Particle Size Distribution in Milled Sorghum Grains of Different Corneousness

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ABSTRACT

The particle size distribution of milled samples of three varieties of sorghum [*Sorghum bicolor (L) Moench*] coded V_3, V_6 and V_8 was determined by sieve analysis. The moisture content of the grains ranged between 9.83 and 10.60%, wet weight basis. The milling was carried out on whole grains using a laboratory pin mill while the sieving was carried out using six metric standard sieves of 810, 572, 500, 400, 315 and 210 μm apertures. The particle size distribution was displayed graphically by plotting the size frequency bar charts. From the investigation it was concluded that the particle size (d) distribution of milled sorghum grains is bimodal at the 210-315 μm and 500 – 572 μm size ranges; that the less corneous the grain the less pronounced is the 500 – 572 μm size range peak and that the more corneous the grain the more resistant it is to comminution even at increased milling intensity. There was a significant difference ($p<0.05$) among the grain varieties in terms of particle size distribution.

Key words: Sorghum, comminution, corneous, particle size, texture, textural levels

1.0 INTRODUCTION

Sorghum (*Sorghum bicolor)* (L) *Moench)* is renowned for its resistance to drought and hence its potential as an important food crop in the tropical semi arid zones. It is malted for use in beer brewing and milled into flour for production of soft and stiff porridges. One of the potential uses in many developing countries is the use of sorghum in a blend to extend wheat supply for bread making (Rao and House, 1972). In some areas however, its acceptability as stable food is low compared with such other cereals as maize, rice or wheat. The reason for this is its relatively high tannin content and/or the difficulty in milling it to fine flour.

According to Hulse et al. (1980) sorghum grain, as with other cereals is divisible into three main parts: a seed coat, a germ and an endosperm. The sorghum endosperm is further divisible into two main zones, the corneous and the floury zones. The corneous zone is hard and translucent while the floury zone is soft and reflective. The two zones are readily discernible by the naked eye upon dissection. Rooney and Sullins (1973) point out that heredity and environment influence the texture of the endosperm. Whether sorghum is described as "floury" or 4 corneous" depends on the ratio of these components within the kernel. This ratio varies between and within sorghum varieties and it is likely to influence the particle size distribution of the milled kernel. A review of literature carried out by KSU (1980) as well as by this research team showed that no detailed studies have so far been conducted on the particle size distribution after comminution of sorghum grains. It was of interest, therefore, to characterize their fragmentation patterns.

1.1 Theoretical background

Size reduction refers to the breakdown of solid material by application of mechanical forces. Normally, such particulate systems consist of a wide range of sizes and it is often necessary to give a quantitative indication of the mean size and the spread of the sizes. There are two convenient ways of presenting the particle distribution after conducting a sieve analysis (Coulson and Richardson, 1980), a cumulative weight fraction (w) curve, which is a plot of the weight proportion of particles (w) smaller than a certain size (d) against the size (d). The second and more descriptive way is the size frequency curve in which the slope ($\triangle w/\triangle d$) of cumulative curve is plotted against the size (d). Where $\triangle d$ is the difference in aperture between consecutive sieves (mm); $\triangle w$ is the difference in cumulative mass fraction retained between consecutive sieves and $\triangle w/\triangle d$ is the size frequency.

The most frequently occurring size is thus shown by the peak of the frequency curve. For naturally occurring homogeneous materials the curve will generally have a single peak. For a mixture of particles or for a grind resulting from non-homogenous materials there may be as many peaks as the components in the mixture (Coulson and Richardson, 1980). However, in the comminution of crystalline materials, where the fracture behaviour is dependent upon the presence of structural flaws in the material, bimodal distributions are frequently observed (Sheard et al., 1990).

The spread of the particle sizes is indicated by a shallow curve while a higher curve shows that the particle sizes are confined to a narrow band. An early rising cumulative curve indicates that the system is dominated by smaller particles while a late rising one signifies a coarse system (Perry and Green, 1984). However, to plot these two types of curves one need to have a reasonable number of points in order to trace the trend of a particular curve. An alternative way of presenting sieve analysis results is to use a bar chart whereby the size frequency is plotted against particle size ranges. The boundaries of the ranges represent the apertures of the sieves used. The number under each bar represents the minimum particle size in the range. This is the method employed in this study.

