



**DETERMINATION OF SOME SELECTED PHYSICAL PROPERTIES OF THREE
VARIETIES OF GARLIC (*Allium sativum* Linn) AT DIFFERENT MOISTURE
CONTENTS**

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ABSTRACT

Some physical properties of three common varieties (in Kano State, Nigeria) of garlic cloves *Ex-kofa*, *Dangin kura* and *Mai-makulli* variety were determined and compared. These properties were obtained at five moisture content levels of 56.72, 42.85, 34.93, 26.48 and 13.68 % d. b. The ranges of the dimensions measured at the stated moisture content levels for *Ex-kofa*, variety were 25.35-20.56 mm, 13.33-8.16 mm, 16.36 -10.51 mm, for polar diameter, equatorial diameter and thickness respectively. Similarly, the values obtained for *Dangin Kura* were 22.25-18.41 mm, 9.78-5.85 mm and 11.91-7.21 mm. The values for *Mai mukulli*, respectively, were 24.46-20.41 mm, 14.25-10.05 mm and 11.16 - 6.64 mm. The Geometric mean diameter, Arithmetic mean diameter and Sphericity ranges were 14.83-10.64 mm, 16.15-12.09 mm and 0.61-0.53 for *Ex-kofa*, while 14.23-10.49 mm, 15.57-11.89 mm and 0.64-0.53 are for *Dangin kura* variety. Similarly, for *Mai-makulli* variety respectively, the values are 15.10-10.47 mm, 13.93-9.68 mm and 0.63-0.52. The Surface area, Cross-sectional Area and Shape Index range was 232.25-129.83 mm², 618.86-348.19 mm² and 0.72-0.65 for *Ex-kofa*. That for *Dangin kura* were 244.87-125.06 mm², 701.36-335.90 mm² and 0.68-0.65. While 233.35-122.80 mm², 617.92-313.33 mm² and 0.71-0.62 were values for *Mai-makulli* variety respectively. The range for mean values of bulk density, true density and porosity for the garlic cloves were measured as 768.30-350.40 kg/m³, 1185-699.30 kg/m³ and 34.83-49.93 for *Ex-kofa* variety. While 762.96-352.46 kg/m³, 1197.73-757.73 kg/m³ and 35.80-49.42 were for *Dangin kura* variety. Similarly, the ranges of values for *Mai-makulli* variety were 759.70-353.20 kg/m³, 1208.06-692.73 kg/m³ and 35.41-49.01 respectively. Results of statistical analysis ANOVA showed that the moisture content had significant effect on all the properties. The variety has significant effect on dimensions and arithmetic mean diameter. From the findings, it reveals that mean values of these properties were found to be higher at higher moisture levels for all the varieties. For porosity, however, the higher values were obtained at lower moisture levels.

Keywords: Area, Bulk, Cross, Density and Surface

INTRODUCTION

Garlic was described as one of the most important spice in the Nigeria due to its medicinal value, good export potential and source of employment in the processing industries (Sa'adatu and Mshelia, 2013). Manjunatham *et al.* (2014) studied physical properties of garlic relevant for peeler development. Bakhtiari (2015) determined physical and aerodynamic properties of garlic to design and development of a pneumatic garlic clove metering system. These physical properties are moisture content, dimensions, bulk density, porosity, shape index, surface area, cross sectional area. Hyung (2024) on his part carried out an investigation on garlic physical properties prior to collection for the development a garlic collector. Model is method applies by scientist to represent properties of garlic through development of regression equations. These equations can be used to evaluate properties at different crops at different moisture contents level.

Lack of basic data on physical properties of the varieties of garlic commonly grown in Kano, Nigeria (*Ex-kofa*, *Dagin kura* and *Mai makulli varieties*) was identified as challenge to most of the garlic processing industries as it created a vacuum in design data for new equipment for handling, processing and storage of garlic. Operations such as peeling of garlic are very critical and hence are in dire need of such data. The main objective of this study is to determine some selected physical properties of (*Ex-kofa*, *Daginkura* and *Mai makulli varieties*) of garlic (*Allium sativum L.*). The desire to produce specialized equipment has emphasized the necessity of the knowledge of the physical properties of garlic. Therefore, this study would help fill the gap by providing necessary data required for the design of cleaning, sorting, grading and peeling equipment.

