Design Related Parameters of Nigerian Ginger (*Zingiber Officianale*) Rhizomes

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Abstract
The value derived from ginger is a function of the level to which it is processed. Value addition in ginger is achieved basically by using a processing device. The performance of any agriculture processing device is affected by the shape and size of the agricultural material being handled.
The operational efficiency of a processing machine is said to be a function of the orientation of the feed being loaded. Knowledge of the physical properties of a material will go a long way to enhance efficient design of machines and systems for the processing of such material.
This work is about determining some of the parameters measured for yellow ginger variety (UGI) include: angle of repose on different surfaces of common materials of fabrication such as wood, mild steel, galvanized iron and stainless; other parameters were size, weight, tensile strength and compressive strength using simple analytical methods for materials of irregular surfaces. The angle of repose which determines the flow –ability of the ginger in a hopper with respect to stainless steel as chosen material of construction was 35.0^0. The tangent of this angle is the coefficient of friction between ginger and the stainless steel (Type 314). The compressive stress was $1.75N/mm^2$ while the tensile stress was $0.37N/mm^2$.The mechanism of the crushing can be selected by determining the minimum force required to crush the ginger rhizome hence, the tensile stress and the compressive stress analysis.

Keywords: Ginger, Angle of Repose, Compressive Strength, Tensile Strength.
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1 Introduction

Ginger is a rhizome (an underground stem), which consist of numerous short-finger branches. These are borne horizontally near the surface of the soil. Botanically, it is called *Zingiber officinale*, *Roscoe* [1, 2, and 3]. Two commercial varieties of ginger are commonly grown in Nigeria; the yellow variety has a yellow rhizome flesh. The plant tends to be stout with short internodes. The rhizome flesh is dull gray in colour. The description “Black” is therefore a misnomer.

This agricultural crop has a lot of economic importance. Among which is its use for food in the production of drinks; beverages; spices; tea; peppermint; beer; wines; sausages; biscuits; bread; etc. It's used medicinally because of its active biological components which have the ability of reducing cholesterol in the body; warm the body to liberate it of stagnant fluids; aids digestion; quickens the body of general weakness; ensure easy menstrual flow; educes high blood pressure, amongst others [4, and 5].

Although, cultivation of ginger in Nigeria started seriously in 1927 [6, 7 and 8], yet the presence of Nigerian ginger in the international market is only being noticed for its oleoresin and pungency the recent years [9]. Due to the awareness of ginger as a foreign exchange earner, many individuals and companies have begun to cultivate and process ginger in large quantities. In addition to the export trade, there is a considerable domestic market for ginger and its products, for use in confectionery, perfumery, beverages and pharmaceuticals.

Although ginger is an old crop in Nigeria, exploration into its processing machinery is poorly developed locally. Recent developments in ginger processing by adding value show that it can be processed into ginger non-alcoholic drinks (juice) from fresh rhizome as a means of preventing or reducing post – harvest losses [10]. The present local production of this ginger soft drink is faced with the problem of unit operational equipment that will pulverize the ginger into pulp for the liberation of its extractives. The need for the development of a pulverizer for this industry becomes critical as a result of the following.

i. The use of chemical extraction is no longer acceptable because of its health – associated problems.
ii. Water is a friendly solvent for extraction of the rhizome herbs (extractives) after pulverization.
iii. The yield of this product (ginger juice) is a function of this limiting unit operation (pulverization). In a plant, each separate unit influences all others in obvious and subtle ways.

Pulverization problem arises because of the fibrous nature of ginger. Ginger matures and becomes stronger in flavor and more fibrous as the time goes by [4, 11 and 12]. It is paramount to note that the stronger the flavor in ginger, the better the quality and quantity of the pungent components therein for commercial purposes.

However, until the fibres are broken and the ginger rhizome pulverized into pulp, higher extraction yields of the pungent component will remain impossible.

Traditional methods employed in ginger crushing are quite primitive, favours low capacity output and susceptible to increase in microbial load on the crushed ginger, thereby, reducing the shelf life of the soft drink. However, modern methods that offer higher capacity output require skilled manpower to operate and maintain, in addition the supporting technology is wholly imported.

There is, therefore, the need to develop machinery that will provide intermediate technology to bridge the gap between local and complex methods of crushing ginger especially for communities where ginger is produced and processed [13].

