THE EFFECT OF MOISTURE ON PHYSICAL PROPERTIES OF SORGHUM AND MILLET

***E. L. Lazaro*[1]*, N. B. Shayo*[2]*, B. E. Chove*[3] *and A. B. Gidamis*[4]**

[1]*Department of Agricultural Engineering, Sokoine University of Agriculture, P. O. Box 3003, Morogoro, Tanzania.*

[2,3,4]*Department of Food Science and Technology, Sokoine University of Agriculture, P. O. Box 3003 Morogoro, Tanzania*

ABSTRACT

Knowledge of how the physical properties of grain vary with changes in moisture content is one of the prerequisites for the design and development of efficient processing and handling machines for the grains. Physical properties of two varieties of sorghum (Dionje and Jumbo) and one variety of pearl millet (IM) were investigated at different moisture levels within the moisture range 12 to 25% dry basis. Grain samples with different moisture levels were obtained by adding calculated amounts of distilled water to the grain. Mixing was done thoroughly, the samples sealed in polythene bags and kept in refrigerator at 5°C for fourteen days to allow moisture to get distributed uniformly within each. The results showed that within this moisture range, all the physical properties studied varied linearly with moisture content. Linear dimensions (length, width and thickness), geometrical mean diameter, sphericity, surface area, volume, kernel density and porosity increased with increase in moisture content of the grain. On the other hand, bulk density decreased with increase in moisture content of the grain.

1.0 INTRODUCTION

Sorghum and millet are important cereal grains in the semi-arid tropics of Africa and Asia. In these areas, up to 70% of the dietary protein and energy intake is supplied by locally milled sorghum and millet products (Hulse *et al,* 1980). These two crops are expanding rapidly in acreage in these regions due to their excellent adaptability to semi-arid conditions compared to other cereals like maize, wheat or rice. However, although nutrition-wise they are comparable to other cereals, sorghum and millet are considered as inferior staple food and are consumed only by the economically poor section of the community. One of the reasons hindering widespread acceptance of sorghum and millet, especially in urban areas, is the lack of improved processing technology for production of refined products as is the case for other cereal grains like wheat, rice and maize.

Most sorghum and millet harvests are processed manually by the age-old traditional methods, which are very tedious and time consuming. Mechanical dehullers are also available in some areas, but most of these are inefficient, resulting in large losses and poor quality end products (Reichert and Young, 1976). Due to their significant contribution to cereal production in drought-prone regions of the world, these crops require special attention, especially in processing of the grain to refined products. Knowledge of the physical properties of the grain is one of the pre-requisites for the design and development of efficient processing machines. This paper presents results on the study of various physical properties of sorghum and how these properties are affected by variation in grain moisture content within 12% to 25% moisture range. This moisture range was selected because it is the one likely to be encountered between harvesting and storage of these grains.

2.0 MATERIALS AND METHODS

Two varieties of sorghum, Dionje (a local white branned hard endosperm sorghum from Tanzania) and Jumbo (a large grain red branned soft endosperm sorghum from Australia) and one pearl millet variety (IM) from India, were used in this study. It was necessary to use both sorghum and millet because these are the most important grains in the semi-arid tropics. Initial moisture content of the grain was determined by the standard oven method (ASAE Standards S352.2, March 1995) and was found to vary from 11.8 - 12.4% dry basis (db). Grain samples of different moisture levels were prepared by adding calculated amount of distilled water to the grain, mixing thoroughly then sealing in polythene bags. The samples were then kept in a refrigerator at 5^0C for fourteen days to allow moisture to distribute uniformly throughout the sample and within individual grain kernels (Ogut, 1998; Deshpande *et al*, 1993). [This method of obtaining samples with different moisture content was used because it was difficult to get samples from the field with different moisture levels at the time of the research]. Before the beginning of each test, the required quantity of the grain was taken from the refrigerator and allowed to warm up to room temperature while still in the polyethylene bags.

