Performance Evaluation of a~~the~~ Portable Ginger Slicing Machine

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ABSTRACT

The performance of a simple and affordable portable ginger slicing machine was conducted at various levels of impeller speed, impeller gang, and slicing compartments. The indices for the performance evaluation were the ~~slicing efficiency~~Slicing Efficiency and ~~output capacity~~Throughput Capacity. The machine was powered by one horse power petrol engine and ginger moisture content of 77.44%. Data collected were subjected to statistical analysis using Analysis of Variance (ANOVA) to test the significance level of the experimental factors and their interactions; and those found significant were further subjected to Duncan Multiple Range Test (DMRT) for mean separations at (P=.05), respectively. The results showed that the machine slicing efficiencies for the cushion and spring compartments were: 63.5 and 50% while the output capacities were: 58.32 and 6.32 kg/h, respectively.

Keywords: Evaluation, DMRT, ginger slicing, spring and cushion compartments

1. INTRODUCTION

Ginger (~~*Zingiber officinale*~~*Zingiber officinale* R~~r~~oscoe) is a root crop grown in many parts of the world (India, China, Indonesia, Nigeria, Brazil, Philippines and Thailand). [7] and [12] reported that, India is the largest producer of ginger in the World with a production~~volume~~ of 1,109,000 metric tonnes and Japan is the largest importer in the World. However, Nigeria is the fourth producer in the world and~~but~~ largest producer in Africa with a production~~volume~~ of 522,964 metric tonnes/year?. The crop is an important source of foreign exchange for

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Nigeria. It can be used in pharmaceutical, bakery, culinary, cosmetic preparation and soft drink in beverage industries [14]. As reported by [4], ginger has a moisture content of 80 - 85% wet basis when freshly harvested and 10 - 12% moisture content dry basis for storage. It can be consumed fresh or dried [6]. The plant is grown in different parts of Nigeria such as Kaduna, Nasarawa, Sokoto, Zamfara, Akwa_Ibom, Oyo, Abia and Lagos States, ~~although~~ Kaduna being ~~is~~ the largest ~~producer of fresh ginger in Nigeria~~ [10].

Comment [H3]: Are you sure? Justify the claim with a souce (reference).

Ginger enters the international markets as fresh, preserved or dried forms. However, the most important commercial form is the dried ginger (split or whole) [1]. Report by [2], stated that demand for dry ginger locally and internationally is increasing by the day~~becoming greater~~. Slicing longitudinally is to enable maximum surface exposure for quick and uniform drying thereby retaining the aroma, flavour and pungency which are the qualities requirements in ginger trade [14]. Traditional method of slicing is the most practiced. It involves use of kitchen knife which has different edge directions, the moisture content and the cross sectional area has significant influence over the cutting energy.~~.~~ Slicing 14 - 15 kg of ginger takes about 5 man- hours which is relatively time consuming thus manual slicing of ginger becomes cumbersome and cannot meet the demands and hence, the need for mechanizing ginger production particularly, its processing. The aim of this study therefore is to evaluate the functional performance of a~~the~~ developed portable ginger rhizomes longitudinally slicing machine.

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2. MATERIALS AND METHODS

The developed ginger slicing machine consists of the following components: frame, hoppers, slicing units, and power transmission unit as in Figure1.

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Frame

The machine has~~d~~ trapezoidal shape~~dimensions of the~~ with parallel sides of~~as~~ $600\ mm$ and $960\ mm$, and height of $300\ mm$. The frame was fabricated with $30\ mm \times$

$30\ mm \times 3mm$ angle iron. Mounted on the frame are bearings, shaft, slicing units, hoppers and a prime mover.

Hopper

The hoppers are rectangular in cross section and made from 3 mm mild steel sheets. They had $190\ mm \times 150\ mm \times 65\ mm$ dimensions as length, breath and width with an inclination of 42^0.

Slicing units

The chamber is composed of two types of slicing chambers, spring and cushion compartments to accommodate the irregular thickness of ginger rhizomes. The slicing chambers have~~d~~ cross sections of $300mm \times 300mm$ and widths of $50\ mm$. The widths of the chambers were to accommodate all thickness of ginger. It compresses/deflects when a bigger size is fed into the chamber.

