



DESIGN, CONSTRUCTION AND PERFORMANCE EVALUATION OF A MANUAL CUM MOTORIZED ORANGE JUICE EXTRACTING MACHINE

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ABSTRACT

A manual cum motorized operated juice extractor was designed and fabricated using locally sourced materials. Polytetrafluoroethylene (PTFE) a synthetic fluoro polymer was used in the construction of the screw shaft and stainless steel for the extraction chamber. Rotational motion needed by the screw shaft to compress and transport the fruits was supplied both manually cum motorized to the machine through a handle and electric motor device of 10w because this has capacity to handle the performance operation. The screw shaft crushes, squeeze and facilitate the movement of residues to the waste outlet while the juice passes through the screen to the juice collector. Tests were carried out to investigate the performance of the machine on the basis of juice yield, extraction efficiency and extraction loss. The fruits were washed and weights (1kg, 1.5kg and 2kg respectively) of fruit slice (8 and 16 slices) were then processed using the extractor to extract the Juice. The juice yield, extraction loss and extraction efficiency were determined by standard Formula and methods. Maximum juice yield of 64.6 % extraction efficiency of 68.2 % and Corresponding extraction loss of 7.05 % were obtained from the 16 slice lengths orange fruits were used for the test. The juice produced from the extractor was of good quality which further proves the effectiveness of the extractor. The manual fruit juice extractor is cheap(N48770), durable and cost of operation is low while motorized juice extractor is faster in terms of operation or extraction efficiency and extraction loss, and also it could be used by an average Nigerian household and small-scale farmers.

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1.0 Introduction

Orange (*Citrus sinensis*) is a dominant member of a large botanical family known as citrus. This fruit is the largest fruit crop in the world with about sixty million metric tons grown (Barry *et al.*, 2020). The local methods of extracting fruits juice are prone to contamination and are unhygienic. It also has a low efficiency and high human drudgery (Shirke, 2023). Sophisticated juice extractors are available but unaffordable by average Nigerian farmers and processors. Harvested orange fruits deteriorate if left for long period without being used or processed. Economic losses experienced due to spoilage are in developing countries, especially in Nigeria. Therefore, there is a need to develop simple equipment to process the fruits easily. Oranges, lemon, limes, grapefruits and tangerines are from the class of fruits known as citrus fruits (Olife *et al.*, 2015). It is universally acknowledged that citrus fruits are originated from northeastern India (Ortese *et al.*, 2012). The federal department of agriculture and missionaries in the 1930s introduced citrus fruits into Nigeria. Since its introduction, the cultivation of citrus fruits has spread to every part of the country and recently ranked as the third most extensively cultivated fruit tree in the country particularly in South-Western Nigeria (Oyedele and Yahaya, 2010). With regard to international trade, citrus fruits are ranked highest worth fruit crops. The market available for citrus fruits is the fresh fruit market and the processed citrus fruits market chiefly orange juice (Olife *et al.*, 2015). Citrus products contain very high nutritional contents; they are rich and cheap sources of vitamins (particularly vitamin C), minerals and dietary fiber which are essential for healthy living. Orange fruits are generally known to have poor shelf life and face the problem of postharvest losses (Joshi *et al.*, 2017). This is due to the high temperature. It is impossible to store and preserve oranges for an extended period of

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time without deterioration. Furthermore, high moisture content and poor postharvest handling also contribute greatly to the relatively short shelf-life of orange fruits. This aforementioned reason calls for processing of orange fruits into juice. Juice is the liquid extracted from the cells of mature fruits.

The Nigeria space requires a technology in which an orange juice extraction machine may be equipped and operated by both manual and mechanized processes. This dual operationalization offers the advantages of versatility of usage and application. Orange fruits cell wall is made of cellulose, hemicelluloses, pectic substance and proteins. (Ashurt and Taylor, 1991) reported that fruit juice extractor is an agricultural technology implement that involves the pressing of some fruits in order to get juice. Orange juice extractor involves the process of crushing, squeezing and pressing the whole fruit in order to obtain the juice and to reduce the bulkiness of the fruit to liquid and pulp. While hand extraction of juice involves (peeling with knife and squeezing the juice out with bare hand), is very slow and tedious and also not hygienic enough. The merits of using machine for extraction are time saving, improve efficiency, increase capacity, and reduction in spoilage and waste (Abulude *et al.*, 2007). This paper provides the combined advantages of a designed, fabricated and evaluation of the operations of manually and motorized orange juice extraction machine.

2. Materials and Methods

2.1 Description of the Juice Extractor Component Parts

2.1.1 Hopper

The hopper was fitted directly above the cylindrical drum. It is made of steel material and was designed to accommodate the allowable volume required of the mass of fruits (assume 4kg to 6kg). The fruits are to run down the hopper into the cylinder by means of gravity. The hopper was inclined at an angle of 61° . The hopper is in form of a frustum.

2.1.2 Cylindrical Pipe (chamber)

Its main function is to collect the squeezed juice and pulp via its outlet. The cylinder was fabricated from 3 mm galvanized steel sheet with an appropriate diameter 15.5cm and length 66 cm. The cylindrical pipe was housing the cylindrical mesh sieve that is responsible for sieving the masticated and macerated fruits. The cylinder was designed to have two outlets (juice outlet and pulp/fiber outlet) attached to it to aid in juice and pulp collection.