The physical properties of the grains were determined at four different moisture levels ranging from 12 to 25% db. with ten replications at each moisture level. The ambient temperature was maintained at 20^0C throughout the experimental period. To determine the grain principal dimensions (i.e., length, width and thickness), 10 sub-samples of approximately 100 grains were randomly taken from the main sample. From these sub-samples, 10-grain kernels were randomly picked and labelled for easy identification. For each grain kernel, the three principal dimensions were determined using a micrometer screw gauge reading to 0.01 mm. These principal dimensions were used to calculate other important geometrical parameters of the grain as explained below:

The geometric mean diameter (G.M.D) of individual grain kernel was calculated using the following formula (Mohsenin, 1986);

$$G.M.D. = (LWT)^{\frac{1}{3}} \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ 1$$

where, L is the length of the grain (mm), W the width of the grain (mm) and T the thickness of the grain (mm).

The sphericity (ϕ) of the grain, which is an index of its roundness, was determined from the following relationship (Mohsenin 1986);

$$\phi = \frac{\text{geometric mean diameter}}{\text{major diameter}}$$

$$\phi = \frac{(LWT)^{\frac{1}{3}}}{L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

The surface area (s) of single grain was found using the following relationship (Deshpande *et al* 1993);

$$S = \pi(G.M.D)^2 \quad (3)$$

where *G.M.D* is the geometric mean diameter (mm).

The grain volume and kernel density as a function of moisture content was determined by the liquid displacement method using toluene. In this test, fifty-kernel sample displacement was measured with aid of toluene and a measuring cylinder. The kernels volume was determined by dividing the displaced toluene volume by the number of kernels used in the sample. The weight of each grain kernel used in the volume measurement was also determined and used in computing the kernel true density. The bulk density was determined using a mass per hectolitre tester, which was calibrated in kg per hectolitre (Deshpande *et al.*1993). The grain was poured into the calibrated vessel up to the top from a height of about 15 cm and excess grains were removed by striking off. The grains were not compacted in any way.

The porosity (ε) of the grain sample which is the percentage of volume of voids in the grain sample at a given moisture content, was calculated from the following relationship (Mohsenin, 1986);

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_k}\right)100 \quad (4)$$

where ρ_b is the bulk density and ρ_k is the kernel density.

3.0 RESULTS AND DISCUSSION

3.1 Grain Dimensions

The average values of the three principal dimensions of sorghum and millet varieties used in this investigation are summarised in Table 1. All the principal dimensions of the grain increased with increase in moisture content, indicating that upon moisture absorption, the grain kernels expand in length, width and thickness within the moisture range investigated here. It was also observed that the kernels expanded more along their thickness in comparison with the other two principal axes.

The relationship between moisture content and any principal dimension (*Y*) of the grain kernel was found to bear the following linear relationship with moisture content;

$Y = A + B M$ 5

where Y is the kernel dimension (mm), A and B are constants and M is the moisture content of the grain (% db) The linear model parameters for the grain dimensions at different moisture contents are presented in Table 2.

Table 1: Physical properties of sorghum and millet at different moisture contents

Grain variety	*m.c. (%d.b)*	*L (mm)*	*W (mm)*	*T (mm)*	*G.M.D. (mm)*	*Sphericity (%)*	*S/area (mm^2)*	*K/density (kg/m^3)*	*B/density (kg/m3)*	*Porosity (%)*
Dionje	12	5.05	3.80	2.40	3.57	71.00	40.30	1240	684.7	44.8
	15	5.07	3.84	2.41	3.62	71.37	41.14	1260	678.5	47.8
	20	5.13	3.90	2.44	3.67	71.70	42.36	1304	669.2	49.1
	25	5.14	3.94	2.49	3.71	72.11	43.00	1370	661.4	52,9
Jumbo	12	5.21	4.16	2.51	3.83	72.80	45.97	1070	619.7	41,9
	15	5.26	4.24	2.58	3.86	73.39	46.92	1140	611.5	42.3
	20	5.32	4.30	2.65	3.93	73.80	48.53	1160	601.2	44.2
	25	5.36	4.34	2.66	3.95	73.85	49.19	1220	592.8	51.4
Millet (IM)	12	3.88	2.84	2.44	2.99	77.20	28.23	1110	688,1	34.5
	15	3.90	2.86	2.47	3.02	77.59	28.75	1150	674.5	35.9
	20	3.92	2.90	2.54	3.07	78.18	29.61	1170	755.3	44.0
	25	3.96	2.92	2.57	3.09	78.39	30.18	1230	636.0	48.3

