THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Juices Extractor: Development and Performance Analysis

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Abstract:
A juice extractor is a device that helps to extract juice from the fruit. A functional juice extractor was developed using locally sourced materials in Nigeria mainly stainless steel to reduce the bottleneck of using hand and cup to extract juice from fruits. The extractor consists of Hopper, Auger, Cylinder and belt and pulley. The fruits such as pineapple, orange and watermelon were purchased in Koko Junction Market at Oghara, Delta State. This fruits were washed, clean and cut into pieces and then feed into the extractor via the hopper. Several tests were carried out such as extraction efficiency, juice extraction capacity, juice yield, and extraction loss. It was observed that watermelon has the highest juice yield and efficiency. Also, orange had the highest extraction loss when compared to pineapple and watermelon.

Keywords: *Extractor, hopper, belt and pulley, performance*

1. Introduction

Agriculture was the backbone and sustaining the source of Nigerian economy prior to the discovery of crude oil in large amount during the 1970s. Initially, the agricultural sector contributed hugely to the gross domestic product (GDP) of the country, but the discovery of oil has resulted in a negative setback in the sector because more interested had tilted towards petroleum products (Fasanya et al., 2013; Osueke et al., 2018).

The Market Demand for vegetable and fruit juices is increasing rapidly due to their health benefit. (Chandi, 2019; Borderías, Sánchez-Alonso, and Pérez-Mateos, 2005). Citrus is a fruit which consists of the family of lime (Citrus aurantifolia), orange (Citrus sinensis), lemon (Citrus limon), grapefruit (Citrus paradisi), and tangerine (Citrus x tangerina). These juices can be processed further into healthful beverages or consumed freshly contain nutrients such as Potassium, Calcium, Iron, folic acid and vitamins A, B and C and other nutrients (Olaniyan, 2010). Also, these fruits have a short-lived after they are harvest due to their high water contents (70-90%) which aid chemical deterioration (Taylor, 1998;) and are vulnerable to damage by environmental, chemical, mechanical impacts, and consequently requiring storage, processing, preservation, packaging and consumed as juice (Aremu et al., 2016).

A machine that mechanically separates juices from the solid part (Pulp) of most organic products such as vegetable, herbs, fruits and leaves known as juice extractor (Farrell, 2014). Initially, mechanical juice extractor was made of roller press like skinner. This extractor is known as drum type and handles fruits cut into halves. Presently, several types of juice extractors are used which includes turn gear, centrifugal pump, single gear, and anger juicers, etc. (Guss, 1958; Duckworth, 1968; Abulude et al. 2007).

A pineapple fruit juice extractor was developed by Badmus and Adeyemi (2004). The machine was able to process 12 kg of ripe pineapple fruit into 8 L of pineapple juice successfully. Aremu et al. (2016) developed a portable multipurpose juice extractor from some tropical fruits such as orange, watermelon, and pineapple. Tests were performed for both unpeeled and peeled fruits using different sieve opening diameter (0.5, 1, 1.5 and 2 mm. results showed that an increase in the diameter of the sieve increases the yield and efficiency of the juice. Ishiwu and Oluka (2004) design and fabricated a juice extractor. This extractor machine comprises a frame, screw jack, feeding pot, pressing mechanism, frame, interlock, and discharge mechanism. Test performed showed that the efficiency and juice yield of the extractor is 3% and 76 respectively.

Abulude et al. (2007) developed a manually operated juice extractor to save time and prevent spoilage and wastage of juices. Tests were carried out on the fabricated juice extractor using pineapple and orange juices. It was deduced that the efficiency of the orange and pineapple yield was 83.86 and 85.38% respectively.

In the work of Odewole et al. (2018), a manually-operated multipurpose fruit juice extractor was developed. The test was performed on the juice yield, juice content, extraction capacity, extraction efficiency and extraction loss using sweet orange, red apple, green apple, pineapple, lime, lemon, watermelon, and grape. Results show that the highest yield was pineapple why sweet orange had the lowest extraction loss.

This research aims to develop a juice extractor machine using locally available materials in Nigeria at low cos and reduce the burden of extracting juice with hand and cup. Also, performance evaluation will be carried out on the fabricated juice extractor such as juice yield, extraction efficiency and losses, extraction capacity and juice content.