The cutting blades (saw blade) are sharpened at one side and were ~~stationary~~ positioned at a tension through adjustable to prevent distortion during operation. It has overall dimensions of $400\ mm \times 30\ mm \times 1.6\ mm$.

Impellers of $145\ mm \times 20\ mm \times 5\ mm$ cross section were fabricated and keyed to a rotating shaft. The impellers were curved and spaced equally at 7 *mm* across the cutting blades lateral cross sections and along the shaft's longitudinal axis to avoid obstruction.

Power transmission unit

The V- belt and pulley assembly were used to transmit the power from the prime mover to the slicing chambers at different levels of impeller speeds. The prime mover is mounted on a frame slit to facilitate adjustment of the belt tension.

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Comment [H6]: Adjustable what?

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Figure 1: The pictorial view of the portable ginger slicing machine

Comment [H7]: The report could be richer if you can include the details about the development of the slicing machine where your design calculations as well as detailed drawings could be provided.

Principle of operation

The machine was operated by one horse power petrol engine through a V-belt. The ginger rhizomes were washed to remove all the soil particles. Each rhizome sample was prepared by cutting off the fingers from the interconnecting tangled clumps (Nwadikom and Njoku, 1988; Guwo, 2008). The ginger rhizome was fed manually into the hopper. It slides down to the slicing chamber to meet rotating impeller. The centrifugal force of rotating impeller forced the fallen ginger rhizome on a thin-sharp stationary cutter to accomplish the slicing process. The sliced ginger rhizome was discharged through the outlet directly below by gravity and it was collected in a container. The impeller speed was varied at five levels (250, 300, 350, 400 and 450 rpm) and also, the number of impeller varied from one ~~in~~to four (one, two, three and four gang arrangements).

Instrumentation

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The instruments used for measuring mass, shaft speed and time were: Mettler Model (PN20001) top loading balance with capacity of 2 kg and accuracy of 0.1 g; ~~ram,~~ Lutron Digital Photo Tachometer that can measure a range of 0.5 to 100,000 rpm and accuracy of 0.05 % + 1 digit and digital stop watch.

Experimental procedure

The constructed ginger slicing machine was evaluated based on ~~slicing efficiency~~Slicing Efficiency and ~~output capacity~~Throughput Capacity. Equal weights of 500 g~~ram~~ were used for the experiment for the respective slicing units (spring and cushion compartments). The collected sliced ginger were separated and weighed to determine the ~~slicing efficiency~~Slicing Efficiency. Times for slicing were recorded for each experiment to determine the ~~output capacity~~Throughput Capacity of the machine. The experimental procedures were repeated three times~~unit was taken at~~ (three replications).

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Figure 2: The pictorial view of unsliced ginger

Figure 3: The pictorial view of sliced ginger

Statistical analysis

The experiment was conducted using Completely Randomized Design (CRD) with the experimental factors arranged in $5 \times 4 \times 2 \times 1$ (impeller speed, number of impeller, type of compartment and crop) factorial design. Data from the performance evaluation was subjected to statistical analysis using Analysis of Variance (ANOVA) to test the significance of experimental factors and their interactions. Mean separation with observed significant differences was compared using Duncan's Multiple Range Tests (DMRT) using SAS 9.13 portable package. The ANOVA was computed at probability level of 5% (*P*=.05).

Comment [H8]: You need to be very explicit here. Your experimental design is not well explained and this willaffect the quality of your result and discussion.
You may need to overhaul this aspect of the work.