Each data point is an average of 10 replications

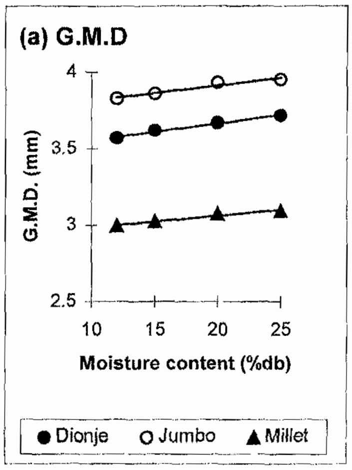
GMD = Geometrical mean diameter, L= Length, W = Width, T = Thickness

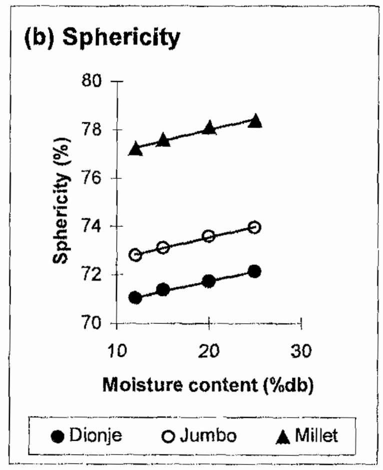
3.2 Geometrical Mean Diameter, Sphericity and Surface Area

The average values for geometric mean diameter, sphericity and surface area of individual grain kernels at different moisture contents are summarised in Table 1. All these parameters increased linearly as the moisture content increased from 12% to 25% (db). The relationship between these parameters and moisture content is shown in Figure 1 and can be described by the following general equation:

$Y=b+aM$ 6

where Y is the grain property, M the moisture content (% d.b), a and b are constants. The linear model parameters for geometric mean diameter, sphericity and surface area of individual grain kernels at different moisture contents and R^2 values are presented in Table 2.





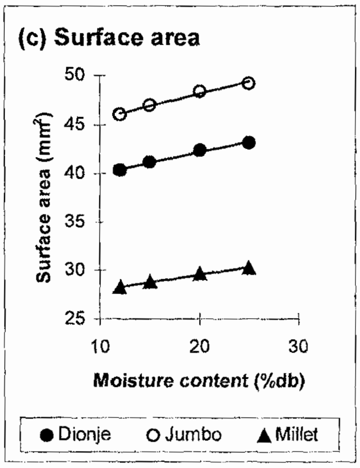


Figure 1. The effect of moisture content on Geometric mean diameter, Sphericity and Surface area of Sorghum and Millet

3.3 Kernel Density

The kernel density increased from 1,240 kg/m^3 to 1,370 kg/m^3 for Dionje, 1,070 kg/m^3 to 1220 kg/m^3 for Jumbo and 1,110 kg/m^3 to 1230 kg/m^3 for IM. The variation of kernel density with moisture content is shown in Figure 2. Kernel density showed a linear increase with increase in moisture content for both sorghum and millet. This agrees well with previous observations in other grains such as corn, wheat, pigeon pea and sunflower (Gupta & Das, 1997). The linear model parameters for equations representing relationship between moisture content and kernel density for different varieties are given in Table 2.

