Development and Performance Evaluation of an Orange Juice Extractor

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Abstract: The design and construction of orange Juice extraction was undertaken with the aim of achieving the extraction of pure orange Juice, free of squashed seeds and peels. The extractor consists of the cutting chamber which is made up of rotary shaft, knives attached at both ends and an inclined tray. While the squeezing chamber is made up of crankshaft, the rammer and a sieve. The machine has a shaft diameter of 12mm, torque and power transmitted as14252Nmm and 1.5kw respectively. The pulley has a linear speed of 10.74mls, the cross sectional area of the squeezing chamber (flat plate) was 12,000mm2 with a force of 5.32N on the plate due to pressure from the orange. While the net force acting on the plate was 3059N.The machine performance evaluation was carried out using tangelo and Tiv orange varieties. The actual efficiency of the machine was found to be 76.04% with a capacity of 6 l/hr (5.73kg/h). It was concluded that efficient Juice extraction would be better achieved with the use of this kind of machine than with a turning screw.

Key words: Orange Juice, cutting chamber, squeezing chamber, Extraction, Crank shaft.

1 Introduction

Citrus (Citrus sinensis) fruits are second only to apple in world trade and have been grown for millennia in their area of origin. They belong to six genera namely; fortunella, Eremocitrus, clymenia, poncitrus, microcitrus and citrus [1], but from an economic point of view, only furtunella, poncitrus and citrus fruits are important and the major commercial citrus fruits are eight species of the genus citrus. They are probably the most sought after fruits and consequently the most eagerly developed fruits in advanced as well as developing countries, climate permitting [1].

The group (genus) citrus, comprises species in which sweet orange, grape fruits, lemon and lime are included. In the sweet orange, good varieties include Valencia, Washington Navel, king, Ibadan sweet, Nigerian green skin and tangelo. The fruit tree is grown very extensively in the southern guinea savanna and high rainfall areas of Nigeria [2]. Although the plant is well adapted to area with high rainfall, it can be grown further north as an irrigated tree crop.

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Orange (citrus sinensis osbek) is the most popular among the citrus. Every parts of the orange including the ring have some nutritional value [3]. The fruit can be consumed raw or in form of juice, after peeling the ring. Orange Juice has become an indispensable part of our daily breakfast, it is considered as a fresh and perfectly nutrition way to start a day [4]. Like any other citrus fruits, oranges are also loaded with vitamin C. It contains minerals like calcium, sodium, potassium magnesium, phosphorus, copper, and sulphur. An orange also contains 15.4gms of carbohydrate, 12.2gms of sugar, 3gms of dietary fiber, 1gm of protein and 0.2gm of fat [4]. Apart from the vitamins and minerals, orange contains more than 170 phytonutrients, which include carotenoids, terpenoids, limonoids, glucarates,and flavanoids. Flavanoids, posses' anti-inflammatory, anti- tumor and anti- carcinogenic properties. They also prevent blood clotting and thereby reduce the chances of coronary thrombosis. The carotenoids which have antioxidant properties help in the prevention of blindness after 65. As orange contain a good amount of fiber, they help in digestion and in lowering blood sugar level. They fight colon cancer and diarrhea, prevent kidney stone formation, rheumatoid arthritis and cancer [4].

Today many people drink orange juice for breakfast, while lots of oranges waste due to inadequacy in the processing and preservation in the mist of great demand. In other words, there are few machines to match the growing demand for this product. Hence, the need to design and construct a hand-operational machine capable of extracting juice from the orange fruits.

2 Materials and Methods

2.1 Description of the orange juice extractor

The main feature of the extractor is shown in figure 1, which include the cutting chamber and the squeezing chamber working side by side each other. The cutting chamber is made up of flat metals attached to a rotary shaft fixed at both ends to the bearing, with knives held at 90^o to a fixed base. When the orange rolls over an incline tray, it stops at the base of the knife edges where the rotary flat metal pushes it through the knives to produce orange fragments at the other end, which then fall off the cutting chamber into the squeezing chamber.

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The squeezing chamber is made up of crankshaft, rammer and sieve with the fragmented oranges in the chamber. The rammer by means of a reciprocating rotary motion of the crankshaft, squeezes the juice out of the orange, the juice exuding through the sieve is pure.

The materials used for the construction of the orange juice extraction are: mild steel sheet, mild steel rods, brackets, sieve (stainless steel) and stainless steel knives with shear strength of 41 to 48 GN/m^2 [5]. The choice of these materials was based on their unique properties that are adoptable to particular sections of the machine such properties include; durability, availability, machinability, cheapness light weight and malleability. The machine comprises the following components; shaft, pulley, hub, bearings, plunger (squeezing chamber), key and main body.