Determination of ~~slicing efficiency~~Slicing Efficiency

The ~~slicing efficiency~~Slicing Efficiency is the ratio of effective capacity to theoretical capacity expressed in percentage. The ~~slicing efficiency~~Slicing Efficiency was determined as given by [8]; [14], [9] and [13] in Equation (1):

$$SE(\%) = \frac{Q_{CS}}{Q_{CO}} \times 100 \qquad (1)$$

Where:

SE= ~~slicing efficiency~~Slicing Efficiency, %

Q_{CS} = Total quantity of ginger completely sliced, g

Q_{CO} = total quantity of ginger collected at outlet, g

Determination of ~~output capacity~~Throughput Capacity

The ~~output capacity~~Throughput Capacity of the machine is the ratio of the mass/weight/quantity of ginger that can be sliced per time. ~~Output capacity~~Throughput Capacity was determined as given by [8]; [14], [9] and [13] in Equation (2):

Comment [H9]: I guess this should be Throughput Capacity

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$$OC(g/sec) = \frac{Q_{CO}}{t} \qquad (2)$$

Where:

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OC= ~~output capacity~~Throughput Capacity, g/sec

Q_{CO} = total quantity of ginger collected at outlet, g

t = time taken to complete splitting, second

3. RESULTS AND DISCUSSION

The results of the performance evaluation (Slicing Efficiency and Throughput Capacity) of the developed portable ginger slicing machine are shown in Table 1 and 2~~2, respectively~~.

The results of interaction of type of compartment, number of impeller and speed of impeller on ~~slicing efficiency~~Slicing Efficiency are shown in Table 1. The combination do not have definite pattern. The highest mean ~~slicing efficiency~~Slicing Efficiency recorded with cushion compartment was 63.5% at 350 rpm speed of impeller and one impeller gang. However, the highest mean recorded with spring compartment was 50% at the same conditions. This is because of the friction at the surface of the cushion material which enabled it held the ginger rhizome tightly before accomplishing the slicing. The lowest mean ~~slicing efficiency~~Slicing Efficiency of 30.7 and 27.2% was observed with cushion and spring compartments at the same speed of impeller for four and two impeller gangs, respectively. The ~~slicing efficiency~~Slicing Efficiency obtained is within the range reported as mean splicing efficiency by [15], [3], [8], and [1].

Comment [H11]: For which product and by what machine?

The results of the variation on Throughput ~~output~~ C~~c~~apacity in type of compartment, different number of impeller gangs and speed of impellers is shown in Table 2. The combination do not have definite pattern. The highest mean ~~output capacity~~Throughput Capacity was obtained as 26.3 g/sec (94.68 kg/h) at 300 rpm for one impeller gang with spring compartment and 24.9 g/sec (89.64 kg/h) at 300 rpm for one impeller gang with cushion

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compartment, respectively. This is because, ginger rhizome slides with relatively low resistance with spring compartment than cushion compartment. The machine ~~output capacity~~Throughput Capacity obtained was similar to [14], [13], and [8]. The difference in results obtained by [8] may be due to the thickness of the knife used.

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Table 1: Interaction of type of compartment, number of impeller and speed of impeller on ~~slicing efficiency~~Slicing Efficiency

Treatment	Mean ~~Slicing Efficiency~~Slicing Efficiency (%)	Mean Ranking	Treatment	Mean ~~Slicing Efficiency~~Slicing Efficiency (%)	Mean Ranking
Cushion compartment, c_1			**Spring compartment, C_2**		
$S_3N_1C_1$	63.5	A	$S_3N_1C_2$	50.0	d-g
$S_1N_2C_1$	60.6	Ab	$S_4N_2C_2$	49.8	efg
$S_1N_4C_1$	60.4	Ab	$S_1N_1C_2$	49.7	efg
$S_1N_1C_1$	59.2	Ab	$S_1N_4C_2$	46.5	f-k
$S_3N_2C_1$	58.2	abc	$S_2N_2C_2$	44.7	g-l
$S_2N_3C_1$	57.5	Bc	$S_2N_3C_2$	44.6	g-l
$S_1N_3C_1$	56.0	bcd	$S_1N_2C_2$	42.8	i-n
$S_4N_2C_1$	53.2	cde	$S_2N_1C_2$	42.1	k-o
$S_2N_1C_1$	52.6	c-f	$S_2N_4C_2$	41.9	k-o
$S_2N_2C_1$	49.1	e-h	$S_3N_4C_2$	39.2	l-p
$S_4N_1C_1$	48.5	e-i	$S_4N_1C_2$	38.1	m-p
$S_3N_3C_1$	48.3	e-i	$S_5N_2C_2$	38.1	m-p
$S_4N_3C_1$	47.2	e-k	$S_5N_1C_2$	38.0	m-p
$S_5N_2C_1$	43.8	g-m	$S_4N_4C_2$	36.3	o-q
$S_5N_1C_1$	43.4	h-n	$S_1N_3C_2$	35.2	pq

