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Evaluation of Development and Performance of a Manually Operated Orange Juice Extracting Machine

By

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Abstract

This paper was intended to present the significance of harnessing all aspects of engineering education-Mechanical, Electrical, Chemical and others including sciences for a rigorous exercise of productive decision making. Therefore, this machine was developed on the basis of mechanical and physical properties of the sweet orange fruit produced in Ondo and adjoining South Western States of Nigeria. Those properties involved were fruit density, size peeled whole fruit mass ratio, epicarp/mesocarp thickness, crushing strength, stiffness modulus, modulus of resilience, bioyield point, toughness modulus maximum breaking force and minimum deformation at failure. Test conducted on a fabricated machine showed that the maximum production capacity was 8.450l/h at an applied force of 0.280KN while maximum extraction efficiency was 90% for fruits cut into small pieces. Residue increased with the extent to which the fruit was reducing into pieces before extraction. Machine power requirement is between 0.02 and 0-28KN.

Orange also refers to citrus which belongs to the family of dicotyledonous berries. This fruit contains sweet tasting juice, when ripe are eaten to give maximum Vitamin C which is a source of good health. When ripe the fruit deteriorate so fast but if the juice in extracted and preserved, the better. The juice is normally used in squashes, preparation of pleasant tasting “soft drinks” as flavoring agent and source of Vitamin C in the diet. The methods and equipment used for the juice extraction as described by Pyke (1970), Nelson and Tressler (1980), Benman (1981 and Saravacos (1986) are sophisticated and mainly suitable for production at an industrial scale. The plastic juice extractor types are of low output and tiresome, while the electrically powered ones are costly and cannot be used in places where there is no electricity. Therefore there is need to develop an orange juice extractor which could be easily

fabricated and operated without rigour, used without electricity and of reasonable output. To meet this need, a portable and manually operated orange juice extractor was designed and constructed. This paper presents the design details and performance evaluation of the machine.

Materials and Methods

This extractor was designed on the basis of physical and mechanical properties of sweet orange produced in Ondo State, in particular Owo town..

Determination of Physical and Mechanical Properties

Freshly harvested sweet orange fruits were purchased at Owo. The bulk fruits were stored in the laboratory under normal (room temperature) for about 20 hours to enable them acquire uniform thermal and moisture conditions. They were then sorted and sampled for use in evaluating the physical and mechanical properties of whole and peeled fruits. Fruit size was determined by measuring the longitudinal and lateral diameters of fifty fruits randomly selected form the bulk using a veneer caliper of 0.1mm precision. Fruit mass obtained with the help of an electronic balance weighing 0.001g and density was determined by the water displacement method reported by Mohsenin (1986). Moisture content was determined by drying peeled whole fruits for 5 hours at 100^0C.

Quasi-Static uni-axial parallel plate compression tests were done on peeled and unpeeled fruits. Loading was done on the longitudinal axis using a universal testing machine. After loading to failure, the contact area of the fruit surface with the plates was determined from an impression stained on a sheet of white cloth placed in between them as carried out by Oguntuyi,V F(1987),also Dinrifor and Faborode (1993). This impression was traced on a graph sheet and was obtained by the method of counting the squares. This was used in evaluating the resistance to crush the fruits.

The force determination curves obtained were analyzed for the stiffness modulus i.e. the ratio of the average maximum force to the average maximum deformation at failure and modulus of resilience i.e. area under the force-deformation curve up to bio yield and toughness modulus i.e. area under the force deformation curve up to failure (Zoerb and Hall 1960, Mohsenin and Gholich1962). Bioyield point was taken as the point on the force-deformation curve at which juice from loaded fruit just oozed without the skin tearing, and failure point was obtained as the point at which the fruit epicarp broke and the juice flowed freely. The cross-head speed used was 4mm/min. Each test was repeated five times an the average values were taken

Outlook of the Orange Juice

Main components of the orange juice extractor are the cylinder, cylinder seat, base plate, tool frame, lever arm, spring housing, connecting rod and piston (fig a).