2.0 MATERIALS AND METHODS

Three varieties of sorghum (coded V_3, V_6 and V_8) were used in this experiment and four other cereals (wheat, maize, finger millet and bulrush millet). All of them were purchased from a local market. The sorghum varieties locally known as "Sandala, "Mngindo and "Serena" were taken as reference and coded V_3, V_6 and V_8 respectively. The selection of these sorghum varieties was based on the relative distribution of the floury and translucent portions of the endosperm of the dissected grain. V_3 was largely floury, V_6 was largely corneous while V_8 was approximately 50% floury. Their moisture content, was determined using the constant weight method in an oven at 105°C. The moisture content of the grains was found to be in a narrow range of 9.83 to 10.60%, wet weight basis.

Triplicates of 180g samples were milled using a laboratory pin mill (Magic Mill 111 Plus) for two minutes. The weight was chosen on the basis of a convenient amount that could best be handled by the mill's feed chute while the time was selected on the basis of noise produced by an empty running mill. A sieving process followed using metric 'sieve' of 810, 572, 500, 400, 315 and 210 gm apertures. A Portable Sifter [(Eng.) Ltd., Stoke on Trent, Portable Stifter No.2969] was used to shake the sieves until no visible material was coming through them. A small brush was used to desegregate flour lumps.

The weight of particles remaining on each sieve was taken and an average value calculated from the triplicates. The weight retained (overtails) was obtained by weighing each sieve empty and loaded after sieving. Below the smallest sieve (210µm), the finer particles were collected on a pre-weighed pan and again overtails was obtained by difference.

Experiments were conducted at three settings of machine milling intensifies (textural levels); 1,3 and 6 with level 1 representing the mildest intensity of milling while level 6 stands for the severest intensity for the machine used. Finally, the intensity level was set at 3 for a dehulled sample of V_6 (85% extraction) and whole grain sample of the same variety. The same setting was used for the four other cereals namely, maize, wheat, bulrush and finger millet for comparison purposes.

The data was processed on Microsoft Excel software to plot the bar charts. The data was also subjected to statistical analysis using Anova programme.

3.0 RESULTS AND DISCUSSION

All the size frequency bar charts obtained for sorghum samples were characterised by a bimodal distribution, implying that the sorghum grain is comprised of two distinct fractions with different milling characteristics. The first peak occurs at the 210-315 μm range while the second one is observed in the 500-572 μm range. The authors' interpretation is that one fraction disintegrates easier than the other and these peaks are characteristic of the sub-systems in the mix. It is assumed that the two modes correspond to the floury portion and the outer corneous part of the grain.

At textural level 1 (Fig. 1 a) the bar heights at the 210-315 μm range were very close for V_3 and V_8 V_6, which is the most corneous grain, had at textural level 1 a slightly higher peak at the 210 μm range size. This may appear contradicting since one would expect the floury sorghum to give higher proportion of finer flour than the rest of the varieties. However, since the flanking size ranges compensates by exhibiting low peaks then it can be argued that this variety has a small floury portion which disintegrates very readily and thus even at the lower textural level a big portion of the small floury part was almost completely pulverized. This further suggests that there is still a varietal difference in communition response even within the two-grain portions among the tested varieties. Increasing the textural level however does not appreciably affect the corneous zone of this variety, though it does to the other two varieties, further suggesting a different response for the other portion as well as for this variety. At the 500-572 μm range the peaks are differentiated with the most corneous (V_6) being highest followed by V_3 and V_8 in that order. At textural level 3 (Fig. 1 b) there is not much change at the corneous peak for V_3 and V_6 but some material for V_8 is moved to the floury range, although the spread for all varieties is generally increased towards the 0-210 μm range. At textural level 6 (Fig. 1 c) the heights for V_3 and V_8 are further reduced at the corneous peak and correspondingly increased at the floury peak. V_6 did not change much in height at 500-772 μm range but increased at the other peak range. This implies that there was still substantial material in the corneous range even after increasing the milling intensity to level 6. Since this variety was predominantly corneous the phenomenon is not unexpected. The differences are not very marked when the textural level changes from 1 to 3 as compared to the change from 3 to 6. Indeed the latter is a much bigger change in intensity as compared to the former. Figure 1 (d) represents the bar charts for whole grain and dehulled samples of V_6. Here the bimodal distribution still featured for these samples. As a general trend the dehulled samples dominate the small size ranges while the whole grains have more of their particles in the corneous mode. The effect of dehulling thus is to reduce the corneous fraction in the kernel.