The value derived from ginger is a function of the level to which it is processed. Value addition in ginger is achieved basically by using a processing device. The performance of any agriculture processing device is affected by the shape and size of the agricultural material being handled.

The operational efficiency of a processing machine is said to be a function of the orientation of the feed being loaded. Knowledge of the physical properties of a material will go a long way to enhance efficient design of machines and systems for the processing of such material.

Nwandiko and Njoku [14] determined some design related physical properties of ginger as follows:

i. The ginger is approximately a cone with an elliptical cross – section.
ii. Empirical equations relating mass, volume and surface area to the linear dimension were:

$$Volume = 0.503abl_o + 0.55, cm^3 \quad (1)$$

$$Mass = 0.50abl_o + 0.540, g \quad (2)$$

$$Surface\ Area = 0.91(a+b)(l_1+l_2) - 3.12, cm^2 \quad (3)$$

$$Average\ Density\ of\ Ginger\ Finger = 1.02 \pm 0.13, kg/l \quad (4)$$

Where
a = major diameter, cm
b = minor diameter, cm
l_o = vertical length of the finger, cm
l_1, l_2 = slangth lengths of the finger, cm

While, Simonyan *et al* (2003) determined the following ginger parameters:

Minimum cutting energy = 3.10kg-cm /cm^2; Cutting velocity = 2.68m/ s; Shear angle of cutting knife = 63^o; and knife bevel angle for slicing = 37.5^o. The successful development and production of any machinery is a function of adequate available design parameters. Thus, this paper is an attempt to delve further into measurement of some design related parameters of the common varieties cultivated in Nigeria as related to dimensions using the method specified in Perry *et al* [15], moisture content, tensile strength, compressive strength and mass.

2 MATERIALS AND METHODS

The ginger used for the analysis was purchased in the local markets in Kafanchan and Kachia of Southern Kaduna, the most commercial producing localities of ginger in Nigeria. The methods used involved the determination of such properties as moisture content, angle of repose, size and mechanical strength of the fresh ginger rhizome.

2.1 1 Moisture Content Determination (Wet Basis)

15g of representative portion of sample were placed in a dish and thereafter placed in an oven for 19hrs at 130^{o}C [16]. At the end of the heating period, the dish and material was weighed at room temperature. The weight loss in the original sample in percentage, % due to heating was calculated as:

$$W_c = \frac{W_w - W_d}{W_w}\ x\ 100\% \quad (5)$$

Where
W_w = Wet weight of ginger rhizome, g
W_d = Dried weight of ginger rhizome, g
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2.2 Determination of Frictional Properties (Angle of Repose)

The angle of repose is an angle with the horizontal at which the material stand when piled. The size, shape, moisture content and orientation of the particles influence the angle of repose of the packed material. The angle of repose was measured with a calibrated tilting table; Glass; wood; galvanized iron; mild steel and stainless steel were used to obtain the sliding angle of the fresh ginger rhizome. The tangent of this angle is recognized as the coefficient of friction of the material [17].

2.3 Size Determination

This was done by measuring the statistical diameters as shown in Figure1 [15].

2.3.1 Ferret's diameter – is the perpendicular, projection, onto a fixed direction of the tangents to the extremities of the particle profile.

2.3.2 Martin's diameter – is the line parallel to the fixed direction, that divides the particle unto two (2) equal areas since the magnitude of the statistical diameters varies with orientation for a particular particle, 50 samples were measured using tracing paper and meter rule and then averaged (Appendix1).

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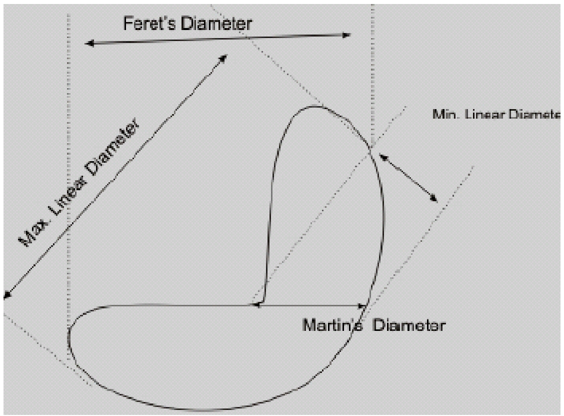

Fig. 1: Various Diameter of an Irregular

2.4 Mechanical Properties Determination

2.4.1. Compressive strength

Using a compressive Seidner meter (Model, UPM 300/10) the force at rupture was noted for 10 samples as recommended by Mohseni [18], and the compressive strength for the ginger rhizome at 75.3% moisture content was computed from the maximum load during the compressive test and the original cross – sectional area of the specimen.