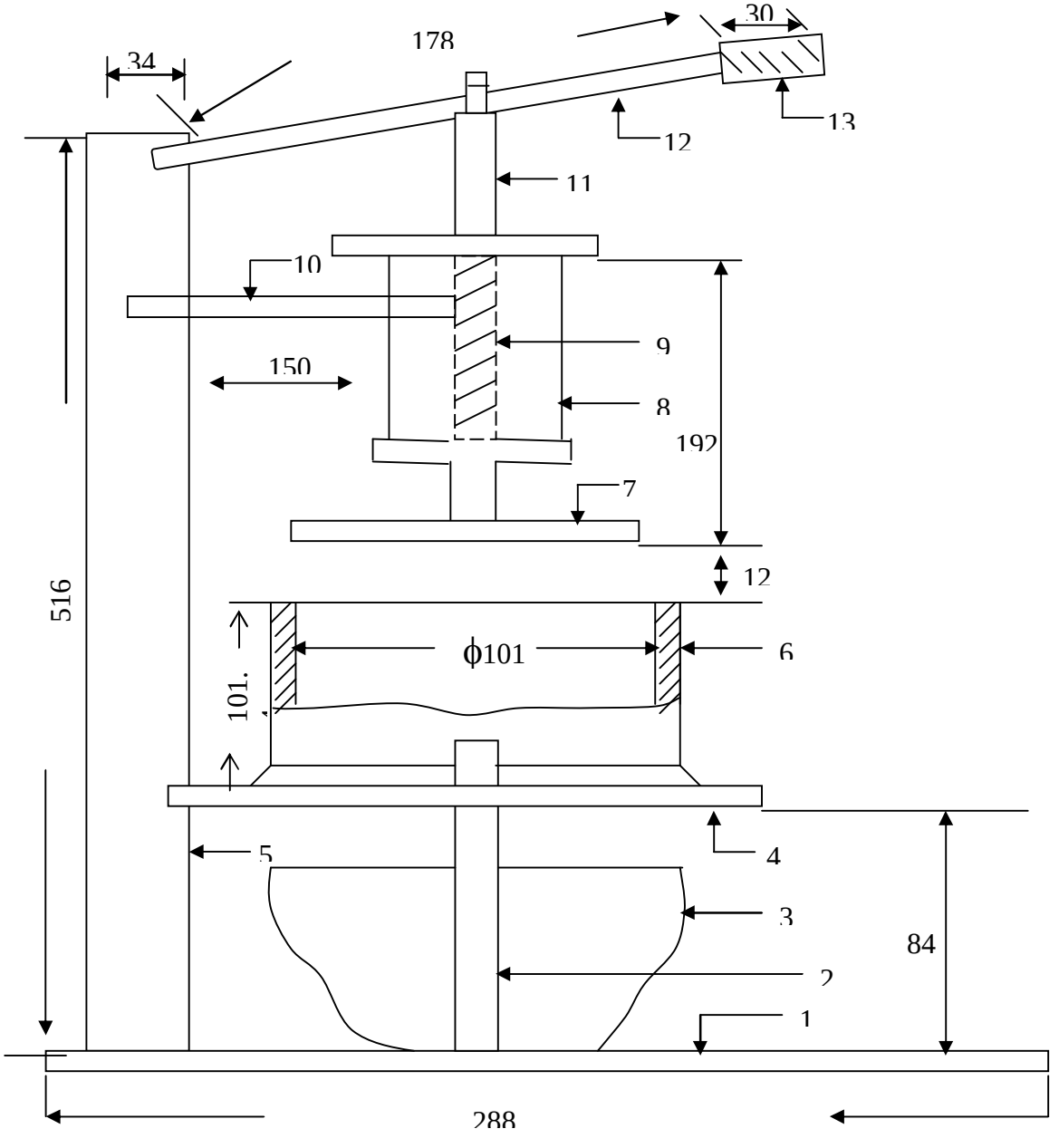


Figure (a): Assembly drawing of orange juice

Part List

S/No	Description/Specification	Quantity	Material
1.	Base plate (ϕ288 X 160mm)	1	Steel plate
2.	Retort stand (ϕ10 X 86mm	2	Mild steel
3.	Juice collector	1	It varies
4.	Cylinder seat (ϕ103mm)	1	Mild steel
5.	Tool frame (ϕ33.5 X 516mm)	1	Galvanized iron pipe
6.	Cylinder (ϕ101 X 101mm)	1	Mild steel
7.	Piston (ϕ10 X 101mm)	1	Mild steel
8.	Spring housing (ϕ33.5 X 192mm)	1	Galvanized iron pipe
9.	Compression spring (ϕ16 X 192mm)	1	Metal spring
10.	Hinge support (ϕ10 X 100mm)	4	Mild steel
11.	Connecting rod (ϕ16 X 278mm)	1	Mild steel
12.	Lever arm (ϕ16 X 214mm)	1	Mild steel
13.	Wooden handle (ϕ10 X 36mm)	1	Wood

The cylinder, which has a perforated base, is made of mild steel and rests on a seat which is held in position by the tool frame and retort stands. It has an opening at the top through which the piston can move to the bottom of the juice extractor. It can be removed and can equally be replaced on its seat. This made it possible for it to be filled with fruits before mounting it in place for operation of the machine. This piston is made of mild steel and it is connected to the lever arm by a connecting rod. This rod runs through a cylindrical housing for the spring with which it gets loaded. The spring housing and lever arm are both connected to the tool frame with the arm and held by a bolt and nut which allows up and down movement of the lever. The lever arm also rests on a groove formed at the end of the connecting rod and terminates at the wooden handle. The applied force at the handle by depressing it manually is transmitted through the connecting rod to the piston. This makes the piston to be lowered into the cylinder which compresses the orange fruit and extracts the juice through the perforations at the base of the cylinder. Juice collection is done in the container placed under the cylinder. The tool frame and retort stands are