2.2 Design Calculations

Design of Shaft

The extractor consist of two shafts, the cutting shaft and the squeezing shaft (James, 1983). The shaft diameter is determined using equation (1) (Mott, 1985).

$$D^3 = (16 / \pi S_s \sqrt{(KbMb)2} + (K_tM_t)^2 \quad \cdots\cdots \quad 1$$

Where, D = diameter of shaft.mm

S_s = shear stress, Nmm^2

K_bK_t = Combine shock and fatigue factors applied to the bending and torsion moment respectively.

M_t = torsional movement, Nmm

M_s = bending movement, Nmm

Torque transmitted through the shaft is obtained from equation (2).

$$T = \frac{\pi c d3}{16} \quad \ldots\ldots\ldots\ldots \quad 2$$

Where, T = torque

C = shear stress N/mm2

D = diameter, mm

Power transmitted by the extractor was calculated from equation (3)

$$P = \frac{2\pi NT}{60} \quad \ldots\ldots\ldots \quad 3$$

Design of Pulley

The pulley standard chamber and width of 200mm and 25 mm as given by james (1983). The linear speed of the pulley was obtained from equation (4)

$$\text{Linear speed (v)} = \frac{\pi DN}{60} \quad \ldots\ldots\ldots.4$$

Where, D = diameter, mm

N = number of rev.

Design of hub.

The diameter and length of the hub where obtained from equation (5) and (6) respectively.

$$\text{Diameter of hub } (\delta) = 2d \text{ ------ } 5$$

$$\text{Length of hub (L)} = \frac{\pi d}{2} \quad \text{-------- } 6$$

Where, d = diameter, mm

Design of key

The width, thickness and length of key where also obtained from equation 7, 8 and 9 where,

Width of key (w) = $\frac{d}{4}$ ……..7

Thickness of key (t) = $\frac{2w}{3}$ ……….8

Length of key (l) = $\frac{\pi d}{2}$ ------------9

Where, d = diameter, mm,

w = width, mm

Design of bearing

Approximate service life of bearing (in revs)

$L = (\frac{c}{w})k \times 10^6$ ……. 10

Where, c = dynamic radial load rating of ball bearing (144.25N)

k = 3. (For ball bearing).

Reliability of the bearing (R)

$Log_e \left(\frac{1}{R}\right) = (\frac{L}{a})b$ ------- 11

Where, L = life span of bearing

a = 6.84, and b = 1.17

Squeezing chamber (plunger)

Cross sectional area of flat plate

$A = L \times B$………… 12

Where, L = length of plate

B = breadth of plate.

Force in the plate due to pressure from orange.

$F_L = P \times A$…………… 13

$= P \times L \times B$ ………….. 14

Where, p = axial load (N)

A = area of plate (mm^2)

Ratio of length of connecting rod to radius of crank.

$N = \frac{L1}{r}$ ………… 15

Where, L_1 = length of connecting rod.

R = radius of crank.

Net force acting on the plate.

$F_p = f_L + F_1$ ……………. 16

where, F_c = force on plate due to orange.

F_1 = Initial force of reciprocating part.

Force in connecting rod (f_c)

$Fc = \frac{fp}{cos\theta} = \frac{\sqrt{(1-(sin\theta)2}}{n2}$ ………..17

2.3 Performance Evaluation.

The performance evaluation of the juice extractor involves evaluation of the machine's capacity and efficiency. The parameters investigated include capacity (kg/h) and efficiency (%). The parameter were calculate using two varieties of orange namely tangelo and Tiv orange weighing 141 and 148g respectively. The orange weight and volume of whole orange peeling were determined, while orange weight and volume of juice collected and

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extracted, % by weight of juice extracted and orange squeezing time was all determined after subjecting the oranges to the machine.

3 Results and Discussion

Table 1 shows the design and calculated result while table 2 shows the average orange juice yield for the two orange varieties.

Table 1: Design Parameter

S/N	DESIGN PARAMETERS	RESULT
1	**Shaft Design**	
	Torgue transmitted through shaft, Nmm	14252
	Power transmitted, kN	1.5
2	**Pulley Design**	
	Linear speed m/s	10.74
3	**Design Of Hub**	
	Diameter of hub, mm	24
	Length of hub,mm	19
4	**Design Of Key**	
	Width of key, mm	3
	Thickness of key, mm	2
	Length of key, mm	19
5	**Bearing Design**	
	Life span of bearing, rev	10^6
	Reliability of bearing, %	72
6	**Squeezing Chamber (Plunger)**	
	Cross sectional area of flat plate,mm2	12000
	Force on the plate due to pressure from orange, N	5.32N
	Ratio of length of connecting rod to radius of crank.	6.67
	Net force acting on the plate, N	3059
	Force in connecting rod, N	3090
	Calculated parameter	
	7 capacity (L/m	6.00
	8 Efficiency (%)	76.04

Table 2: Average Juice Yield for Two Orange Varieties.