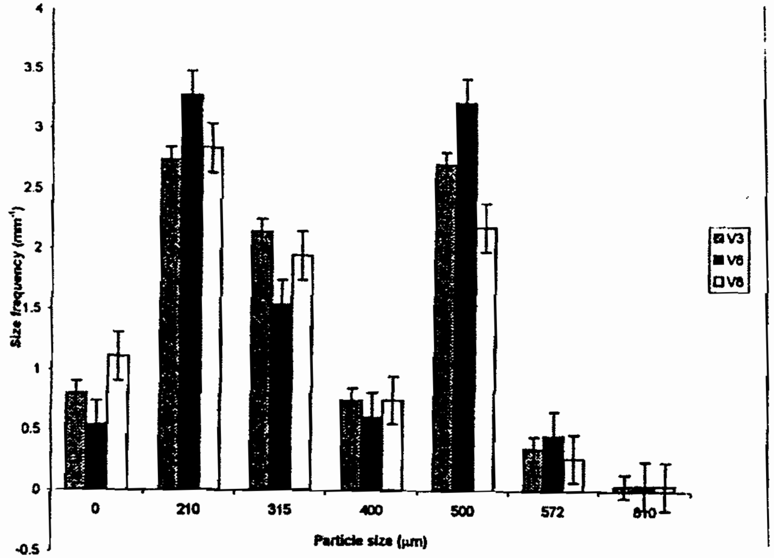

Fig. 1 a Size frequency bar chart at textural level 1

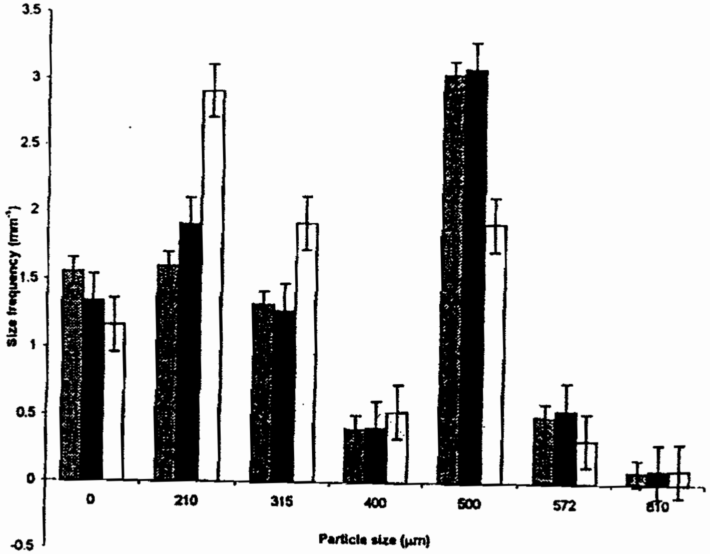

Fig. 1 b Size frequency bar chart at textural level 3

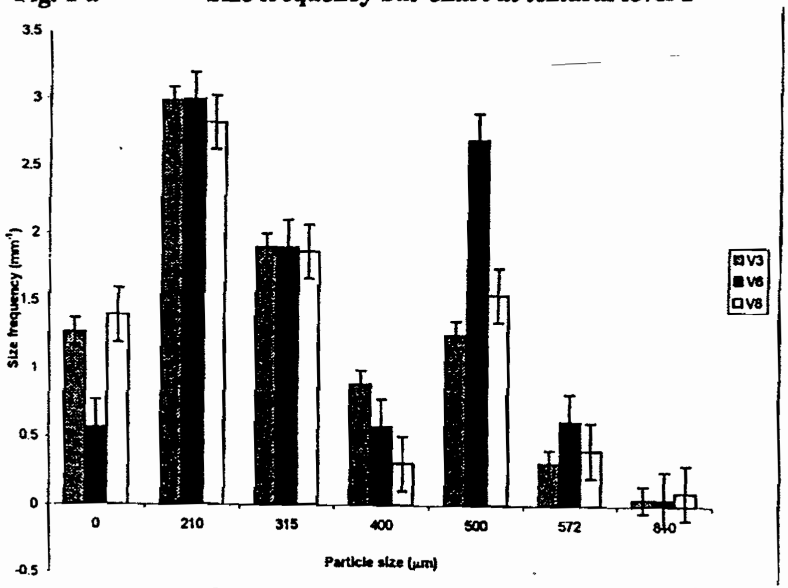

Fig. 1 c Size frequency bar chart at textural level 6

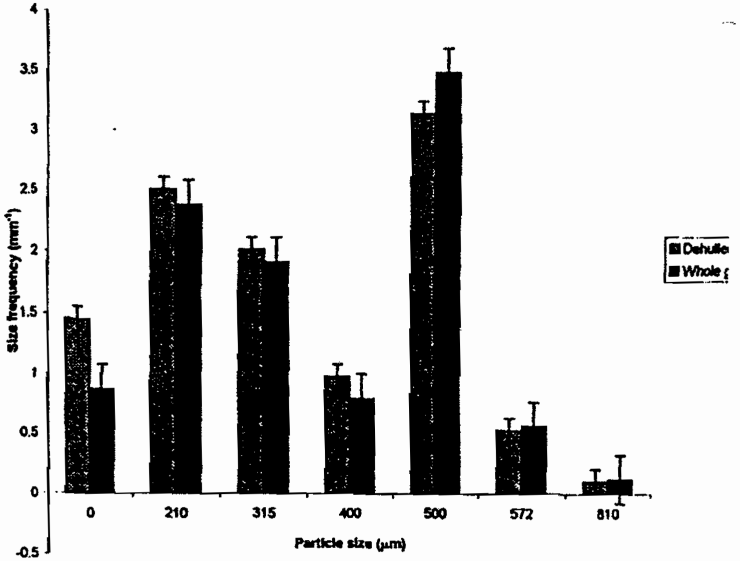

Fig. 1 d Size frequency bar chart for dehulled samples of V_6

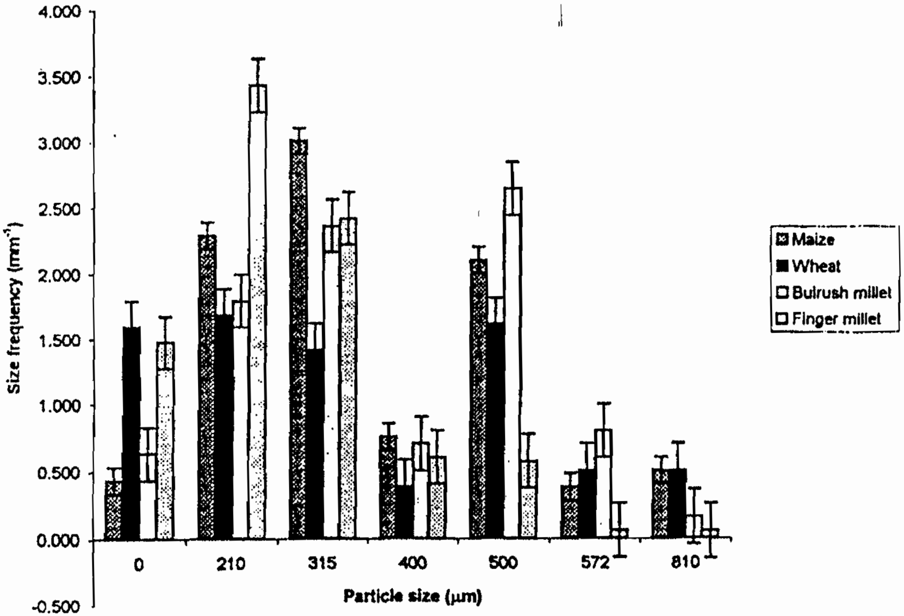

Fig. 2 **Size frequency bar chart for the other selected grain cereals**

Figure 2 represents the bar charts for the other four cereals. It is observed that finger millet does not exhibit a bimodal distribution while the other three cereals do. This testifies that the particle size distribution after the comminution process is dependent upon the nature and structure of the grain. Wheat is characterized by a wide but reasonably uniform fine mode. There is no apparent peak, but ranges of sizes with the same frequency. Indeed wheat flour is normally very fine and uniform, especially if dehulling proceeds comminution. Bulrush millet and maize behave in a similar manner to sorghum, although the floury peak is shifted to the 315-400 µm range. An interesting feature is observed for wheat and maize and at the > 810 µm range. The size frequencies are relatively higher than those for the other two cereals. The relatively elastic hulls of these grains are very difficult to pulverize, as they store the milling stress as strain energy and release it when the stress is removed without appreciable disintegrating into smaller particles.

4.0 CONCLUSION

Based on the observations from these experiments it is apparent that the particle size distribution of milled sorghum is double peaked. The relative heights of the peaks appear to correspond to the corneousnes of the grains. The less corneous the grain the higher is the small particle size peak. The more corneous the grains the more resistant they are to particle size reduction. Dehulling does not change the bimodal behaviour, although it influences the particle size distribution within the two modes. By comparison with other grains, sorghum compares favourably with bulrush millet in terms of milling characteristics. There was a significant difference ($p<0.05$) among the grain varieties in terms of particle size distribution.

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