2.1.3 Cylindrical Mesh Sieve

This is going to be responsible for sieving the crushed and pulverized fruits. It is designed to cover the rotation shaft in such a way that both of them will be situated inside the cylindrical pipe. It was manufactured from galvanized steel sheet of an appropriate diameter 10.5 cm inlet diameter, 6.5 cm outlet diameter and 2 mm thickness. The length of the sieve/strainer is 240mm. The pressing operation take place inside this cylindrical which was perforated with circular holes (openings 2mm x 2mm) to allow the passage of the expelled juice into the juice outlet created in the cylindrical pipe.

2.1.4 Concave (Main Chamber)

It is a mesh of semicircle shape in between the drum and the sieve, and the concave clearance is 310 mm and the minimum clearance between blades and sieve surfaces needed for mastication and maceration was equal to the fruit size sliced / fed into the system, thus; reducing drum clearance tends to reduce drum losses and increase seed damage.

2.1.5 Power Shaft

The rotating shaft will be translated to form a conveyor auger. Cutter blades and nylon brushes was welded to it to aid mastication (crushing) and maceration (softening). The shaft auger ensures that the pulverized fruits are conveyed throughout the whole process until the pulp is finally collected from the fiber outlet. The rotating shaft auger is directly attached to a bearing and a pulley and power will be transmitted from an electric motor through belt transmission to the drive shaft auger. Shaft shall be sized on the basis of strength, stress, deformation and rigidity.

2.1.6 Frame and Supports

The main frame was made of mild steel of considerable strength and size in which the whole system was rest upon. In order to withstand the pressure exerted by the shaft during extraction, the frame and supports must be appropriately considered so that the design doesn't collapse or rupture.

2.2 Design Considerations

The major material selected for use in the fabrication of the machine was steel, considering the following qualities:

Mild steel has about 0.16 to 0.28% carbon content which makes it easy to be worked on and welded. It also has density of $7.68 \times 10^3 \text{ kg/m}^3$, heat expansivity of $11.7 \times 10^{-6} \text{K}^{-1}$, Young's modulus of elasticity 210GN/m^2 , tensile strength of 350MN/m^2 and elongation of 30%.

The design considerations of juice extractor were both for the biomaterials used (oranges) and the materials for construction. The bio-materials strength in maximum loading were considered based on the following:

2.2.1 Engineering properties

- i. strength, rigidity and simplicity of materials of construction
- ii. The expression pressure must be high enough to ensure acceptable level of extraction
- iii. The transmission belt should be properly aligned such that it permits easy rotation of the shaft auger during extraction.
- iv. The power shaft should be rigid enough to withstand combined bending and tension stresses to which it will be subjected to while transmitting power under various operating and loading conditions.
- v. Required force to expel out the juice.
- vi. Portability of the machine.
- vii. Easy inspection, serviceability, and maintenance of the machine.
- viii. Durability of the machine was considered on the machine component.
- ix. Cost of construction; and
- x. ease of operation and maintenance and also energy requirement.

2.2.2 Economic Factors and Safety Considerations

Construction materials of the machine (Figure 1) were selected based on economic factors and safety consideration. These factors are as follows.

- i. Availability and the cost of construction and materials;
- ii. Durability and strength of materials;
- iii. Manufacturing /fabrication methods that will be employed in construction;
- iv. Efficiency of extraction and minimizing juice contamination; and
- v. Corrosion resistant properties.