$S_5N_3C_1$	42.3	j-o	$S_3N_3C_2$	34.5	pq
$S_4N_4C_1$	37.5	n-p	$S_5N_4C_2$	34.1	pq
$S_2N_4C_1$	34.9	Pq	$S_5N_3C_2$	34.0	pq
$S_4N_5C_1$	33.1	Pq	$S_4N_3C_2$	33.0	pq
$S_3N_4C_1$	30.7	Qr	$S_3N_2C_2$	27.2	r

Means followed by same letter(s) on the same column and row are not different statistically at P=0.05 using DMRT.

S= impeller speed, N= number of impeller, C1=cushion compartment, C2= spring compartment

Table 2: Interaction between type of compartment, number of impeller and speed of impeller on ~~output capacity~~Throughput Capacity

Treatment	Mean ~~Output capacity~~Throughput Capacity (g/sec)	Mean Ranking	Treatment	Mean ~~Output capacity~~Throughput Capacity (g/sec)	Mean Ranking
Cushion compartment, C_1			**Spring compartment, C_2**		
$S_2N_1C_1$	24.9	ab	$S_2N_1C_2$	26.3	A
$S_1N_1C_1$	20.7	cde	$S_1N_4C_2$	22.5	Bc
$S_1N_2C_1$	19.7	c-g	$S_5N_3C_2$	21.3	Cd
$S_4N_1C_1$	18.4	d-i	$S_1N_1C_2$	20.4	cde
$S_4N_2C_1$	17.9	d-j	$S_1N_2C_2$	20.0	c-f
$S_1N_4C_1$	16.2	g-l	$S_2N_4C_2$	19.4	c-g
$S_3N_1C_1$	16.2	g-l	$S_3N_4C_2$	18.8	d-h
$S_2N_4C_1$	15.7	h-l	$S_3N_1C_2$	18.7	d-h
$S_5N_2C_1$	15.5	h-l	$S_2N_2C_2$	18.4	d-i
$S_5N_1C_1$	15.4	h-l	$S_4N_1C_2$	17.2	e-k
$S_3N_2C_1$	15.3	h-l	$S_1N_3C_2$	16.6	f-l
$S_3N_4C_1$	15.3	h-l	$S_4N_2C_2$	16.6	f-l

$S_2N_2C_1$	14.7	i-n	$S_5N_1C_2$	16.1	g-l
$S_2N_3C_1$	14.6	i-n	$S_4N_4C_2$	15.2	h-m
$S_4N_3C_1$	14.6	i-n	$S_5N_4C_2$	15.2	h-m
$S_3N_3C_1$	14.0	k-n	$S_4N_3C_2$	14.8	i-n
$S_1N_3C_1$	13.4	k-n	$S_3N_3C_2$	14.3	j-n
$S_4N_4C_1$	13.2	lmn	$S_2N_3C_2$	13.6	k-n
$S_5N_3C_1$	13.1	lmn	$S_5N_2C_2$	12.9	lmn
$S_5N_4C_1$`	11.5	mn	$S_4N_2C_2$	11.3	N

Means followed by same letter(s) on the same column and row are not different statistically at P=.05 using DMRT.

S= impeller speed, N= number of impeller, C1=cushion compartment, C2= spring compartment

4. CONCLUSION

The performance evaluation (Slicing Efficiency and Throughput Capacity) of a portable ginger slicing machine was carried out to suit the need of the farmers. It was powered by one horse power petrol engine. At ginger moisture content of 77.44% wet basis, and at operating speed of 350 rpm, the machine has an average slicing efficiencySlicing Efficiency and output capacityThroughput Capacity of 63.5 %, 58.32 kg/h, and 50 % and 67.32 kg/h for cushion and spring compartments, respectively.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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