Orange varieties	Av. wt. of whole peeled orange	Av. of whole peele d orang	Av. wt of juice collected (g)	Av. of juice extracte d (cm3)	% by wt of juice extracted (%)	Av. squeezing time (s)

		e (cm3)				
Tangello	141	150	72.20	50.30	58.2	30
Tiv orange	148	152	67.46	48.60	52.7	30

Table 3: Cost Analysis

ITEMS	Quantity	Unit cost(#)	Amount (#)
Angle iron	1 length	1400	1400
Bearings	4pieces	250	1000
Shaft	2×500mm	1000	2000
Metal sheet	1length	600	600
Weiding eletrate	1lump	200	200
Paint	-	1000	1000
Labour	-	-	
Transportation	-	-	

The power transmitted by the shaft was found to be 1.5kw, while torque transmitted by the shaft was 14252Nmm. The linear speed of pulley was 10.74m/s and they had diameter and length were 24 and 19mm respectively. The key width, thickness and length were found to be 3, 2 and 19mm respectively while reliability of the bearing was obtained at 72%. The cross sectional area and force on the flat plate due to pressure from orange(squeezing chamber) where 12,000 mm^2 and 5.32N respectively. The net force acting on the plate and the force in the connecting rod were 3059 and 3090N respectively.

The orange juice extraction was found to have a capacity of 6 *l/hr* (5.73kg/h) and an efficiency of *76*.04%.

4 Conclusions

The development of the juice extraction was carried out with the aim of achieving efficient and quality juice extraction. The performance evaluation of the juice extractor showed that it can be used effectively for extracting juice from different varieties of oranges especially tangelo and Tiv orange. The actual capacity of the extraction was 6 *l/hr* (5.73kg/h) with an efficiency of 76.04%. The juice extraction could overcome the waste due to inadequacy in processing and presentation of the orange as well as bridging the gap between demand and supply of orange juice.

5 REFERENCES

[1] Chapot. H. (1973). The citrus plant; plant production and protection division. FAO. Rome, Italy.

[2] Agricultural Extension and research liaison sources (AERLS,1987). A guide to the production of citrus, Ahmadu Bello University, Samaru Zaria.

[3] Morton, J (1987). Fruit of warm climate http://www.hortpurdue.edu/newcrop/morton/banana.html. Retrieved on 6/08/2012.

[4] Sonia, N. (2011). Nutritional facts about oranges; Calories in oranges. http://www.buzzle.com/articles/nutritional-facts-about-orange-calories-in-oranges.html. Retrieved on 6/08/2012.

[5] Redford, G. D. (1975). Mechanical Engineering Design, Macmillian Inc. Ltd., England.

[6] James, H.E (1983). Engineering design Graphics (4th edition). Addison –Wesley Educational Publishers Inc. United Kingdom.

[7] Mott, R.C (1985): Machine element in mechanics design., Merril publishing company. Columbia Tiront.