MATERIALS AND METHOD

The Study Area

The materials are three garlic varieties brought from the garlic irrigated farm at Kofa, Bebeji L.G.A, Kano State, Nigeria at harvesting period. Different equipment at Bayero University Kano (processing and storage) laboratories were used for the conduct of the experiment.

Method of Data Analysis

The moisture content of the bulbs was determined by following the ASAE S352.2 standard methods (ASAE, 1999). Each sample weighing about 100 g, was placed in a convection oven set at 130°C for 50 minutes. (Visvanathan *et al.*, 2010).

$$\% \text{ Mc} = \frac{wtW}{wtD} \times 100 \quad \dots (1)$$

The polar diameter (Dp), equatorial diameter (De), and thickness (T), of each 15 bulbs was measured with a digital Vanier caliper reading to 0.01 mm.

$$GMD = (Dp \times De \times T)^{\frac{1}{3}} \quad \dots (2)$$

Where; GMD is geometric mean diameter, all dimensions in mm.

$$AMD = \frac{(Dp + De + T)}{3}$$

Where; AMD is Arithmetic mean diameter in mm

The surface Area (SA) was determined as:

$$SA = \frac{\pi}{4} Dp \cdot De \quad \dots (3)$$

Where SA is Surface area in mm²

The cross-sectional of areas (CSA),

$$CSA = \frac{\pi (Dp + De + T)^2}{4 \cdot 3} \quad \dots (4)$$

Where; CSA is Cross - sectional area mm²

Shape index is used to evaluate the shape of garlic bulbs and it is calculated according to the following equation by Abdallah, (1993):

$$SI = \frac{De}{\sqrt{Dp * T}} \quad \dots (5)$$

The garlic bulbs are considered an oval if the shape index > 1.5, on the other hand, it is considered spherical if the shape index < 1.5.

The sphericity (S) of the cloves was calculated using the following equation (Mohsenin, 1986):

$$S = \frac{(Dp \times De \times T)^{1/3}}{L} \quad \dots (6)$$

The bulk density of garlic varieties at different moisture content was determined by filling a container of known self-weight and volume to the brim with garlic cloves and weighing to determine the net weight of the cloves. Uniform density is achieved by tapping the container 10 times in the same manner in all measurements. The bulk density is calculated as (Olayanju, 2014).

$$BD \left(\frac{\text{kg}}{\text{m}^3} \right) = \frac{Ws (\text{kg})}{Vo (\text{m}^3)} \quad \dots (7)$$

Where; BD= Bulk Density (kg/m^3), Ws = Weight of the sample (kg), Vo = Volume occupied (m^3)

The true or solid density defined as the ratio of a given mass of sample to its volume was determined by the water displacement method accordingly, a known weight (50 g) of sample is poured into 100 cm^3 fractionally graduated cylinder containing 50 cm^3 distilled water. The volume of water displaced by the garlic cloves is observed (Olayanju, 2014). The true density is calculated as

$$TD = \frac{WS (\text{kg})}{VwD (\text{m}^3)} \quad \dots (8)$$

Where; TD is True Density (kg/m^3), Ws is Weight of sample (kg), VwD is Volume of Distilled water displaced

. The porosity of garlic bulbs was determined using the relationship presented by Mohsenin (1986) as follows;

$$Po = \left(1 - \frac{BD}{TD} \right) \times 100 \quad \dots (9)$$

Where; Po= porosity%

The experiment was conducted for three varieties V_1 , V_2 and V_3 for Each sample was Replicated three times (RI, RII and RIII) at five moisture content levels (M_1 , M_2 , M_3 , M_4 and M_5). Hence, total number of experiment was 45 runs.