mounted on the base plate which helps in maintaining machines stability. The juice extractor has a height of about 516mm and base length and width of about 288mm and 160mm respectively. It can also be mounted on a table. In order to operate the extractor, peeled orange fruit are loaded into the cylinder until it is filled. It is placed on its seat with the machine standing on a level ground or kitchen table and aligned to the piston. The wooden handle of the lever arm is then depressed to push the piston down the cylinder to compress the orange for juice extraction. The juice flows through the perforations into the cylinder base.

Results

Results obtained from the measurement , physical and mechanical properties of sweet orange fruits are presented in tables a and b bellow.

Table a: Some Physical Properties of Orange Fruit. Standard Deviation in Parenthesis)

Property	**Whole Fruit**	**Peeled Fruit**
Longitudinal Diameter (mm)	67..5	57
	(6.23)	(5.08)
Lateral Diameter (mm)	7.2	62.6
	(5.4)	(4.1)
Density (8/Cm^3)	1.36	-
	0.30	-
Peeled-whole fruit mass ratio	0.74	-
	(0.48)	-
Epicarp/Mesocarp thickness (mm)	4.4	-
	(1.3)	-

Table b: Some Mechanical Properties of Sweet Orange fruits (Standard deviation in parenthesis).

Property	**Whole Fruit**	**Peeled Fruit**
Maximum breaking force (KN)	0.55	0.35
	(0.635)	(0.20
Maximum deformation at failure (cm)	2.73	2.15
	(0.635)	(0.20)
Bioyield Point (KN)	0.5	0.3
	(0.12)	(0.08)
Crushing Strength (kN/m^2)	0.028	0.022
	(0.007)	(0.005)
Stiffness modulus (KN/m)	18.35	13.61
	(3.43)	(1.48)
Modulus of resilience (J)	2.85	1.60
	(0.11)	(0.4)
Modulus of toughness (J)	4.66	2.5
	(0.53)	(0.38)

From these, the following design parameters were established: (i) cylinder bore and base (ii) power required (iii) piston surface area (iv) spring content (v) minimum extraction force.

To extract juice from an orange fruit using mechanical device, the applied force must exceed the maximum crushing strength of the fruit.