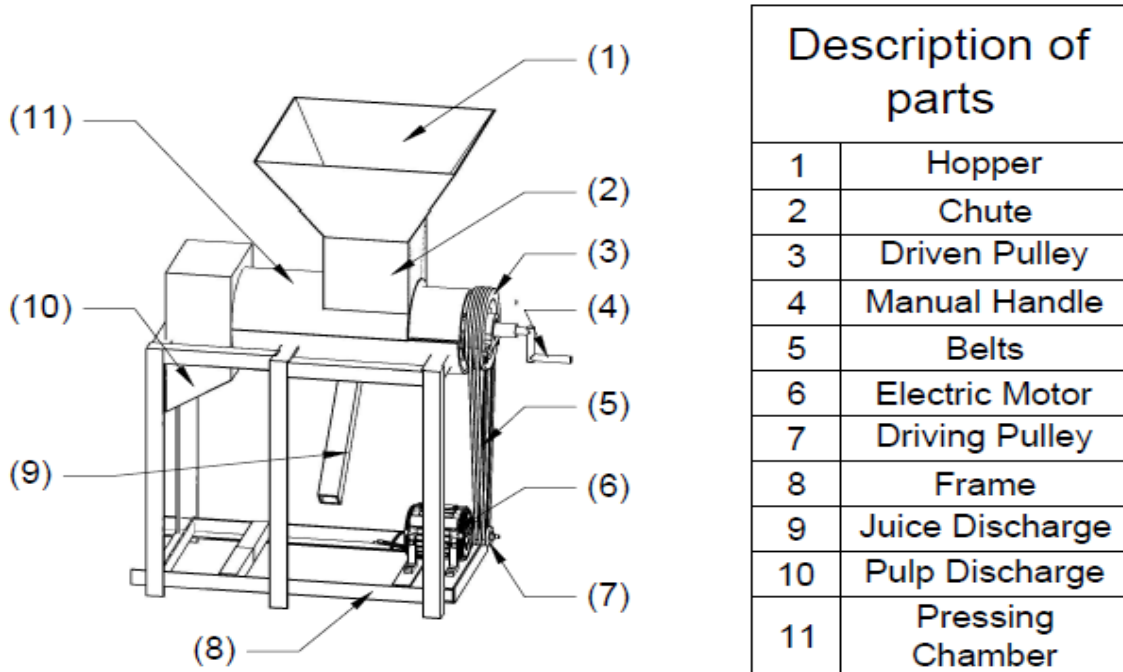


Figure 1: Isometric drawing of orange juice extracting machine

2.3 Design Calculations

2.3.1 Efficiency of Motor

For the efficiency of the machine at 95% at engine speed $N_1 = 1400$ rpm

where:

$$\frac{95}{100} \times 1hp = 0.95hp$$

But $1hp = 0.75kW$

$$0.95hp \rightarrow 0.95 \times 0.75kW = 0.713kW$$

An engine pulley diameter of 152mm diameter was chosen from standard table with belt thickness of 0.12mm.

Engine pulley diameter, $d_1 = 152mm$ or $0.152m$

Radius, $r_1 = 0.076m$

$$\text{Angular velocity of engine (motor), } \omega_1 = \frac{2\pi N_1}{60} \tag{1}$$

Where $N_1 =$ Speed of the engine.

$$\omega_1 = 146.6147 \text{ rad / sec}$$

$$\text{The linear velocity of the engine, } V = \omega r \tag{2}$$

Substituting the value of ω_1 in equations (1) into (2) we have,

$$V = 11.14 \text{ m / s}$$

2.3.2 Belt and Pulley Selection

A speed reduction ratio of 3 was chosen

$$\mu = \frac{N_1}{N_2} \tag{3}$$

Where N_1 = Speed of driver pulley, N_2 = Speed of driven pulley, μ = Reduction ratio = 3

$$N_2 = 466.7 \text{ rpm}$$

Diameter of driven pulley, d_2

$$\frac{N_1}{N_2} = \frac{d_2}{d_1} = (\text{Khurmi and Gupta, 2005}) \tag{4}$$

N_1 = Speed of driver pulley N_2 = Speed of driven pulley, d_1 = diameter of driver pulley,

d_2 = diameter of driven pulley.

Substitute the value of N_2 in equation (4)

$$d_2 = \frac{N_1 d_1}{N_2} = 0.456 \sim 0.46 \text{ m}$$

Radius of driven pulley, $r_2 = 0.23 \text{ m}$

$$\text{Angular velocity of the driven pulley, } \omega_2 = \frac{2\pi N_2}{60} \tag{5}$$

Substitute the value of N_2 in equation (5)

$$\omega_2 = 48.87 \text{ rad / sec}$$

2.3.3 Size of Belt

For an efficient torque in V- belts, a minimum angle of contact of the belt on the smaller pulley should not be less than 120° (Anaya-Esparza et al., 2018). Therefore, an angle of 165° is chosen for the smaller pulley.

2.3.4 Belt Arrangement

The appropriate belt arrangement in the pulley is shown in Figure 2 below.

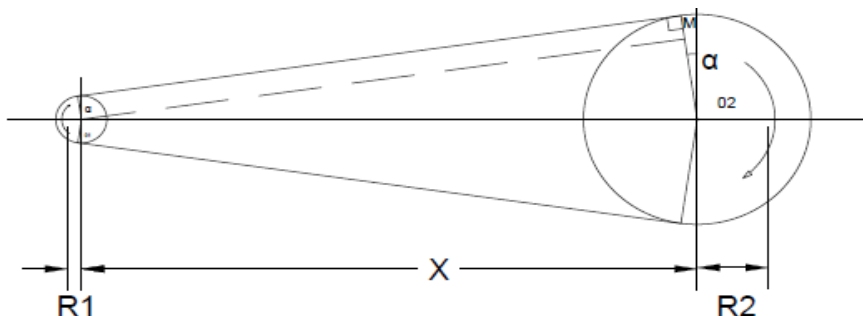


Figure 2: Belt arrangement in the pulley

$$\sin \alpha = 2m / O_1O_2 = r_2 - r_1 / X = d_2 - d_1 / 2X \text{ (Khurmi and Gupta, 2005).} \tag{6}$$

Where r_1 and r_2 are radii of smaller and larger pulleys, x is the distance between the centers of the two pulleys and the angle of contact (θ) in this case is 165° as shown in equation (6)

$$\text{But } \theta = 180 - 2\alpha$$

$$\alpha = 7.5$$

$$\text{Or } 7.5 \times \frac{\pi}{180} \text{ rad} = 0.13 \text{ rad}$$

$$\text{But } \sin \alpha = d_2 - d_1 / 2x = d_2 - d_1 / \sin \alpha \quad (7)$$

An A48 V – belt size was selected in equation (7)