Descriptive Statistics were used to analyze the findings. The analysis of variance (ANOVA) and comparison of means was performed using CRD ANOVA and LSD.

RESULTS AND DISCUSSION

Polar diameter D_p , equatorial diameter D_e , thickness T, Geometric Mean Diameter GMD, Arithmetic Mean Diameter AMD and Sphericity of three varieties of Garlic at five moisture levels

The result of the mean (mean \pm SD) values of the polar diameter D_p , equatorial diameter D_e , thickness T, geometric mean diameter GMD, arithmetic and AMD and Sphericity S for Garlic Cloves *Ex-kofa*, *Dangin kura* and *Mai makulli* varieties at five moisture levels were presented in Table 1. The ranges of the dimensions measured at the stated moisture content levels for *Ex-kofa* variety are 25.35-20.56 mm, 13.33-8.16 mm, 16.36-10.51 mm, for polar diameter, equatorial diameter and thickness respectively. Similarly, the values obtained for *Dangin Kura* are 22.25-18.41 mm, 9.78-5.85 mm and 11.91-7.21 mm. The values for *Mai mukulli*, respectively, are 24.46-20.41 mm, 14.25-10.05 mm and 11.16 - 6.64 mm. These values are comparable with values obtained by El-Gayar and Bahanas (2005).

The ranges of mean value of geometric mean diameter, arithmetic mean diameter and sphericity were 14.83-10.64 mm, 16.15-12.09 mm and 0.61-0.53 for *Ex-kofa* while they were 14.23-10.49 mm, 15.57-11.89 mm and 0.64-0.53 for the *Dangin kura* variety and 15.10-10.47 mm, 13.93-9.68 mm and 0.63-0.52 for *Mai-makulli* variety respectively. These values are compactible to those values obtained by Bahanasswy (2007) and Manjunatha (2014).

Table 1: Mean values of Polar diameter, equatorial diameter, thickness, geometric mean diameter GMD, arithmetic mean diameter AMD and sphericity of three varieties of garlic at five moisture level

Mc% (db)	Dp	De	T (mm)	GMD (mm)	AMD (mm)	S
<i>Ex-kofa</i>	(mm)	(mm)				
56.7	25.35±0.78	13.33±0.69	16.36±2.26	14.83±1.59	16.15±1.57	0.61±0.02
42.8	24.56±0.33	11.52±1.09	14.52±2.6	11.82±1.3	15.19±1.69	0.59±0.03
34.2	23.68±0.26	10.24±0.29	12.84±0.95	12.72±1.63	14.12±1.66	0.57±0.02
26.3	21.91±0.70	9.36±0.41	11.27±0.17	11.62±1.68	13.05±1.57	0.55±0.04
13.6	20.56±0.43	8.16±0.24	10.51±0.09	10.64±1.53	12.09±1.49	0.53±0.03
<i>Dangin kura</i>						
56.7	22.25±0.18	9.78±0.55	11.91±0.41	15.90±2.45	17.13±2.43	0.64±0.05
42.8	21.71±0.28	8.34±0.14	10.24±0.18	14.23±2.47	15.57±2.33	0.61±0.06
34.2	20.39±0.44	7.43±0.53	9.02±0.62	12.54±2.13	14.03±1.97	0.55±0.06
26.3	19.59±0.18	6.52±0.45	8.18±0.41	11.40±1.27	12.81±1.17	0.54±0.04
13.6	18.41±0.45	5.85±0.46	7.21±0.75	10.49±1.26	11.89±1.23	0.53±0.03
<i>Mai-makulli</i>						
56.7	24.46±0.47	14.25±0.82	11.16±0.88	15.10±1.77	13.93±3.30	0.63±0.04
42.8	23.26±0.25	13.05±0.92	9.79±0.39	13.47±1.30	12.42±3.60	0.58±0.03
34.2	22.36±0.14	11.88±0.61	8.61±0.32	12.60±1.35	11.51±3.48	0.57±0.02
26.3	20.98±0.68	11.16±0.82	7.65±0.22	11.61±1.57	10.54±3.21	0.55±0.04
13.6	20.41±0.27	10.05±0.20	6.64±0.18	10.47±1.47	9.68±3.19	0.52±0.05

Where, Dp = Polar Diameter, De = Equatorial Diameter, T = thickness.

