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DESIGN AND CONSTRUCTION OF A MOTORISED JUICE EXTRACTOR

Aderinlewo A. A1 , Biobaku O. L.1 and Adepoju V. O.1

1Department of Agricultural and Bioresources Engineering, Federal University of Agriculture, Abeokuta, Nigeria

**Corresponding Email: aderinlewoaa@funaab.edu.ng*

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ABSTRACT

A motorized jul/nice extractor was designed, fabricated and evaluated with orange, pineapple and golden melon fruits. The major components of the extractor included the hopper, slicing chamber, extracting chamber, frame and outlets for juice and pulp. The machine was powered by a 2 h.p. electric motor. The results of the evaluation showed a fruit yield of 38.00, 51.43 and 39.67% for orange, pineapple and golden melon respectively and extraction efficiency of 65.47, 83.94 and 53.17% for the three fruits respectively while the juice extraction loss was 6, 9 and 28% respectively for the three fruits. The cost of producing the machine is N 58,130 (USD 161.47) which makes it affordable to small scale fruit juice producers.

INTRODUCTION

Fruits are rich in vitamins and fibre which are essential nutrients needed for good health and easy digestion of food in human beings. However, fruits have high rate of deterioration and about 30 – 50% of fruits produced in Nigeria is lost annually (Aviara *et al.,* 2013). Furthermore the production of the fruits is seasonal hence they are not available all year round. One way to overcome these problems is to extract juice from fresh fruits. The extracted juice can easily be transported, preserved, stored and package for all year round availability.

To achieve these, machines known as juice extractors are needed. Imported juice extractors are available but the present high foreign exchange rate in Nigeria has made them unaffordable to many farmers and processors. Efforts are now focused at local production of fruit extractors.

Different local researchers have produced different juice extractors. Aviara *et al.,* (2013) designed and constructed a multi-fruit extractor. The extractor was tested using pineapple, orange and water melon. The percentage fruit yield of 68.7 to 89.7% and extraction efficiency of 83.6 -97.1% were obtained for the fruits. Kasoli and Kasisira (2005) designed and constructed a banana juice extractor. The extracting efficiency obtained from the extractor was 47% which was less than 69% obtained for manual extraction. Ogunsina and Lucas (2008) designed and constructed a manually operated cashew juice extractor with an extracting efficiency of 85.38%. Sylvester and Ashwe (2012) designed and constructed an orange juice extractor capable of extracting juice from 100-220 oranges per hour. Aremu and Ogunlade (2016) developed a multipurpose juice extractor with a fruit yield in the range of 45.0 – 47.6% and extracting efficiency in the range of 38.2 – 67.4% for tropical fuits. The objective of this work was to design, construct and evaluate the performance of a motorized juice extractor.

MATERIALS AND METHOD

Design Consideration

Engineering and physical properties of fruits relevant to juice extraction such as crushing strength, size and shape, bulk and true densities were taken into consideration in the design. Other factors considered include strength and rigidity of materials for machine components, cost of materials and ease of inspection, serviceability, and maintenance of the machine. The isometric view of the extractor is shown in Figure 1.

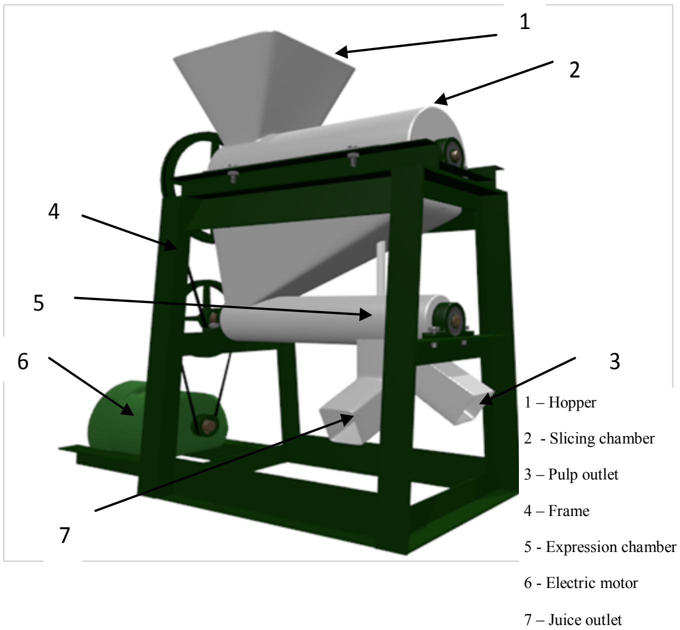

Figure 1. Isometric view of the juice extractor

Design of Machine Components

Design of power requirement of the machine

The pressure required to crush different fruits range from 141 – 316 kN/m^2 (Michael,1987; Ogunsina and Lucas, 2008). This translates to a force of 0.32 kN – 1.043 kN for different fruits. (Agunloye, 2014). The power to produce a force of 1.043 kN was calculated using the expression:

$$p = \frac{2f\pi rN}{60} \quad \text{.....................(1)}$$

Where p is the power requirement, f is the force required for crushing fruit (1.043 kN), r is the radius of drive pulley (0.038m) and N is the speed of driving shaft (300 rpm). Thus, p = 1245.14 w = 1.7 hp then an approximate 2 h.p. electric motor was selected.