2. Materials and Methods

2.1. Description of the Machine Components

Cost and availability of materials, efficiency, and quality of Juice, the capacity for processing the juice, tensile strength, corrosion-resistant as well as bending and shear forces were considered during the design of the extractor. The design and selection of materials were carried out according to Cruz et al. (2016); Ogunsina (2008); Olaniyan (2010) and Aremu (2016)

2.1.1. Hopper

The design and fabrication of the hopper were carried out to accommodate the allowable the volume of fruits per stroke of the piston 1.5x 10-3m (Ogunsina, 2008). Stainless steel with thickness 1.5mm was chosen because of its high strength and rigidity, corrosion-resistant and does not decolorize the food. Also, it can be machined easily. The total weight of the hopper was 9.86N. It has four faces with two opposite face equal with dimension. The first two opposite face of the Hooper has the top and bottom as 230mm x 80mm, other parts are 230mm x 120mm, its Overall length is 230mm and angle of repose 25o to allow an excellent flow of fruits to be discharged into the cylinder by gravity without hanging up.

2.1.2. The Cylinder

The weight of the cylinder was 14.21N and its volume was 1.24 x 10-4m3. The material used for the cylinder is stainless steel of thickness 2.5mm and diameter 25mm. This enhances the quality and safety of juice to be processed because of its resistance to pitting, the machine easily and it does not decolourized the food. Also, the cylinder's chamber was perforated at the base to ensure that the juice is expelled out easily Aremu, 2016).

2.1.3. The Auger

The auger helps uses a profiled screw style moulding to compact and crush the fruits against a static screen allowing the juice to flow through the screen while the pulp is expelled through a separate outlet(Aremu, 2016; Olaniyan, 2010).. Stainless steel of thickness 1.5mm was used to fabricate the auger to minimize cost, ensure quality and efficiency of juice expelled from the extractor.

2.2. Design Calculation

2.2.1. Design of the Pulley and belt

V–belt was used to transmit short-distance power. It matched groove within the pulley to ensure that the belt does not slip out. These devices were used to increase the torque transmission during operation. The maximum permissible ratio of the diameter of the shaft pulley to that of an electric motor is 4:1 (Aremu, 2016). If N1 is the speed of the motor in rpm, N2 is the speed of the worm conveyor shaft in rpm, D1 = diameter of the motor pulley in inch, D2= diameter of the shaft pulley in inch. The warm shaft speed was determined using eqn. (2.1).

$$N_2 / N_1 = D_1 / D_2 \quad (2.1)$$

$$L = \frac{\pi}{2}(D_1 + D_2) + 2C + \frac{(D_1 + D_2)^2}{4C} \quad (2.2)$$

Given that

$$N_1 = 1500rpm, D_1 = 1in, D_2 = 4inches$$

$$N_2 = \frac{N_1 \times D_1}{D_2} = \frac{1500 \times 1}{4} = 375mm$$

The machine is driven by a conveyor while the driving machine is a single-phase electric motor. The service factor is N_{sf} =1.6 (Cruz et al., 2016)

The ratio of the amount of work that the motor can perform to time is known as design horsepower. The type of belt can be determined using eqn. (2.3)

Design horsepower $N_{sf} \times hp$ (Design of Machine Element by Faires (1968) (2.3)

$$D_{hp} = 0.8HP$$

The speed of the belt, V_m can be determined using eqn. (2.4)

$$V_m = 2\pi rN \quad (2.4)$$

$V_m = 2\pi rN$

$= 2 \times 3.142 \times \frac{1}{2} x10^{-3} \times 1500$

$= 4.713 m/s$

With D_{hp}=0.8HP and $N_{small\ sheave}$ =1500rpm. Type A V-belt is used from the various types of V-belt (Cruz, 2016)
The length of transmission of the belt is determined using eqn. (2.5)

$$L = 2C + \frac{\pi}{2}(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C} \qquad (2.4)$$

Where, C=19.67inches

$$L = 2(19.67) + \frac{3.143}{2}(4+1) + \frac{(4-1)^2}{4(19.67)}$$

$L = 47.43 in$

Since the length of the belt transmission is 47.4inches, V-belt A-46 is chosen (Cruz, 2016).
The torque and power was calculated according to Cruz (2016)
Torque, $T = 1.5 ft \times 0.86 Ib = 1.29 ft - Ib$

$2\pi TN$

Power, $= 2\pi(1.29 ft - Ib)(1500 rpm)$

$P = 0.41 hp$

The available horsepower of the motor in the market is 0.5Hp. Thus, the horsepower used to fabricate the juice extractor is 0.5

2.2.2. Worm Shaft

The design of the worm shaft was determined using eqn. (2.6)

$$d^3 = \frac{16T}{0.27\pi\delta_0}$$ (Shigley and Mitchell, 1983; Olaniyan, 2009) (2.5)

Where, d is the diameter of the shaft in m, δ_0 is the yield stress in N/m² and T is the maximum torque in Nm.