Angle of contact, \emptyset is selected to be 165°

$$\text{Therefore, } \emptyset = 2.88 \text{ rad}$$

We know that

$$2.3 \log \left(\frac{T_1}{T_2} \right) = \mu \times \emptyset \quad (8)$$

Coefficient of friction, μ for rubber belt material on dry cast iron is 0.3

$$\text{From equation (8), } 2.3 \log \left(\frac{T_1}{T_2} \right) = \mu \times \emptyset = 0.3 \times 2.88 = 0.864$$

$$\text{Log } \left(\frac{T_1}{T_2} \right) = \frac{0.864}{2.3} = 0.376$$

$$= \log^{-1} (0.376) = 2.37$$

2.3.5 Power transmitted by Belt

$$P = (T_1 - T_2) v \quad (9)$$

Where P = Power in watts

$T_1 - T_2$ = Overall belt tension

T_2 = Tension in tight side of belt

T_2 = Tension in slack side of belt

$$\text{Equation (9) transforms into } T_1 - T_2 = 64 \text{ N} \quad (10)$$

$$\text{From equation } T_1 = 2.37 T_2$$

Substituting the value of T_1 from equation (10), equations (11), (12) and (13) are generated

where,

$$2.37T_2 - T_2 = 64 \text{ N} \quad (11)$$

$$T_2 = 46.7 \text{ N} \quad (12)$$

Substituting T_2 in equation (12),

$$T_1 - 46.7 = 64$$

$$T_1 = 111 \text{ N}$$

2.3.6 Length of Belt

$$L = \frac{\pi}{2} (d_2 + d_1) + 2x + (d_2 - d_1)^2 / 4 \quad (\text{Khurmi and Gupta, 2005}) \quad (13)$$

Then,

$$L = \frac{\pi}{2} (0.46 + 0.152) + 2 (1.18) + (0.46 - 0.152)^2 / 4$$

$$L = 3.34 \text{ m}$$

2.3.7 Hopper Design Specification

The following assumptions are made so as to choose the dimensions for the hopper;

Volume of material, Shape of material, Angle of repose. The hopper is considered to be a frustum. The height is 250 mm and the top and base radii 350mm and 75 mm respectively.

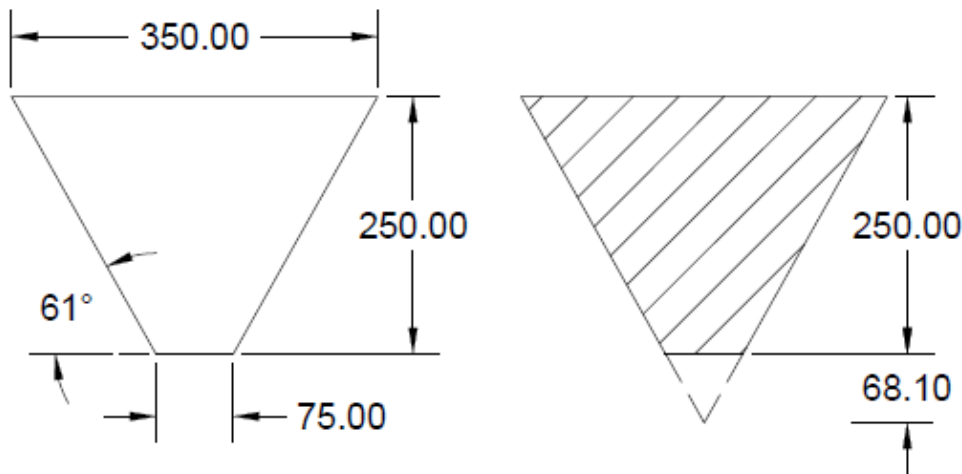


Figure 3: Orthographic view of the hopper

2.3.8 Volume of the hopper

Area of big triangle – Area of small triangle

$$\frac{1}{2} b \times h_1 - \frac{1}{2} b \times h_2$$

Area of big triangle

$$A_B = \frac{1}{2} b h_1$$

$$\alpha^2 = 199.8 h_1$$

2.3.9 Area of Small Triangle

$$\frac{75\sqrt{2}}{2} \quad 37.5\sqrt{2}$$

$$\alpha^2 = 42.72 h_2$$

2.3.10 Volume of hopper

Area of big triangle – area of small triangle

$$\frac{1}{2} (122.5) \times 199.8 - \frac{1}{2} (5625) \times 42.72$$

$$= 266.95\text{m}^3$$

2.3.11 Shaft Design

The shaft was made up of ductile material to resist cyclic load. It was designed against bending and torsion failures and the design is governed by the maximum shear stress Torque transmitted by shaft, T. The auger design and specifications are shown in Figure 4.

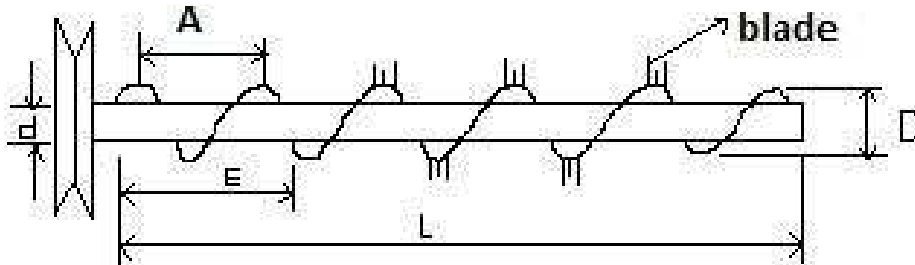


Figure 4: Auger design and specification

A – Auger pitch

D – Outside diameter of auger

d – Outside diameter of auger shaft

E – Length of intake opening

L – Effective length of conveyance

B – Blade length, T – Blade thickness,

W – Blade width

2.3.12 Torque or Power Transmitted by Shaft

Let N = Number of revolutions per minute

$$T = \text{average torque in KNm-I} = \frac{p \times 60}{2\pi N}$$

$$\text{Power} = \text{design horse power} \times 0.713 \text{ KW (Khurmi and Gupta, 2005)} \quad (14)$$