Surface Area, Cross-sectional Area, Shape Index, Bulk Density, True Density and Porosity of three Varieties of Garlic Cloves at Five Moisture Content Levels

Table 2 shows the mean (mean ± SD) values ranges of surface area, cross-sectional area, shape index, bulk density, true density and porosity of *Ex-kofa*, *Dangin kura* and *Mai-makulli* varieties at five moisture content level. The ranges of surface area and cross-sectional area and shape Index for *Ex-kofa* variety are 232.25-129.83 mm², 618.86-348.19 mm² and 0.72-0.65 respectively. While 244.87-125.06 mm², 701.36-335.90 mm² and 0.68- 0.65 are for *Dangin kura* variety. The values for *Mai-makulli* variety respectively are 233.35-122.80 mm², 617.92-313.33 mm² and 0.71- 0.62. Those values agree with the values obtained by Rajabipoor (2014) and according to him those kinds of areas are very useful in determination of heat transfer during heating and cooling process. Similarly, the shape Index indicated that the garlic cloves of all the varieties are a spherical in shape according to Abdallah (1993). Shape index is very important in designing sorting and grading machines, also it's used in peeling machine.

The ranges of bulk density, true density and porosity for *Ex-kofa* variety are 768.30-350.40 kg/m³, 1185.30-699.30 kg/m³ and 34.83-49.93 % respectively. Similarly, the values obtained for *Dangin kura* are 762.96-352.46 kg/m³, 1197.73-695.9 kg/m³, 35.80-49.42 %. The values for *Mai-makulli* variety respectively are 759.70-353.20 kg/m³, 1208.06-692.73 kg/m³ and 35.41-49.01 % these values are comparable with the findings of Rajabipoor (2014) and Manjunatha (2015). These properties are very important in designing the storage rooms,

hoppers of planting machines and capacity of the transportation tools according to Masoumi (2014).

Table 2: Mean Values for Surface Area, Cross-sectional Area, Shape Index Bulk Density, True Density and Porosity of three Varieties of Garlic cloves at various moisture levels

Mc% (db)	S.A (mm) ²	C.S.A (mm) ²	SI	BD (kg/m ³)	TD(kg/m ³)	PO%
<i>Ex-kofa</i>						
56.7	232.25±54.42	618.86±119.48	0.722±0.15	768.30±35.26	1185.30±87.71	35.80±7.13
42.8	206.28±58.98	548.45±11.83	0.706±0.18	624.43±24.92	1007.86±41.54	38.70±4.01
34.2	178.28±50.85	474.18±109.98	0.69±0.195	542.26±25.79	877.93±30.80	39.11±2.97
26.3	149.80±40.27	405.63±95.43	0.65±0.20	420.70±27.50	754.06±17.27	44.71±3.06
13.6	129.83±57.90	348.19±83.18	0.65±0.18	350.40±31.20	699.30±41.70	49.42±2.31
<i>Dangin</i>						
<i>Kura</i>						
56.7	244.87±54.18	701.36±200.73	0.68±0.09	762.96±25.06	1197.73±14.62	35.80±7.81
42.8	201.53±47.62	580.32±175.13	0.644±0.12	629.36±26.86	1028.60±43.19	38.70±4.33
34.2	166.70±33.84	470.10±129.62	0.626±0.14	537.63±25.22	833.36±36.83	39.11±2.56
26.3	143.71±33.84	389.25±69.33	0.647±0.12	418.83±20.54	757.73±11.50	44.71±2.94
13.6	125.06±34.80	335.90±67	0.65±0.17	352.46±32.68	695.90±38.71	49.01±1.87
<i>Mai-makulli</i>						
56.7	233.35±63.07	617.92±288.14	0.715±0.16	759.70±2748	1208.06±38.71	35.41±8.29
42.8	195.52±49.10	526.59±246.03	0.684±0.18	641.46±2584	944.70±44.51	36.41±4.10
34.2	173.34±44.75	437.20±187.76	0.673±0.15	533.43±3541	882.40±9.01	39.56±3.51
26.3	151.88±45.99	360.32±139.33	0.694±0.24	416.06±14.73	750.06±6.52	44.52±2.15
13.6	122.80±41.24	313.33±117.31	0.6224±0.2	353.20±20.72	692.73±38.88	49.01±0.17