2.2.3. The Capacity of the Extractor

The capacity of the machine was calculated using eqn. (2.7)

$$Q = 60 \times \frac{\pi}{4}\left(D_2{}^2 - D^2{}_2\right)pN\phi \qquad (2.6)$$

Where, Q is the theoretical capacity of the machine, p is the screw pitch in m, ϕ is the filling factor and N is the shaft speed in rpm.

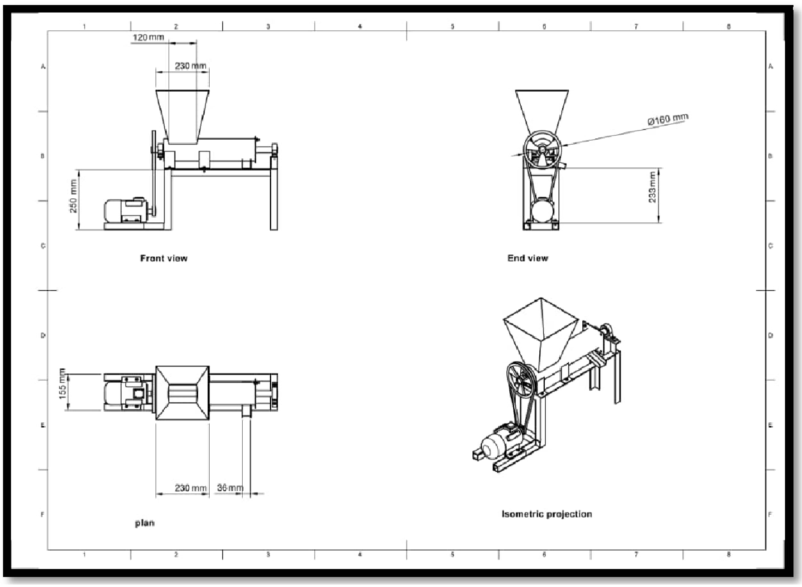

Figure 1: Sectional View of the Juice Extractor

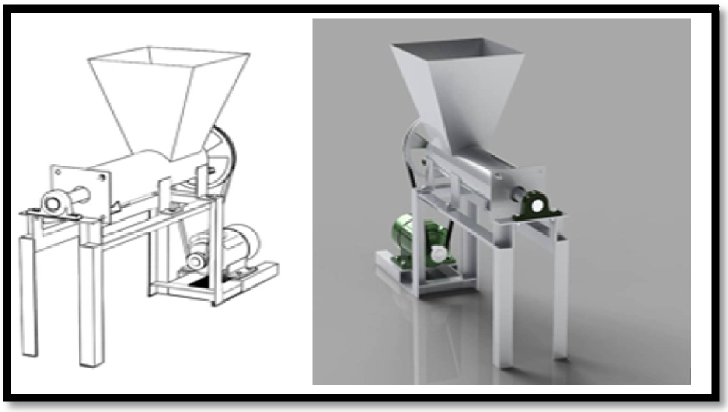

Figure 2: Designed Juice Extractor in 3D

2.3. Preparation of the Sample and Test Analysis of the Juice Extractor

2.3.1. Juice Efficiency

The efficiency of the juice was calculated using eqn. (2.8).

$$\text{Juice Efficiency (\%)} = \frac{\text{Weight of juice extracted}}{\text{Weight of feed sample x juice constant of fruit}} x100 \quad (2.8)$$

$$\text{Extraction capacity (kg/h)} = \frac{\text{Weight of juice extracted}}{\text{Time spent for extraction}} \quad (2.9)$$

$$\text{Juice Yield, } J_Y = \frac{\text{Weight of juice extracted}}{\text{Weight of juice extracted x Weight of residual waste}} x100 \quad (2.10)$$

$$\text{Extraction loss, } E_1\,\% = \frac{(\text{Weight of feed sample} - (\text{Weight of juice extracted} + \text{Weight of residual waste})}{\text{Weight of feed sample}} x100 \quad (2.11)$$