The electric motor used is 1.5 horse powers

Using equation (14) above

$$T = \frac{p \times 60}{2\pi N} = \frac{0.713 \times 103 \times 60}{2\pi \times 466.7}$$

$$T = 14.60 \times 10^3\text{N} - \text{mm or } T = 14.60\text{mm}^3$$

Tangential force acting on pulley, F_{TA} is given by

$$F_{TA} = T / RA \text{ where RA is the radius of the pulley} \quad (15)$$

Mass of pulley = 1.5 kg

Therefore, weight of pulley = $1.5 \times 9.81 = 14.72\text{N}$

Weight of spiral rod + blades = $1.2 \times 9.81 = 11.772\text{N}$

Based on equation (15)

The total load acting on the shaft at A

$$= 1587.972\text{N}$$

The reaction at RB act upwards while RC act downward shown in Figure 5 below.

Taking moment about point C,

RB and RC are the reactions at B and C respectively.

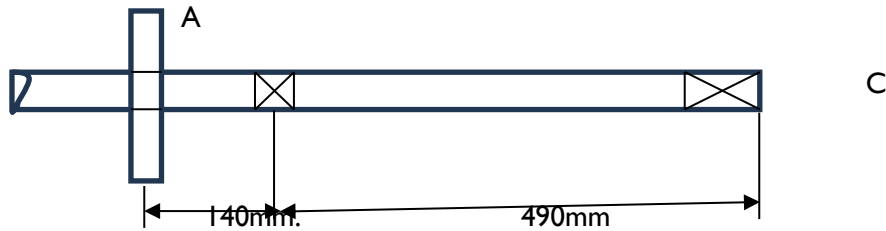


Figure 5: Shaft and Bearing Arrangement

Taking moments about point C

$$R_B \times 490 = 1587.972 \times 630$$

$$R_B = 2041.68\text{N}$$

For equilibrium of the shaft

$$R_C + 1587.972 = R_B$$

$$R_C = 453.708\text{N}$$

Bending moment, (B.M) at A and C = 0

$$\sum m_A = m_C = 0$$

Bending moment, B.M. at B

$$\text{B.M} = 222316.08\text{N-mm}$$

Therefore, bending moment, B.M.

$$= M = M_B = 222316.08\text{N-mm}$$

d = diameter of shaft

$$T = \text{torque} = 14600\text{N-mm}$$

Equivalent twisting moment (equation 16),

$$T_e = \sqrt{(k_m m)^2 + (k_t \times T)^2} \tag{16}$$

From equation (16) K_m = combined shock and fatigue factor due to bending = 1.5, K_t = combined shock or fatigue factor due to tensional moment = 1.0 (for gradually applied loads on rotating shaft).

$$T_e = \sqrt{(1.5 \times 1587.972)^2 + (1.0 \times 14600)^2}$$

$$\tau_e = \sqrt{(5886.88)}$$

But equivalent twisting moment

$$\tau_e = 76.726 \text{ N-mm}$$

$$\tau_e = \frac{\pi}{16} \times \mathcal{T} \times d^3$$

$\mathcal{T} = 42 \text{ mpa}$ (allowable shear stress)

$d = \text{shaft diameter}$

$$76.726 = \frac{\pi}{16} \times 42 \times d^3$$

$$d^3 = \frac{76.726 \times 16}{42\pi} = 99.30 \text{ mm}^3$$

Also equivalent bending moment (Figure 6)

$$M_e = \frac{1}{2} (k \times m + \sqrt{(km \times m)^2 + (kt \times T)^2}): M_e = 1229.342$$

$\sigma_b = 56 \text{ mpa}$ (maximum tensile or permissible stress).