2.4.2. Tensile strength

The force at rupture was noted for 10 samples as recommended by Mohseni [18] using a Monsanto Hundfield Tensiometer and the tensile strength for the fresh rhizome at 5.3% moisture was computed. Linear dimensions of the rhizome were measured using a Digimatic Vernier Caliper.

3. RESULTS AND DISCUSSION

Table 1: Moisture Content Analysis of Yellow Ginger

Replicate	$W_{1,g}$	$W_{2,g}$
1	15.0	3.74
2	15.0	3.76
3	15.0	3.68
4	15.0	3.78
5	15.0	3.66
6	15.0	3.60
Mean, $\bar{x}$	15.00	3.70
Standard deviationδ	0.00	0.17
COV,%	0.00	4.57

Where: W_1= initial weight, g; W_2 = final weight, g; COV = coefficient of variance

3.2 Frictional Property of Yellow Ginger Variety

The angles of repose as determined on various surfaces of materials of contraction are as shown in Table 2. There was a significant level of agreement in values of angle of repose measured from the various surface as reflected in the covariance. The angle of repose on stainless steel was observed as the least with a value of 35.2^o having a coefficient of friction of 0.7054; while on wood, the angle of repose was 37o with 0.7536 as coefficient of friction.

Table 2: Angle of Repose at 75.32% Moisture on Different Construction Materials

S/No/Material	Wood	Stainless Steel	Galvanized Iron	Mild Steel
1	37.0	35.3	35.5	35.8
2	37.0	35.2	35.5	35.7
3	37.0	35.4	35.6	35.8
4	37.0	35.2	35.4	35.9
5	37.0	35.2	35.5	35.8
$\bar{x}$	37.0	35.2	35.5	35.8
δ	0.00	0.08	0.05	0.08
COV,%	0.00	0.23	0.14	0.23

All symbols carry the same meaning

3.3 Physical (Mechanical) Properties of Ginger

The tensile strength and compressive stress analysis is as shown in Tables 3 and 4.

The energy required to tear up the roots of crush them in a machine device is derived from the momentum of rasping drum, a certain kinetic energy is found necessary to obtain such rasping effect. Above a certain speed, it is expected that no further increase in rasping effect will be obtained. The choice of mechanism of a machine device for size reduction of this ginger will be solely based on the minimum amount of tensile of compressive strength, whichever is least of the two.

Table 3: Tensile Strength of Ginger at 75.32% Moisture

S/No.	Moisture, %	Force kgf	N	Area,mm²	Stress. N/mm²
	75.09				
1	74.91	12.0	117.68	213.825	0.550
2	75.49	16.0	158.91	676.10	0.232
3	74.80	23.0	225.55	857.25	0.263
4	75.62	13.5	132.39	278.56	0.475
5	76.00	12..0	117.68	247.17	0.47.6
6	75.32	9.0	88.26	4.33.20	0.204
7		12.0	117.68	284.25	0.413
$\bar{x}$	0.42 0.56	13.93	136.61	427.19	0.37
δ		4.19	41.12	229.09	1.28
COV,%		29.99	30.10	53.63	34.21

Note: To convert kgf to N, multiply by 9.8066

Table 4: Compressive Stress of Ginger at 75.32% Moisture

S/No.	Force (kN)	Area, cm²	Compressive Stress, kN/cm²
1	8.0	45.91	0.174
2	10.0	63.92	0.156
3	10.0	61.20	0.163
4	9.0	48.69	0.185
5	10.0	58.13	0.172
6	6.0	29.85	0.201
$\bar{x}$	8.8	51.28	0.175
δ	1.72	11.55	0.015
COV,%	19.48	22.52	8.410

All symbols carry the same meaning as usual.

A summary of the preliminary investigations on the ginger are shown in Table 5.

