantitatively measure seed coat adhesion strength in cereal grains. The effect of tempering process on the seed coat adhesion strength and kernel strength in cereal grains also has not been fully studied. Such information will be useful for future design of dehulling equipment for tempered sorghum and millet grain and in selection of the most efficient pre-treatment method that can be applied to reduce the adhesion strength of the seed coat in sorghum and millet during the dehulling process. The apparatus could also be useful to other scientists in the field such as breeders for selection of varieties, which have low seed coat adhesion strength and hence good dehulling characteristics.

The aim of this study was therefore to design and construct an apparatus which could be used to measure the seed coat adhesion strength in cereal grains and to investigate the effect of tempering on the seed coat adhesion strength and mechanical strength of sorghum and millet grain under quasi-static compression.

2.0 MATERIALS AND METHODS

Grain samples

Dionje, a local white braned, hard endosperm sorghum variety from Tanzania and Jumbo, a large grain, red braned soft endosperm sorghum variety from Australia and one variety of pearl millet (IM) from India, were used in this study.

Seed conditioning

Tempering was carried out by soaking 5g of each grain variety in distilled water at room temperature (20^0C) for three different soaking durations (15, 30 and 60 minutes).

Seed coat adhesion measurements

Figure 1 show a schematic drawing of the seed coat adhesion strength-measuring device. Basically it consists of a pair of sample holders and a sliding friction plate (where an 80 grit abrasive cloth is glued) sandwiched between them. The grain samples for seed coat adhesion strength determination are clamped on sample holders A and B such that maximum surface area of the grain is in contact with the sliding friction plate C. Sample holder B is connected to a movable arm E which is connected to a lever loading system D and can slide along it to accommodate different sizes of test samples. The lever system is balanced by use of balance weight (S), and can be loaded by placing a dead weight (W), on the pan. The sliding friction plate is connected to a load cell attached to a tensile testing machine cross head. When the crosshead is set in motion it applies a force (F), to the friction plate. The load cell is connected to a computer, which records the force and the displacement of the friction plate.

Seed coat adhesion was determined by measuring the tangential force required to remove a unit area of seed coat in contact with the friction plate from the grain kernel. A constant normal force was applied to hold the seed coat to the friction plate by applying a dead weight (W) on the lever balancing system. Once the normal force was applied, the crosshead was set in motion pulling the friction plate up. As the friction plate moved up, it striped off the part of the seed coat in contact with it. The amount of force required to pull the friction plate was recorded and the peak force recorded was taken as the seed coat adhesion strength. The seed coat area removed was determined using image analysis. From the peak force and the area of seed coat removed, the seed coat adhesion strength per unit area was determined.