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Where: SA= Surface Area, CSA= Cross-sectional Area and SI= Shape Index BD= Bulk Density, TD = True Density and Porosity

Physical Properties of Three Varieties of Garlic at Five Moisture Contents

Analysis of variance for the principal dimensions, geometric mean diameter arithmetic mean diameter and sphericity of the varieties at five moisture contents is shown in Table 3. It shows that there existed a significant difference in the mean values of dimensions between the three varieties at 1% level, while the replicates and interaction between moisture content and variety were not significant.

For the surface area and cross-sectional area and shape index at five moisture content levels, Table 3 shows that there existed significant difference in the mean values of replicates and moisture content while varieties and the interaction between varieties and moisture content were not significant for surface area. For Cross-sectional area, the both the replicates and moisture content are significantly different at 1% while variety was significant at 5% and the interaction between moisture content and varieties are not significant. For shape index, difference between mean values for replicates, moisture content and varieties are significant while the interaction and moisture content are not significant. Analysis of variance for Bulk density, True density and Porosity of the varieties at five moisture content levels from Table 3 shows that there existed significant difference in the mean values of moisture content and varieties of bulk density, True density and porosity.

Table 3: Analysis of physical properties of three varieties of garlic cloves

F-Value	SOV	R	M	V	VM	Error	Total
DF	2	4	2	8	28	44	
Dp	0.90NS	136.38**	150.98**	1.53 NS			
De	0.45 NS	68.10**	199.69**	0.50NS			
T	2.88 NS	49.12**	114.96**	0.54NS			
GMD	175.45**	133.09**	1.16NS	1.26NS			
AMD	2.70NS	5.50**	6.42**	0.50NS			
S	60.60**	37.74**	0.32NS	0.96NS			
SA	176.53**	89.80**	0.32 NS	0.48NS			
CSA	62.65**	30.07**	1.58 NS	0.28 NS			
SI	2336.70**	2.75 NS	2.65 NS	0.77 NS			
BD	145.41**	3519.36**	0.05NS	1.31NS			
TD	4.62NS	138.53**	0.10NS	0.10NS			
PO	23.86**	37.52**	0.18NS	0.39NS			

NS: Not significant, ** significant at 1% (highly significant)

Comparison of Moisture Content on Some Physical Properties

Comparison of significant mean values using t-test (LSD) in Table 4 shows that for all the dimensions, higher values were obtained at the higher moisture content, this agrees with findings of Masoumi *et al.* (2014). Comparison of significant for moisture content using t-test (LSD) in Table 4 shows that for all the geometric mean diameter, arithmetic mean diameter and sphericity, higher values were obtained at the higher moisture content, this agrees with findings of Hasciseferogullari (2012) and Manjunatha (2015). Comparison of significant for moisture content using t-test (LSD) in Table 3.4 shows that for all the Surface area, Cross-sectional area and Shape Index, higher values were obtained at the higher moisture content, this agrees with findings of Banasswy (2007) and Bakhtairar (2015).