2.4. Preparation of the Sample and Performance Analysis of the Machine

The Juice extraction time, weight of fruits introduced to the extraction, weight of juice extracted from the machine, as well as the residual waste were obtained. Also, the juice constant of the fruit (in decimal) was determined and recorded. Fresh fruits (watermelon, orange and pineapple) each of 4kg were purchased from Koko Junction Market, Oghara, Delta State, Nigeria. The fruits were washed, cleaned and peeled using knife and poured into the clean machine via the hopper. Power was transmitted to the screw shaft by turning the machine handle, causes the presser to crushed and cut the peeled fruits against the perforated cylinder for 20 min. the juice then pressed through the perforated holes of the sieve into the collector at the base of the extractor (Abulude, 2007; Aremu, 2016; Eyeowa, 2017) to enable juice to be extracted from the fruits. The presser was then unscrewed so that it can reduce to its initial position and the residue waste was taken out from the extractor after removing the sieve. During the tests, the time taken for extraction, weight of juice feed and juice extracted from the machine were recorded.

3. Results and Discussion

Figure 2-5 show the results obtained from the experimental runs during the operation of the extraction machine. Watermelon has the highest yield and extraction efficiency while orange has the lowest efficiency as shown in figure (3 & 5) respectively. Also, it can be deduced from figure 4 that the machine extraction capacity for Pineapple, Orange and Watermelon are 13.2, 12.9 and 14.8Kg/h respectively. The extraction loss for orange was lower than that of pineapple while watermelon has the least extraction loss. This can be seen in figure 6.

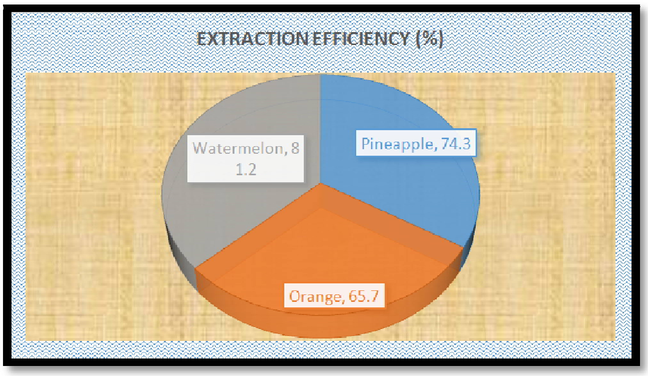

Figure 3: Juices Extraction Efficiency

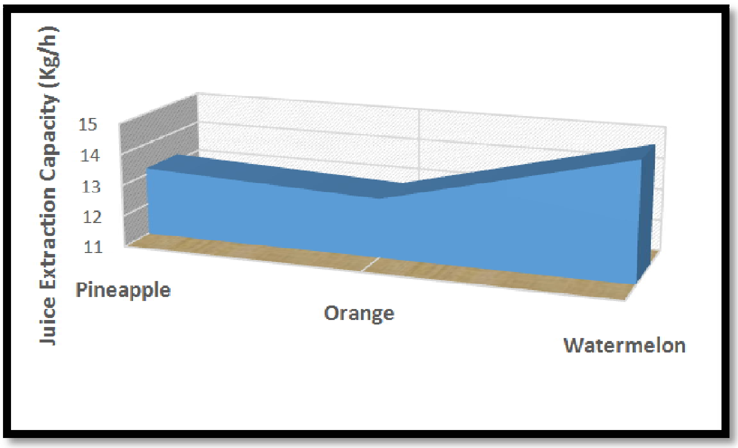

Figure 4: Juice Extraction Capacity

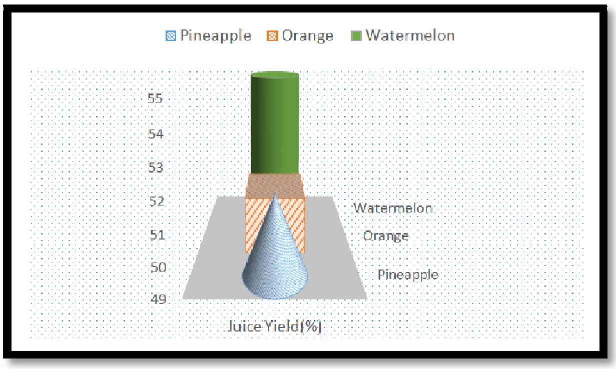

Figure 5: Percentage of Juice Yield

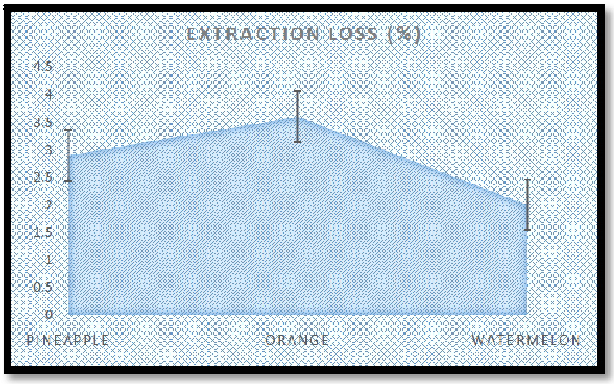

Figure 6: Extraction Loss (%)