Results of performance tests shows that the machine through put is affected by the extent to which the fruit is cut prior to use in juice extraction and this can be seen from Table c bellow.

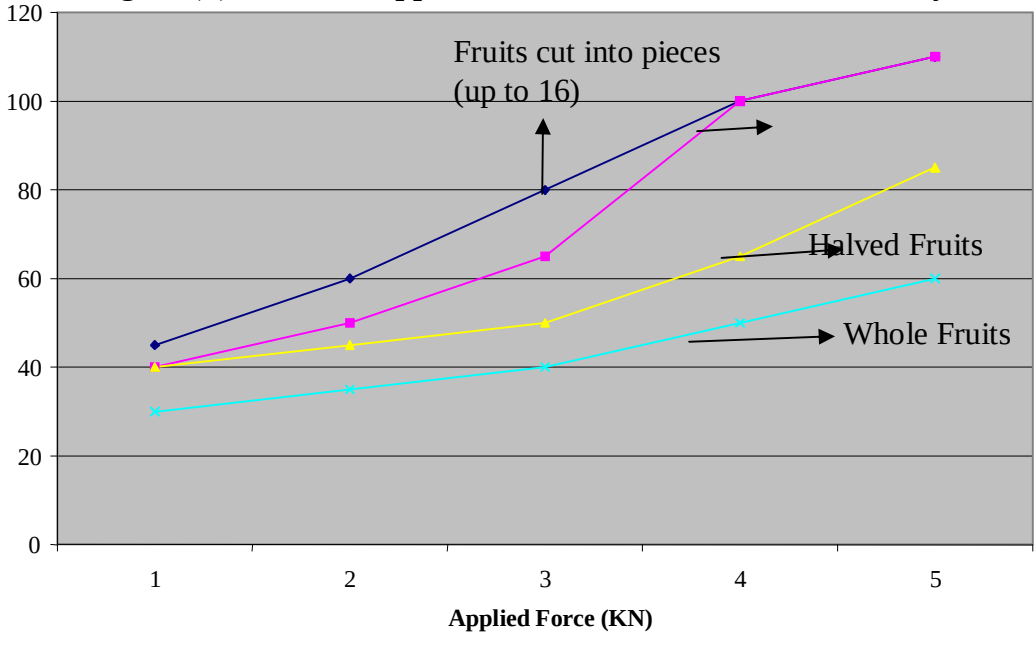
Table c: Maximum throughout Capacities of the Juice Extractor

Sample Form	**Force applied (KN)**	**Maximum Throughout capacity (l/h)**
Whole fruits	0.3	2.51
Halved fruits	0.3	4.83
Quartered fruits	0.25	5.07
Fruits cut into several pieces	0.285	8.44

Maximum average through put capacity was 8.441/h obtained at an applied force of 0.025KN on fruits cut into several pieces (up to 16), while the minimum was 2.51/h obtained at 0.30KN on whole orange fruits.

Figure (B) bellow shows that extraction efficiency increased with the applied force and depend on the extent to which the fruits were cut prior to juice extraction.

Figure (b): Effect of Applied force on the Extraction Efficiency



Maximum extraction efficiency was 98% obtained for fruits cut into several pieces at an applied force of 0.30KN.The power required was found to be about 0.028 and 0.021KW for juice extraction from whole fruit and those cut into several pieces respectively.

For the cylinder base perforations used, residue content of juice increased with the extent to which the fruits were divided.

Conclusions

From the evaluation of development and performance of this domestic orange juice extractor, the following conclusions were made:

a. The power required for the operation of this machine range between 0.021 and 0.028 KW.
b. The machine through put capacity depends on the extent to which the fruits were cut. Through put capacity increased with applied force and has a maximum value of 8.44/h for fruits cut into several pieces at 0.25KN.
c. Residue content of the juice increased with the extent to which the fruits were cut.
d. The extraction efficiency also increased with the applied force and was affected by the extent to which the fruits were cut prior to juice extraction. A maximum efficiency of 89% was obtained for fruits cut into several pieces.

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