$$m_e = \frac{\pi}{32} \times \sigma_b \times d^3$$

$$d^3 = \frac{1229.35 \times 32}{56\pi} = 223.6 \text{ mm}^3$$

$$d^3 = \sqrt[3]{223.6 \text{ mm}^3}, d = 44.9 \text{ mm}$$

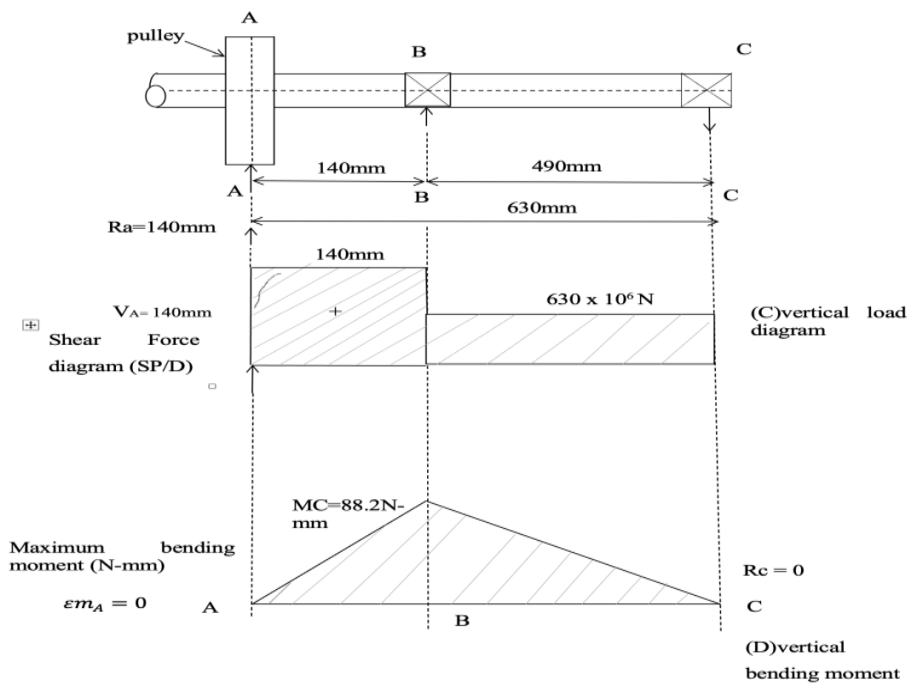


Figure 6: Shear Force and Bending Moments Diagram

2.3.14 First Equilibrium Conditions

Shear force $\varepsilon v_p = 0$

$$R_A + R_B = 0 - 140 - 490 = 0$$

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$$R_A + R_B = 630$$

2.3.15 Second Equilibrium Conditions

Bending moment at point B = F.L

Unit of (B.M) = (KN-m or N-mm)

$$M_A = R_A \times 0 = 0$$

Maximum bending moment at point C

$$R_A = 140\text{mm}, R_B = 490\text{mm}$$

Maximum bending moment at point C

$$m_c = R_A \times 0$$

$$m_c = 140 \times 630 = 88200$$

At point B = 88.2×10^6 N-mm

$$M_B = R_A \times 0 - 630 - 140 - 490 \times 0 = 0$$

2.4 Characterization of Orange Sample

2.4.1 Sizes and Shape

4kg of orange samples were collected and the axial dimensions were measured using a vernier caliper and micrometer screw gauge. From the geometric mean diameter (Dg), arithmetic mean diameter (Da), sphericity (\emptyset), volume (V) and surface area (S) was calculated using equations 17, 18, 19, 20 and 21 respectively as given by (Joshi et al., 2017).

$$\text{Geometric mean diameter (Dg)} = (abc)^{1/3} \quad (17)$$

Where a = length (dimension along longest axis) = 6.5

b = width (dimension along longest axis perpendicular to a) = 5.5

c = thickness (dimension along the longest axis perpendicular to a and b) = 6.0

$$Dg = (6.5 \times 5.5 \times 6.0)^{1/3} = 5.00\text{cm}$$

$$\text{Arithmetic mean diameter (Da)} = \left(\frac{a+b+c}{3} \right) \quad (18)$$

$$Da = 6.0 \text{ cm}$$

$$\text{Sphericity } = \emptyset = \frac{Dg}{a} \quad (19)$$

$$\emptyset = \frac{5.00}{6.5} = 0.76$$

$$\text{For an oblate spheroid like orange, the volume} = \frac{4}{3} (\pi a^2 b) \quad (20)$$

$$V = \frac{4}{3} \times (\pi 6.5^2 \times 5.5) = 973.7 \text{ cm}^3$$

$$\text{Surface area, S} = 2(\pi a^2 + \pi b^2/e) \ln \frac{1+e}{1-e} \quad (21)$$

Where, eccentricity, $e = 0.5$, $S = 2 (\pi 7.5^2 + 6.5^2 / 0.5) \ln \frac{1+0.5}{1-0.5} = 1.09 \text{ cm}^2$

2.4.2 Angle of Repose

This was determined by placing sample of oranges on an adjustable. The adjustable was inclined. This was done using 10 oranges and their corresponding coefficient of friction was analyzed.

2.4.3 Pre-treatment of Orange Fruits

Clean, ripe and mature fruits (orange) were purchased from fruits sellers at 'Kasuwan bera' market in Jalingo. Each orange fruit was washed and weights (kg) of each fruit slice of 8 and 16 respectively were used for the evaluation. Yellow oranges with almost no- acidic content were selected and separated from the green ones and kept in cold place pending when it was to be used and some of the green oranges were kept in cartons at an ambient temperature to inhibit ripening of the oranges when the yellow color begin to appear.

2.5 Performance Evaluation of the Extractor

The machine (Plate 1) was tested in the Faculty of Engineering Workshop Taraba State University, Jalingo. The test was carried out into two different stages. Stage one (1), the free test run (without load) and stage two (2) involves testing with load (i.e. orange fruits) under different weights (1kg, 1.5kg and 2kg) of fruit slice (8 and 16 slices). The test was replicated six (6) times (i.e. 3 weights for each individual slice lengths of 8 and 16 respectively). A stop watch and weighing balance were used to ascertain the time of extraction and measuring the quantity of the extracted fruit and cake.

