Performance Evaluation of 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 compartment. The indices for the performance evaluation were the slicing efficiency and output 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 roscoe*) 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 volume of 1,109,000 metric tonnes and Japan is the largest importer in the World. However, Nigeria is the fourth in the world but largest producer in Africa with a volume of 522,964 metric tonnes. The crop is an important source of foreign exchange for 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, AkwaIbom, Oyo, Abia and Lagos States, although Kaduna is the largest producer of fresh ginger in Nigeria [10].

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 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. The aim of this study is to evaluate the functional performance of the developed portable ginger rhizomes longitudinally slicing machine.

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.

Frame

The machine had trapezoid dimensions of the parallel sides 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 had cross sections of $300mm \times 300mm$ and widths of $50\ mm$. The widths of 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 $400\ mm \times 30\ mm \times 1.6\ mm$.

Impeller 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.

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

Principle of operation

The machine was operated by one horse power petrol engine through a V-belt. The 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 blow 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 into four (one, two, three and four gang arrangements).

Instrumentation

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 gram, 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 and output capacity. Equal weights of 500 gram 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. Times for slicing were recorded for each experiment to determine the output capacity of the machine. The experimental unit was taken at three replications.

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 (P=.05).

Determination of slicing efficiency

The slicing efficiency is the ratio of effective capacity to theoretical capacity expressed in percentage. The 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, %

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

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

Determination of output capacity

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

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

Where:

OC= output 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 of the developed portable ginger slicing machine are shown in Table 1 and 2, respectively.

The results of interaction of type of compartment, number of impeller and speed of impeller on slicing efficiency are shown in Table 1. The combination do not have definite pattern. The highest mean 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 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 obtained is within the range reported as mean splicing efficiency by [15], [3], [8], and [1].

The results of the variation on output capacity 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 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 compartment, respectively. This is because, ginger rhizome slides with relatively low resistance with spring compartment than cushion compartment. The machine output 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.

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

Treatment	Mean Slicing Efficiency (%)	Mean Ranking	Treatment	Mean 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

Treatment	Mean Output capacity (g/sec)	Mean Ranking	Treatment	Mean Output 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 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 efficiency and output capacity of 63.5 %, 58.32 kg/h, and 50 % and 67.32 kg/h for cushion and spring compartments, respectively.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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