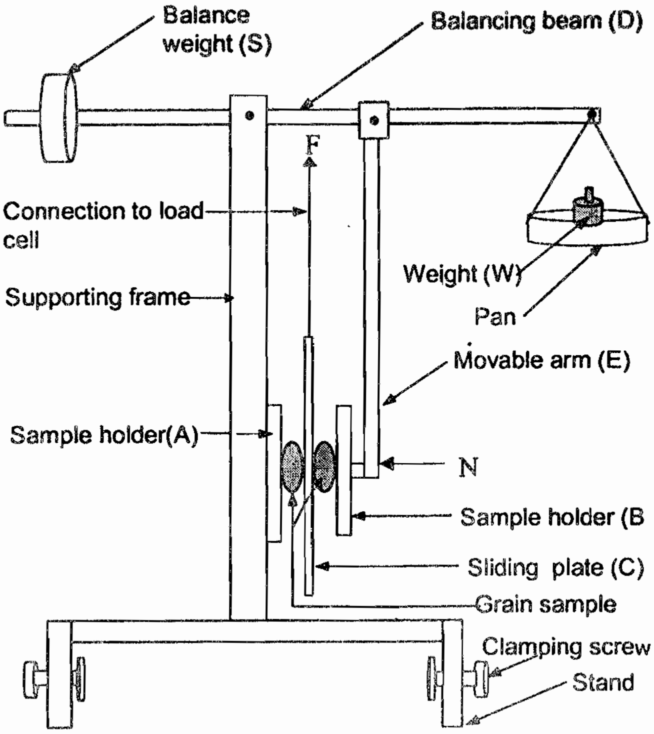

Figure 1. Seed coat adhesion strength measuring instrument

Compressive strength measurements

Quasi-static compression tests were performed on individual grain kernels using a tensile testing machine (model T20K, J.J Lloyd Instruments Ltd.) equipped with a 500 N load cell. The data from the machine was fed directly into a computer for storage and analysis. A deformation rate of 1.25 mm/min was used for all tests according to ASAE recommendations for compression of food samples of convex shape (ASAE standard S. 368.3, 1995). Twenty individual kernels of each grain variety were randomly selected at each tempering duration and loaded between parallel plates up to their breaking point. Prior to loading, the kernels were cemented on a flat plate using fast setting glue to prevent the kernel from slipping or rolling during compression. As the crosshead moved and compressed the grain kernel, a force-deformation chart automatically recorded the data. The break point was detected as the point on the force-deformation curve where the force decreased or remained constant as deformation continued to increase.

From the force-deformation curves the grain strength properties were evaluated. These included; maximum force required to break the grain kernel, energy absorbed by the kernel up to its break point and maximum deformation at kernel break point. The force and deformation at break point were found directly from the force-deformation curve, while the energy absorbed by the kernel up to its break point was obtained by computing the area under the force-deformation curve up to the break point.

Statistical analysis

The data was processed on Microsoft Excel software to plot the graphs. T-test was used to compare the treatment means at 5% level of probability (Mead *et al.*, 1993).

3.0 RESULTS AND DISCUSSION

Seed coat adhesion strength

The results of the effect of tempering duration on the seed coat adhesion strength are summarised in Fig. 2. Tempering caused a significant reduction in the amount of force required to remove a unit area of the seed coat from the endosperm for both sorghum and millet. Tempering the grain for 15 minutes reduced the force required to remove a unit area of the seed coat from the endosperm from 4.2 MPa for untempered grain to only 0.48 MPa for Dionje, 4.7 MPa to 0.42 MPa for Jumbo and from 8.2 MPa to 0.73 MPa for IM millet. Further tempering of the grain up to 60 minutes led to further reduction of the seed coat adhesion strength to 0.21 MPa for Dionje, 0.3 MPa for Jumbo and 0.3 MPa for millet. However, the reduction in force required for seed coat removal between 15 and 60 minutes tempering was significantly ($P<0.05$) smaller compared to the reduction in the initial 15 minutes tempering.

Effect of tempering duration on grain kernel strength properties

The results of the effect of tempering on the strength properties of sorghum and millet are summarised in Fig. 3(a) to (c). All strength properties of the grain investigated in this study except kernel deformation decreased with increase in tempering duration. The results of the effect of tempering on the force required to break the kernel are summarised in Fig. 3(a). The force required to break the grain kernel decreased from 148.4 N to 120.87 N for Dionje, 86.0 N to 36.4 N for Jumbo and from 51.4 N to 31.0 N for millet after 60 minutes tempering duration.

The largest rate of decrease in kernel strength was observed in the first 15 minutes of tempering which was followed by a much slower rate of decrease as the duration increased from 15 to 60 minutes. This could be explained by the fact that during tempering, a rapid absorption of moisture usually takes place in the initial tempering period which is then followed by a much slower absorption rate (Hsu, 1984). This rapid absorption of moisture could have led to the softening of the endosperm.

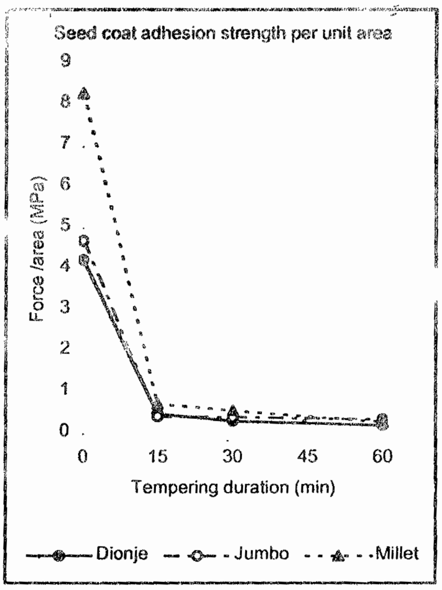

Figure 2. Effect of tempering on seed coat adhesion strength in sorghum and millet

However, the force required to break the grain kernel after 15 minutes tempering, although lower, was not significantly different ($P< 0.05$) from that required to break the untempered kernel for both Dionje and millet.