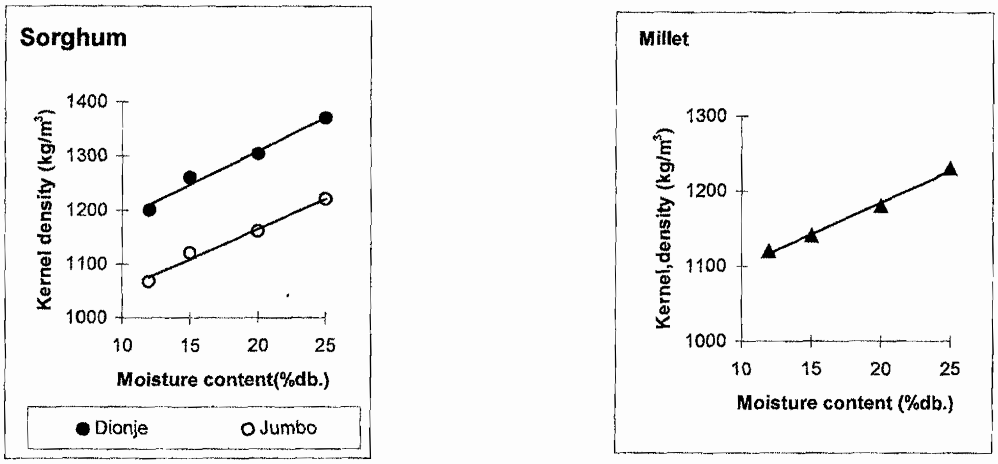


Figure 2: The effect of moisture content on kernel density of sorghum and millet

3.4 Bulk Density (Bd)

The values of bulk density for different moisture levels varied from 684.7 kg/m^3 to 661.4 kg/m^3 for Dionje, 619.7 to 601.2 kg/m^3 for Jumbo and from 688.1 kg/m^3 to 636.0 kg/m^3 for IM millet. For all grain varieties, bulk density decreased with increase in moisture content. The negative linear relationship between bulk density and moisture content was also observed by Carman (1996) in Lentil seeds, Gupta & Das (1997) in sunflower seeds. The relationship between moisture content and grain bulk density is shown graphically in Figure 3 and the linear model parameters for the regression lines are given in Table 2. Of the three-grain varieties studied, the decrease in bulk density with increase in moisture content was higher in the case of millet than in sorghum, as evidenced by the much steeper slope of the millet curve.

3.5 Porosity (ε)

The porosity of sorghum and millet varieties investigated was found to increase linearly with increase in moisture content from 44.8% to 52.9% for Dionje, 41.9% to 51.4% for Jumbo and 34.5% to 48.3% for IM millet. Similar trend was obtained by Carman (1996) for lentils and Shepherd Bhardway (1996) for pigeon pea. The effect of moisture content on porosity within the moisture range studied here is shown in Figure 4 and the linear model parameters are given in Table 2.

Table 2: Model parameters for the changes in different grain dimensions and properties with moisture content

Grain variety	*Grain dimension and property*	*Model parameter*		R^2
		a	b	
(a) Sorghum	Length (L)	4.96	0.007	0.99
(i) Dionje	Width (W)	3.68	0.12	0.99
	Thickness (T)	2.30	0.06	0.98
	GMD	3.40	0.01	0.99
	Surface area	37.80	0.2	0.98
	Sphericity	70.10	0.08	0.99
	Kernel density	1059.8	12.4	0.98
	Bulk density	706.13	-1.8	0.99
	Porosity	35.70	0.65	0.98
(ii) Jumbo	Length (L)	5.07	0.11	0.98
	Width (W)	4.02	0.13	0.99
	Thickness (T)	3.80	0.11	0.98
	GMD	3.70	0.01	0.95
	Surface area	43.10	0.20	0.98
	Sphericity	71.8	0.09	0.99
	Kernel density	940.0	11.20	0.98
	Bulk density	642.67	-2.05	0.99
	Porosity	34.20	0.69	0.98
(b) Millet (IM)	Length (L)	3.80	0.06	0.99
	Width (W)	2.80-	0.06	0.97
	Thickness (T)	2.30	0.01	0.98
	GMD	2.90	0.01	0.96
	Surface area	26.50	0.15	0.91
	Sphericity	76.20	0.09	0.97
	Kernel density	1015.10	8.47	0.99
	Bulk density	734.52	-3.90	0.99
	Porosity	29.65	0.74	0.99