4. Conclusion

A functional juice extractor was developed using locally sourced materials in Nigeria to reduce the bottleneck of using hand and cup to extract juice from fruits. The fruits such as pineapple, orange and watermelon were purchased in Koko Junction Market at Oghara, Delta State. Several tests were carried out such as extraction efficiency, juice extraction capacity, juice yield, and extraction loss. It was observed that watermelon has the highest juice yield and efficiency. Also, orange had the highest extraction loss when compared to pineapple and watermelon.

5. Acknowledgement

Authors deeply express their gratitude to appreciate the efforts of the Management of Delta State Polytechnic, Otefe-Oghara for their immense contributions to the completion of this research work.

6. Conflict of interest

Authors declare that there is no conflict of interest whatsoever.

7. References

i. Abulude, F. O., Elemide, A. O., Ogunkoya, M. O., Adesanya, W. O. (2007). Design and Performance Evaluation of a Juice Extractor Constructed in Nigeria. *Research Journal of Applied Sciences*, 2(1), 31-34.

ii. Aremu, A. K., Ogunlade, C. A. (2016). Development and Evaluation of a Multipurpose Juice Extractor. *New York Science Journal*, 9 (6), 7-14. http://www.sciencepub.net/newyork.

iii. Chandi, K. D. W., Jinfeng, B. Xuan, L., Jianing, L., Jian, L., Xinye, W. (2019). Juice Related Water-Soluble Pectin Characteristics and Bio-accessibility of Bioactive Compounds in Oil and Emulsion Incorporated Mixed Juice Processed by High Pressure Homogenization. *Food Hydrocolloids*, 93 (2019), 56-67. https://doi.org/10.1016/j.foodhyd.2019.02.011.

iv. Cruz, A. L. F., Magnaye, M. V. G., Manalo, E. J. V. (2016). Development of Ginger Juice Extractor. *International Journal of Science and Engineering*, 2(8), 15-26.

v. Duckworth, R.B. (1968). *Fruit and Vegetable*. 3rd Edn. Chaucer Press Ltd. London. 176-179.

vi. Fasanya, I. O., Onakoya, A. B. O., Agboluaje, M. A. (2013). Does Monetary Policy Influence Economic Growth in Nigeria? *Asian Economic and Financial Review*, 3(5), 635-646.

vii. Guss, W. V. (1958). *Commercial Fruit and Vegetable Products*. 4th Edn. McGraw-Hill Book Company Inc. New York. 344-389.

viii. Odewole, M. M., Falua, K. J., Adebisi, S. O. Abdullahi, K. O. (2018). Development and Performance Evaluation of a Manually-Operated Multipurpose Fruit Juice Extractor. FUOYE Journal of Engineering and Technology, 3(1), 48-5.

ix. Ogunsina, B. S., Lucas, E.B. (2008). Development of a Manually Operated Cashew Juice Extractor. Agricultural Engineering International: The CIGR Ejournal. Manuscript FP 07 037. Vol.X.

x. Olaniyan, A. M. (2008). Development of a Small Scale Orange Juice Extractor. *J. Food Sci. Technol,* 45 (1), 105-108.

xi. Onokwai, A. O., Okonkwo, u. C., Osueke, C. O., Ezugwu, C. A., Eze, N. C., Diarah, R. S., and Olawale, O. (2019). Quantifying Cassava Waste Generation and Biogas Production in Eha-Alumona Grinding Mills. *International Journal of Civil Engineering and*

xii. *Technology*, 10(01), pp. 2032– 2043 http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=10&IType=01

xiii. Osueke, C. O., Olayanju, Onokwai, A. O., Uzendu, P. (2018). Design anf Construction of an Automatic Fish Feeder Machine. International Journal of Mechanical Engineering and Technology, 9(10), 1631-1645.

xiv. Taylor, A. O. (1998): *Training manual for UNDP/ UNIDO*. Training programme for women Entrepreneurs in food processing industries.