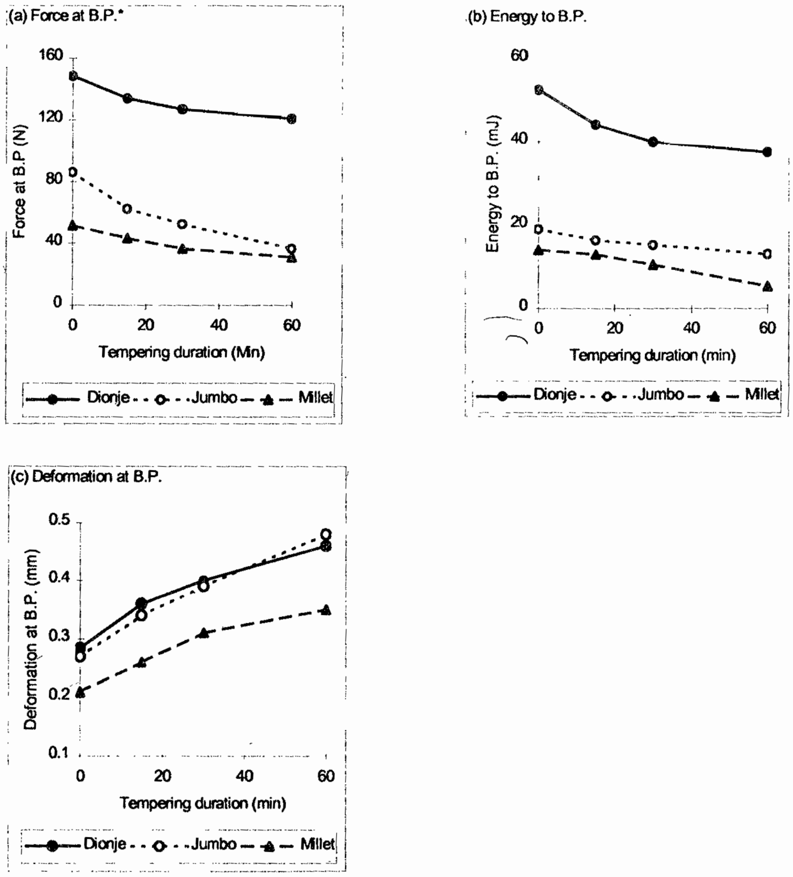

Figure 3. Effect of tempering on the strength properties of sorghum and millet

The effect of tempering duration on energy absorbed by the kernel at the break point in sorghum and millet is summarised in Fig. 3(b). The energy required to break a single grain kernel decreased from 52.5 mJ at 0 minutes tempering duration to 37 mJ after 60 minutes tempering duration for Dionje, from 18.9 mJ to 13.0 mJ for Jumbo and from 14.0mJ to 5.3 mJ for millet within the same tempering period. The effect of tempering on kernel deformation at break point is shown in Figure 3(c). The kernel deformation at break point increased from 0.28 to 0.46 mm for Dionje, 0.27 mm to 0.46 mm for Jumbo and from 0.21 mm to 0.35 mm for millet as the tempering duration was increased from 0 minutes to 60 minutes.

The relationship between tempering duration and different strength properties of sorghum and millet are summarised in Fig. 4(a) to (c). The relationship between tempering duration and force to break point is shown in Fig. 4(a). The rate of decrease in force required to break the grain kernel was much higher in Jumbo variety compared to the other two-grain varieties.