Table 4: Comparison of moisture content on some physical properties

Physical properties	Five moisture content level in percentage					LSD
Dp	56.72	42.85	34.28	26.32	13.62	0.425
De	24.02a	23.18b	22.1456c	20.8300d	19.7967e	0.6043
T	12.4567a	10.9722b	9.8544c	9.0156d	8.0244e	0.82332
GMD	13.1433a	11.5189b	10.1556c	9.03356d	8.1267e	0.46
AMD	15.28	13.84	12.62	11.54	10.53	2.2116
S	15.741a	14.397a	13.221b	12.138b	11.224c	0.0189
SA	0.634416a	0.595527b	0.568517c	0.552814c	0.5300742d	13.329
CSA	236.83a	201.11b	172.77c	148.46d	125.90e	66.697
SI	646.05a	551.79b	460.50c	385.07d	332.48d	0.0416
BD	0.70a	0.67b	0.66b	0.66b	0.64b	8.0436
TD	763.65a	631.75b	537.77c	418.53d	352.02e	49.75
PO	1197.03a	1010.39b	881.23c	753.96d	695.98e	49.45a
	35.72d	37.35c	38.96	44.48b	49.45a	

Means with same letter are not significantly different

Comparison for Mean Values of Physical Properties of Garlic on Three Varieties

LSD comparison for variety in Table 5 shows that *Ex-kofa* variety has significantly higher values of polar diameter, followed by *Mai-makulli* variety then the lowest values are for *Danginkura* variety. *Mai mukulli* has the highest mean values of width followed by *Ex-kofa*. *Danginkura* has the lowest mean values. The mean values for thickness for *Danginkura* and *Mai-makulli* are statistically at par but significantly lower than those for *Ex-kofa*. LSD comparison for varieties in Table 5 shows that for all the varieties the geometric mean diameter was statistically similar. While the arithmetic mean diameter for *Ex-kofa* and

Danginkura are statistically par but significantly higher than *Mai-makulli* variety. Similarly, the sphericity for all the varieties was statistically similar.

LSD comparison for varieties in table 5 shows that for all the varieties the surface area and cross-sectional area was statistically similar. While the shape index for *Ex-kofa* and *Danginkura* are statistically par but significantly higher than *Mai-makulli* variety.

Table 5: Comparison for Mean Values of physical properties of garlic on three varieties

Physical properties	Mean value of three varieties of garlic			LSD
	<i>Ex-kofa</i>	<i>Danginkura</i>	<i>Mai makulli</i>	
DP	23.21a	20.47c	22.29b	0.32
De	10.52b	7.58c	12.08a	0.46
T	13.10a	0.31b	8.77b	0.63
GMD	12.72a	12.91a	12.65a	0.36
AMD	14.12a	14.29a	11.61b	1.71
S	0.57a	0.57a	0.57a	0.0147
SA	179.28a	176.37a	175.38a	10.325
CSA	379.07a	495.39a	451.08a	51.663
SI	0.68519a	0.65092a	0.67829b	0.0323
BD	541.22a	540.25a	540.77a	6.23
TD	904.89a	912.67a	905.59a	38.53
PO	41.03a	41.55a	41.01a	2.07

Means with same letter are not significantly different

CONCLUSION AND RECOMMENDATIONS

The study concluded that, some physical properties of *Ex-kofa*, *Dangin kura* and *Mai-makulli* varieties garlic cloves were determined. The ANOVA showed that the moisture content had significant effect on all the properties. The variety has significant effect on dimensions and arithmetic mean diameter. From the findings, it reveals that mean values of these properties were found to be higher at higher moisture levels for all the varieties. For porosity, however, the higher values were obtained at lower moisture levels. *Ex kofa* variety has the highest mean value of polar diameter at a particular moisture level. *Mai mukulli* has the higher mean values of equatorial diameter. The men values for geometric mean diameter, sphericity, bulk density, true density and porosity at particular moisture content are statistically at par. At a particular moisture level *Mai mukulli* variety had lower values for areas and densities.

It recommended that further studies should be conducted on other physical properties (such as texture and color), mechanical, rheological and optical properties of these verities of garlic for optimum development of garlic processing machine.

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