Design of shaft diameter

The cutting blade of the slicing chamber is arranged in a spiral form on the shaft. Since both the shaft of the slicing chamber and the worm shaft of the extraction unit are subjected to similar loads, their diameters were determined using the equation given by Khurmi and Gupta (2009) as:

$$D^3 = \frac{16}{\pi S_s}\sqrt{(k_b m_b)^2 + (k_t m_t)^2} \quad \text{.....................(2)}$$

Where: Ss is the Allowable combined shear stress for bending and torsion , 40mpa, K_b is the combined shock and fatigue factor applied to bending moment (2.0), K_t is the Combined shock and fatigue factor applied to torsional moment (1.5), M_b is the Bending moment (4.2 x10^3 Nm), M_t is the Torsional moment (45×10^3 N.MM) and D is the Diameter of solid shaft (m). Thus, D = 21 mm therefore, a stainless steel rod of diameter 25 mm was chosen for the extraction unit while a mild steel rod of the same diameter was chosen for slicing unit.

Uniform pitch of six steps was used for the spiral arrangement on the shaft of the slicing unit while the pitch in the extracting shaft also had six steps but in a decreasing order.

Standard equations were used to determine length of belt, pitch length and pulley sizes.

Machine Description and Operation.

The juice extractor has four main units; the hopper, the slicing unit, the extraction unit and the power transmission unit (Fig. 2). It works on the principle of squeezing and compression because of the gradual decrease in the pitch length of the worm on the extracting shaft.

After washing the fruits, it is peeled manually and poured into the hopper from where it flows into the slicing unit where size reduction takes place. From the slicing unit it moves to the extracting unit where squeezing and pressing takes place to extract the juice. The extracted juice comes out from the juice outlet while the pulp comes out from the pulp outlet.

Plate1. Pictorial View of the Juice Extractor

The Bill of Engineering Measurement and Evaluation of Production

The bill of engineering measurement and evaluation of production is presented in Table 1. This includes the cost of materials for the different components of the machine, cost of machining and non machining jobs and cost of fabrication.

Table 1. Bill of Engineering Measurement and Evaluation of a Unit of the Machine

S/N	Material	Specification	Qty	Unit Cost (N)	Total Cost (N)
1	Stainless steel	2mm thickness	1	15000	15000
2	Shaft (mild steel)	25mm	1	1200	1,200
3	Shaft	30mm	1	1700	1700
4	Barrel	60mm	1	4000	4000
5	Stainless pipe	50mm	2	2000	4000
6	Angle iron	2 x 2	2	830	2,490
7	V-belt	A55	1	250	250
8	V-belt	A44	1	250	250
9	Bolts and nuts	M19	2	50	100
10	Bolts and nuts	M17	8	30	240
11	Pillow Bearings	25mm	2pairs	2500	5000
12	Paint	Green and Sliver	2cup	400	400
13	Pulley	200mm	1	1500	1,500
14	2hp single phase electric motor	AC. 240	1	15000	15000
15	Transport			7000	7000
	Total				**58, 130**

Performance Evaluation of the Machine

The performance of the machine was tested using three different fruits namely orange, pineapple and golden melon. The fruits were obtained from Osiele market in Ogun Stae, Nigeria.The fruits were washed, peeled manually and cut to sizes, known mass of each fruit was then fed into the hopper. The fruit was transferred into the slicing unit from the hopper and then to the extracting unit. The machine was left to operate until all the fruits in the hopper were completely extracted and discharged through the pulp and juice outlet accordingly. After extraction, the following indices were evaluated (Aviara *et al.,* 2013):

i. InputCapacity (or work rate) (kg/h) = $\frac{w_1}{t}$ ....(3)

ii Yield $Y_e = \frac{100w_2}{(w_2+w_3)}$ .... (4)

iii. Extraction efficiency (%) = $\frac{w_2}{xw_5} \times 100$....... (5)

iv. Extractionloss (%)= $\frac{(100(w_1-(w_2+w_3)))}{w_1}$ ....(6)

Where; w_1 is the weight of fresh fruit (kg), w_2 is the weight of juice extracted (kg)
w_3 isthe weight of wet cake w_3 (kg), w_4 is the weight of oven dried cake W_4 (kg)
$w_5 = w_1 - w_4$)) is the weight of juice obtainable (kg), t is total time (s)
x is juice constant of fruit (obtained as 0.8, 0.78 and 0.91 from Aviara *et al.,* (2013))

The procedure was replicated three times for the three fruits

RESULTS AND DISCUSSION

The average input capacity, percentage yield, extraction efficiency and extraction loss are presented in Table 2. The juice yield obtained from the machine ranged from 38.00 – 51.43%. Pineapple has the highest fruit yield of 51.43% followed by golden melon with 39.67% and orange with 38.00%. The extraction efficiency ranged from 53.17 - 83.94%. The highest extraction efficiency was obtained from pineapple with 83.94% followed by orange with 65.47% and golden melon with 53.17% respectively. The input capacity of golden melon was the highest with 53.32% followed by pineaple with 43.56% and orange with 35.35% respectively. The extraction loss ranged from 6 – 28% with the highest in golden melon followed by pineapple and orange respectively. These values compare favourably with findings of Olaniyan (2010) and Oyeleke and Olaniyan (2008).

Table 2. Average performance indices of the machine

Performance index	**Fruit type**		
	Orange	**Pineaple**	**Golden melon**
Input capacity, kg/h	35.35	43.56	53.32
Juice yield, (%)	38.00	51.43	39.67
Extraction efficiency, (%)	65.47	83.94	53.17
Extraction loss (%)	6	9	28

CONCLUSIONs

A motorized fruit extractor was designed, fabricated and tested. It was powered by a 2 h.p. electric motor. The average input capacity, juice yield, extraction efficiency and extraction loss when tested with three fruits namely orange, pineapple and golden melon range from 53.32 -35.35 kh/h, 51.43 – 38.00%, 83.94 – 53.17% and 6 - 28% respectively. The machine can be used for small scale juice extraction. An improvement in the design of the screw conveyor in the extraction chamber is recommended to improve the extraction efficiency.

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