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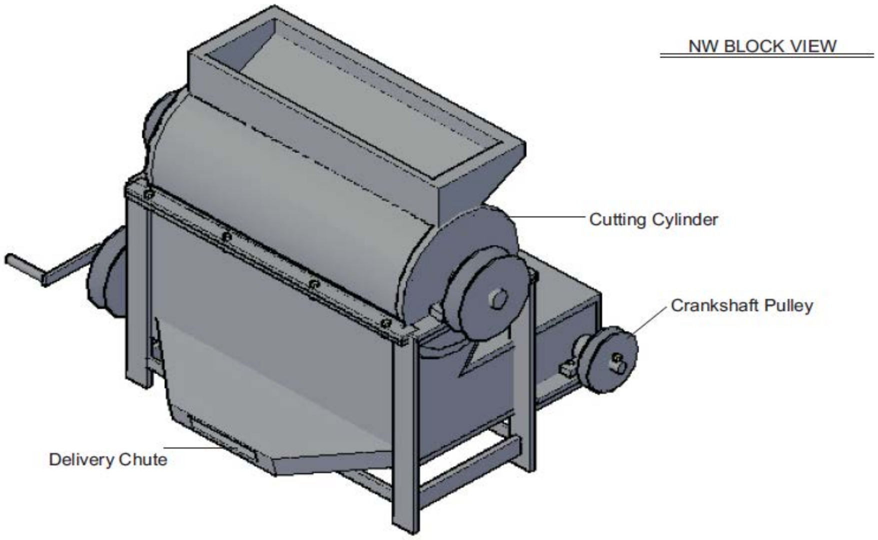
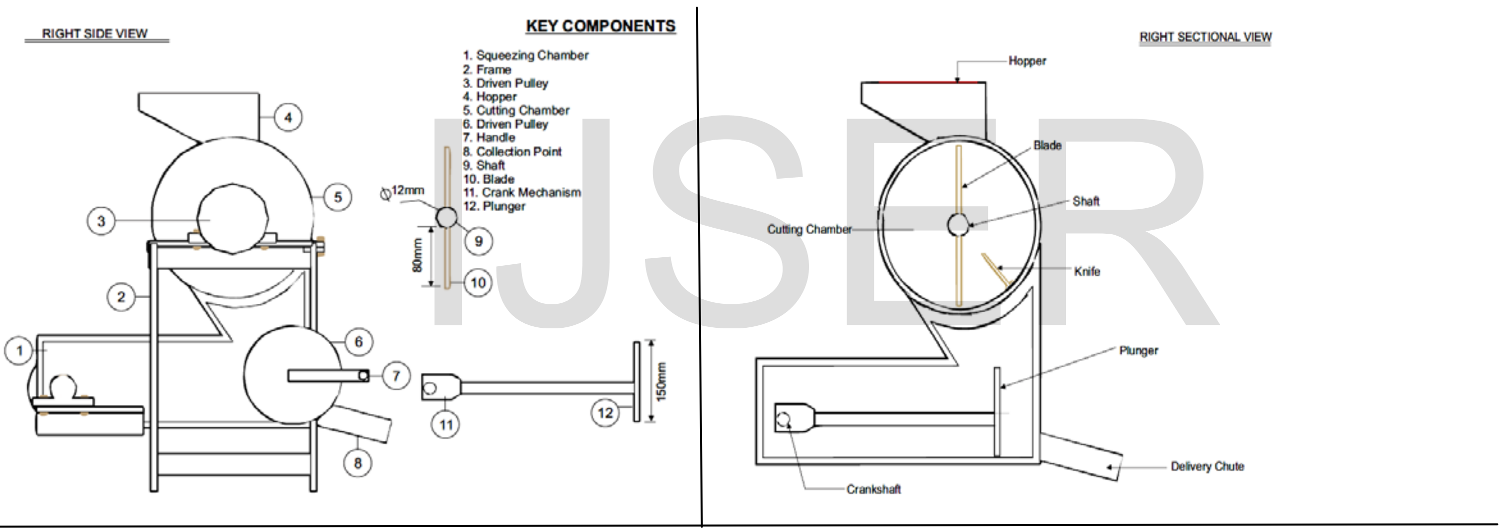


Fig. 1: Isometric drawing of orange juice extractor



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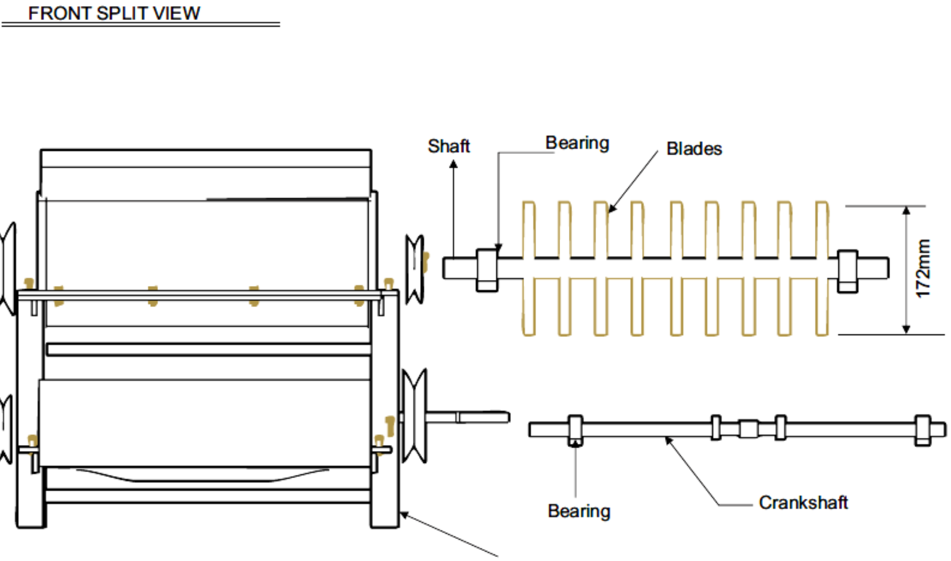

fig.2: detailed drawings