The performance of the extractor was evaluated in terms of,

$$\text{Juice yield (Jy)} = W_2 / W_2 + W_3 \times 100;$$

$$\text{Extraction loss, EL} = W_1 - (W_2 + W_3) / W_1 \times 100$$

$$\text{Extraction efficiency (E)} = W_2 / W_5 \times 100;$$

$$\text{Throughput capacity} = W_1 / \text{hr.};$$

W_1 = Weight of fresh orange;

W_2 = weight of juice obtained;

W_3 = weight of wet cake;

W_5 = weight of juice obtainable.



Plate 1: The Juice Extractor

3. Results and Discussion

The effects of fruit slice lengths on juice yield, extraction efficiency and extraction loss are shown in Tables 1, 2 and 3 respectively.

Table 1: Measurements of orange fruits sizes

Measurements	Minimum	Maximum	Mean
Angle of repose, Θ°	75.00	76.00	75.53
Coefficient of friction, $n=\tan\Theta$	3.73	4.01	3.88
Orange seed length, (cm)	1.58	1.65	1.50
Orange seed width, (cm)	0.48	0.65	0.56
Orange seed height, (cm)	0.86	1.12	1.01
Orange fruit length, (cm)	7.10	7.90	7.50
Orange fruit width, (cm)	6.25	6.73	6.52
Orange fruit height, (cm)	6.63	7.20	6.96

Table 2 describes a range of parameters as shown in the table arising from 16 sliced lengths. Fruit slice lengths is an indication of surface area of the fruit and juice cells exposed to maceration and pressing action. This study showed that surface area of fruits is an important factor to consider when preparing fruits for juice extraction.

Table 2: Juice Yield, Extraction Loss, Extraction Efficiency and Throughput Capacity for 16 Slice Lengths using the extractor

Measurements (kg)	Minimum	Maximum	Mean
Weight of fresh orange, W_1	1.00	2.00	1.50
Weight of juice obtained, (W_2)	0.35	0.99	0.66
Weight of wet cake, (W_3)	0.64	0.91	0.76
Weight of oven dried cake, (W_4)	0.22	0.51	0.35
Weight of juice obtainable, $W_5 = W_1 - W_4$	0.78	1.49	1.15
Juice yield (%), $J_y = W_2 / W_2 + W_3$	35.40	52.00	44.83
Extraction loss (%), $EL = W_1 - (W_2 + W_3) / W_1 \times 100$	0.001	0.005	0.0053
Extraction efficiency, $E_j = W_2 / W_5 \times 100\%$	45.30	66.40	55.00
Time of extraction (hr)	0.054	0.07	0.064
Throughput capacity (kg/hr)	18.51	28.60	23.43

The average juice extraction efficiency and throughput were 57.70 % and 25.83 % respectively. The study showed that juice yield and extraction efficiency decreased while extraction loss increased with increase in the size of fruit slices. Juice yield, extraction efficiency and extraction loss from 16 slice lengths oranges ranged between 48.90 – 64.60 %, 50.00 – 68.20 % and 0.6 – 7.35 % respectively.

Table 3: Juice Yield, Extraction Efficiency using the Hand pressing method

Measurements (kg)	Minimum	Maximum	Mean
Weight of fresh orange, (W_1)	1.00	2.00	1.50
Weight of juice obtained, (W_2)	0.46	1.20	0.79
Weight of wet cake, (W_3)	0.48	0.67	0.60
Weight of oven dried cake, (W_4)	0.08	0.26	0.19
Weight of juice obtainable, $W_5 = W_1 - W_4$	0.92	1.74	1.31
Juice yield(%) $J_y = W_2 / W_2 + W_3 \times 100$	48.90	64.60	58.80
Juice yield,(%), $J_y = W_2 / W_2 + W_3 \times 100$	22	26	24
Extraction efficiency, $E_j = W_2 / W_5 \times 100$	28	29.1	28.5
Time of extraction (hr)	0.05	0.066	0.057
Throughput capacity (kg/hr)	20.00	30.30	25.83

Table 3 revealed that 16 sliced lengths gave the maximum juice yield of 64.60 % while the corresponding extraction efficiency was 68.20%. Also, the minimum extraction loss of 0.6 % was obtained for 16 sliced lengths. This showed that the 16 sliced lengths were the best for preparing fruits for juice extraction. Results also showed that juice yield and extraction efficiency decreased while extraction loss increased with increase in fruit size slice lengths. This is in agreement with the findings of Faus (2000), Kader and Yahia (2011).

Note: An orange contains about 0.036kg of juice; 1kg orange contains 0.22kg juice.

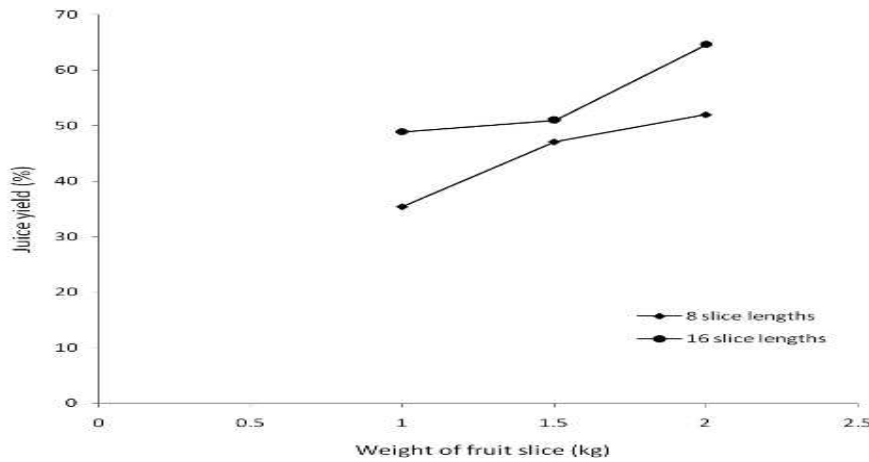


Figure 8: Effect weight of fruit slice on juice yield

In Figure 8, the thicker curve (representing 16 slice lengths) is above that of 8 slice lengths, implying significantly that yield varies with weight of slicing. This is affirming that the heavier the fruit the higher most likely the juice yield.