GMD = Geometrical mean diameter

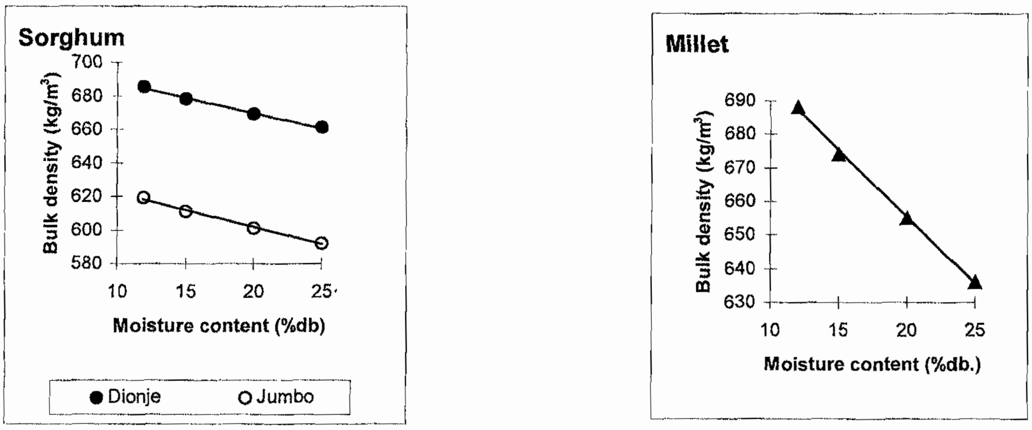


Figure 3: The effect of moisture content on bulk density of sorghum and millet

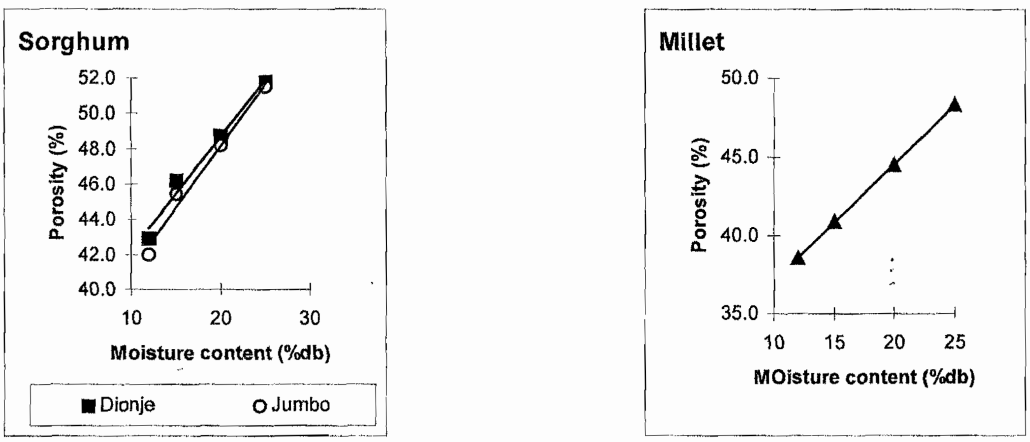


Figure 4: The effect of moisture content on porosity of sorghum and millet

3.6 The response of Physical Properties of the Two Sorghum Varieties to Changes in Moisture Content

The response of the physical properties of the two sorghum varieties to changes in moisture content is shown in Table 3.

Table 3: Percentage change on physical properties of two sorghum varieties within 12 - 25 % moisture range

Sorghum variety	*m.c. (%)*	*L (%)*	*W (%)*	*T (%)*	*G.M.D. (%)*	*Sphericity (%)*	*S/area (%)*	*K/density (%)*	*B/density (%)*	*Porosity (%)*
Dionje	12 - 25	1.78	3.68	3.75	3.1	1.44	6.69	10.48	3.4	18.08
Jumbo	12 - 25	2.88	4..33	5.97	3.13	1.56	7.00	14.02	4.34	22.67

Each data point is an average of 10 replications

GMD = Geometrical mean diameter, L= Length, W = Width, T = Thickness

As can be observed in Table 3, there was a much higher change (percentage change) in the physical properties of Jumbo sorghum, which is a soft variety compared to the changes in Dionje, which is a hard variety. This shows that the soft varieties are more responsive to the changes in moisture content than hard varieties.

4.0 CONCLUSIONS

The results of this investigation revealed that within moisture range 12 - 25% mc.db, all the physical properties of sorghum and millet studied in this work varied linearly with moisture content. This was evidenced by the high linear regression coefficient obtained with all the properties studied.

Linear dimensions (length, width and thickness), geometric mean diameter, sphericity, surface area, volume, kernel density and porosity of sorghum and millet were linearly related to moisture content and increased with increase in moisture content of the grain. On the other hand, bulk density decreased linearly with increase in moisture content of the grain within the same moisture range.

In both sorghum and millet, individual grain expanded more along their thickness in comparison with the other two principal dimensions. Also, soft variety sorghum was more responsive to changes in moisture content compared to the hard variety sorghum.

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