Table 5: Statistical Analysis of Measured Values of (Physical) Mechanical properties at 75.32% Moisture

Parameter	Replicate	Mean, $\bar{x}$	Standard Deviation δ	COV,%
Length, mm	50	90.00	15.51	17.24
Width, mm	50	61.90	11.86	19.16
Thickness, mm	50	24.30	4.14	17.68
Weight, g	50	75.72	28.81	38.04
Moisture, %	06	75.32	0.42	0.56
Angle of Repose, %	06	35.20	0.08	0.23
Tensile Stress, N/mm²	07	0.37	1.28	34.21
Compressive Stress, N/cm²	07	0.175	0.015	8.410

4. CONCLUSIONS

The axial dimensions, frictional properties, tensile stress and compressive stress of the ginger were measured. These properties are useful in the design and construction of machines for processing ginger and for future technical development. The linear axial dimensions from a lot of 50 samples gave the following mean dimensions: Maximum diameter (length) was 90.00mm; intermediate diameter (thickness) was 61.90mm. The minimum diameter 24.30mm can govern the minimum clearance for a ginger rhizome to pass from the concave of pulverizing machine [19]. The mean weight of the fresh ginger rhizomes was 75.72 g with 75.32% moisture content. This moisture is the average storage condition of post – harvests ginger [20]. The angle of repose which determines the flow – ability of the ginger in a hopper with respect to stainless steel as chosen material of construction was 35.0⁰. The tangent of this angle is the coefficient of friction between ginger and the stainless steel (Type 314). The mechanism of the crushing can be selected by determining the minimum force required to crush the ginger rhizome hence, the tensile stress and the compressive stress analysis. The compressive stress was 1.75N/mm² while the tensile stress was 0.37N/mm².

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APPENDIX A 1

Linear and Weight Measurement of Ginger at 75.3% Moisture

S/No.	l (mm)	a(mm)	b(mm)	w(g)
1.	80.0	43.5	18.0	59.0
2.	78.0	55.0	24.0	53.5
3.	109.0	68.0	22.0	90.5
4.	90.0	63.5	19.5	67.5
5.	76.5	56.5	19.0	50.5
6.	132.0	88.0	22.0	187.0
7.	62.6	45.5	22.0	42.0
8.	79.0	62.0	17.0	53.5
9.	89.0	74.3	23.0	68.5
10.	92.0	57.7	25.3	69.0
11.	84.0	59.6	20.8	67.5
12.	71.9	57.8	26.6	52.0
13.	90.0	61.0	20.5	68.5
14.	68.0	45.0	23.0	44.5
15.	82.0	61.8	23.0	60.5
16.	74.0	56.0	22.5	54.0
17.	76.0	48.0	27.0	54.5
18.	105.0	60.0	24.0	87.5
19.	95.0	58.7	24.5	80.0
20.	78.6	67.4	20.4	58.0
21.	90.3	62.0	22.0	77.0
22.	97.8	57.8	26.0	79.0
23.	94.0	59.0	20.5	74.8
24.	103.0	62.0	22.0	91.5
25.	75.0	57.0	17.0	51.3
26.	60.0	41.4	19.0	30.0
27.	83.0	54.0	22.0	64.5
28.	89.0	57.0	26.5	75.5
29.	78.0	51.6	22.0	50.0
30.	83.0	49.3	24.0	66.0
31.	96.0	73.3	38.8	79.0
32.	80.0	74.0	19.0	54.5
33.	80.7	42.0	22.0	58.0
34.	98.0	66.0	26.0	87.0
35.	97.7	65.0	26.5	75.5
36.	98.5	44.3	22.0	86.0
37.	92.5	55.3	21.5	77.0
38.	100.5	87.0	19.9	89.0
39.	101.0	52.0	20.0	99.0
40.	110.0	78.7	24.0	124.0
41.	125.0	72.0	21.8	116.5
42.	83.0	58.6	22.0	62.5
43.	120.0	81.2	32.0	109.0
44.	83.0	81.3	32.0	64.5
45.	86.0	49.0	32.0	65.5
46.	77.6	83.0	24.0	42.0
47.	126.0	63.0	21.0	166.0
48.	110.0	65.7	26.0	125.0
49.	87.7	70.0	22.3	73.0
50.	100.0	65.6	29.0	105.5
$\bar{x}$	90.0	61.9	23.4	75.72
δ	15.51	11.86	4.14	28.81
COV,%	17.24	19.16	17.68	38.04

Where

l = maximum linear diameter, mm (length)

a = Feret's diameter, mm (Width)

b = Average of Martin's diameter, and minimum linear diameter (Thickness)

w = Weight, g

Other Symbols carry the same meaning as usual.