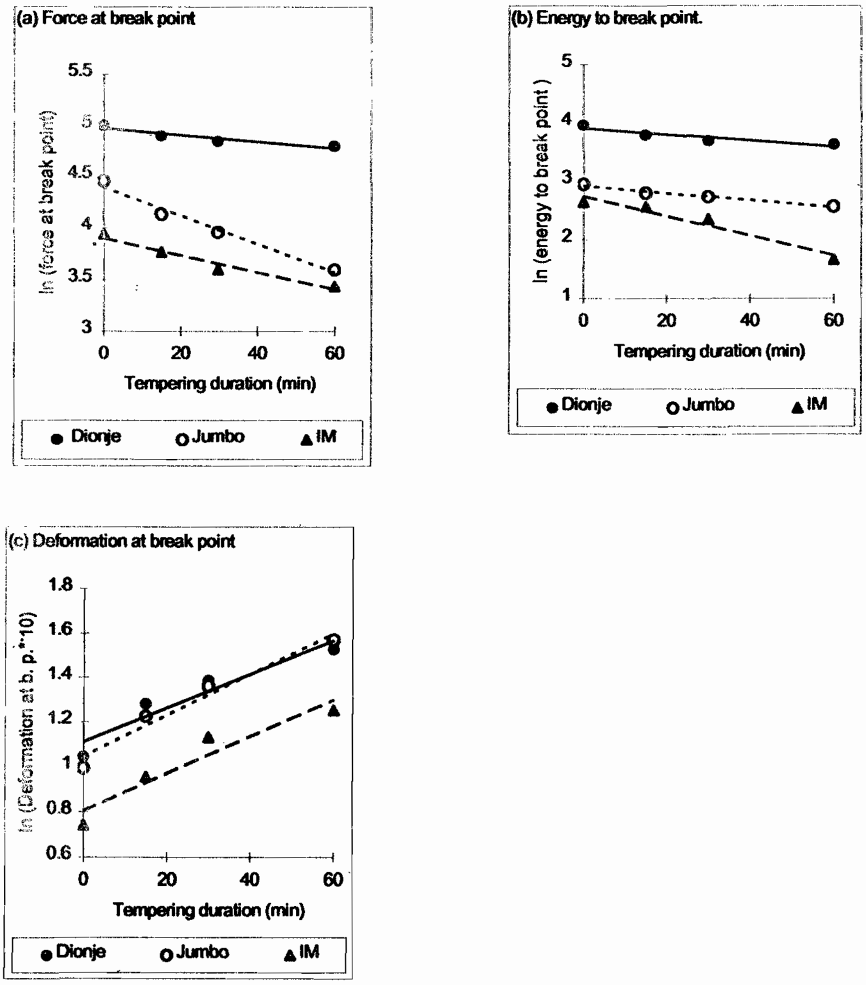

Figure 4. Log-linear plots of the grain strength properties against tempering duration with fitted lines

This could be explained by the difference in the physical properties of Jumbo, which has a soft endosperm and absorbed moisture much faster than the other two varieties resulting in much faster softening of the endosperm compared to the other two varieties which have intermediate (millet) and hard (Dionje) endosperm structures.

The relationship between tempering duration and the energy absorbed by the grain kernel at break point is shown in Fig. 4(b), while the relationship between deformation and tempering duration is shown in Fig. 4(c). The rate of change in deformation with tempering duration within the three varieties was highest in Jumbo which had a soft endosperm followed by millet and Dionje.

4.0 CONCLUSIONS

Statistical analysis (t-test) of both the strength properties and seed coat adhesion strength data showed that there was no significant difference ($P< 0.05$) between the force required to break un-tempered grain and grain tempered for 15 minutes. However, there was a significant difference ($P< 0.05$) between the force required to break un-tempered grain and grain tempered for 30 minutes or more. On the other hand, tempering the grain for 15 minutes significantly reduced the seed coat adhesion strength in both sorghum and millet, further tempering up to 30 and 60 minutes did not lead to further significant reduction ($P< 0.05$) in seed coat adhesion strength. These results suggest that short tempering duration of 15 minutes or less could be carried out without significantly affecting the breaking strength of the grain kernel but reducing significantly the seed coat adhesion strength of the kernel. This can be very beneficial in the development of mechanical dehulling devices for tempered sorghum and millet. Also the results can be an importan [illegible] the evaluation of different tempering pre-treatments for the improvemen [illegible] dehulling efficiency.

ACKNOWLEDGEMENT

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