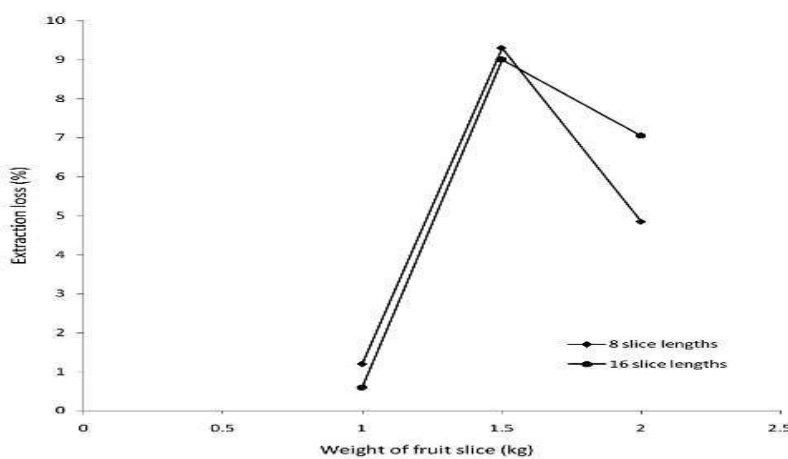


Figure 9: Effect of weight of fruit slice on extraction loss

Figure 9 relates the effect of weight of fruits on extraction loss. The curves of both the 8-slice length and the 16-slice length have not much significant difference in the result of the extraction loss. The 16 slice lengths however have slightly lower extraction loss.

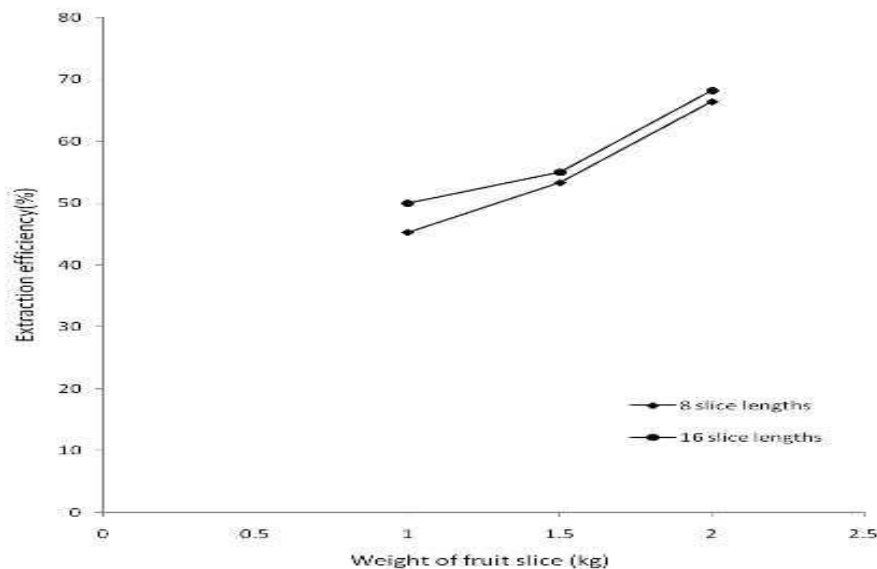


Figure 10: Effect of weight of fruit slice on extraction efficiency

Figure 10 above relates the effect of weights of fruits slice on extraction efficiency: it correlates with Table 3. The higher extraction efficiency (mean value) of 57.70 % of the juice extractor Showed that the extraction rate is more efficient than that of the hand squeezing method which has extraction efficiency (mean value) of 28.5 %. This imply that the juice extractor can be suitably used for small and medium juice processing businesses in rural and urban communities.

4. Conclusion

A machine was designed and constructed to extract juice from orange fruit to forestall the usual wastage during peak harvest on most orchards in Nigeria. The machine was tested and found workable. From the test result carried out using the juice extractor and the hand squeezing method, it was found out that the rate of extraction increases as the weight of fruit increased with a corresponding increase in the juice yield and extraction efficiency. The higher extraction efficiency (mean value) of 57.70 % of the juice extractor Showed that the extraction rate is more efficient than that of the hand squeezing method which has extraction efficiency (mean value) of 28.5 %. This imply that the juice extractor can be suitably used for small and medium4. juice processing businesses in rural and urban communities. The mass production of this locally produced juice extractor will further reduce its cost and therefore making it relatively cheaper, affordable and available to both small and medium scale food industries to purchase. This will no doubt enhance the economic development of our country.

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