



Research Article

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Design and Construction of an Automated and Manual New-Fangled Fruit Juice Extractor

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ABSTRACT: The goal of this study was to design and build an automatic and manual new-fangled fruit juice extractor. People's growing desire for fruit juice, owing to its nutritional benefits, has resulted in the development of a machine that would make the extraction of huge quantities of fruit juice easier and more efficient. The ideal operating criteria for the new-fangled juice extraction machine, juice yield, extraction loss, and extraction efficiency, were assessed for performance throughout the design phase. The entire production capacity of new-fangled juice extraction machines, both automated and manual, was also assessed. The machine was built manually with the use of local materials and tools. The major materials used for the construction of the machine were mild steel, stainless steel, and plastic. During the construction of the machine, the component pieces were fabricated separately using mild steel sheet, stainless steel, and plastic before being finally assembled. It was built in such a way that when the handle is moved, the fruits are crushed and juice is produced. It was also built to run automatically thanks to the incorporation of a drive belt and an electric motor. The orange and citrus fruits were washed and weighed in this study, with fruit weights ranging from 1.4kg to 2.5kg. Maximum juice output, extraction efficiency, and extraction loss were all determined to be 77.6%, 85.3%, and 6.5 percent, respectively. The results demonstrate that the newly planned and manufactured juice extractor performed well in terms of juice extraction capacity.

Keywords: Extraction Efficiency, Extraction Loss, Juice Extractor, Juice Yield, New-fangled Design.

1. INTRODUCTION

Juice extraction industries have advanced fast in developed countries such as the United Kingdom and the United States. The development has enabled the use of juice extractors ranging from domestic models to fully automatic juice lines that can produce litres of juice per day. The majority of our houses, hotels, restaurants, and shopping centers employ juice extractors of various types and sizes. As a result, a juicer is a mechanical device that extracts juice from fruits, vegetables, and leafy greens. Depending on the type of fruit or

vegetable to be extracted, different types of juicers have been designed [1]. Most tropical countries, such as Nigeria, generate an excess of tropical fruits to the point where market supply surpasses demand, resulting in price drops during the fruiting season. As a result, most fruits expire in the market due to insufficient storage facilities, resulting in significant losses [2]. Due to its low production, manual juice extractors have been designed for household usage [3]. The transformation of locally produced fruit aids in the enhancement of a reliable farming system in many parts of Africa [4]. However, the processing facilities required for this conversion are insufficient, and when they do exist, they are usually burdened with maintenance and inadequate supply. Fruit processing should ensure that the fruit is safe for future eating and maintain its quality, which includes flavor, odor, appearance, and nutritional value. When the sugar content and flavor are at optimal peak, the fruit from which the juice is to be extracted must be fully ripe [5]. As a result, fruits should be processed as close to the collection point as possible to reduce fruit transportation over long distances before processing. This will result in fresher fruit and a higher quality of extracted juice. The juice extractor is being developed as a low-cost, environmentally friendly, energy-efficient, and adaptable machine for fruit processing. This effort will go a long way toward providing local alternatives to imported processed fruit juice brands. This will drastically reduce the amount of fruit that is thrown away due to rot. Farmers' commercial demands will be satisfied, as will customer happiness. According to Ballinas et al. and Deck [6, 7], the storage life of fruits can be extended by removing the fluid content and turning them into juice, jam, and jelly. Depending on the method of preservation and packing, extracted juice might survive for months or even years before spoiling [7]. A small scale whole pineapple fruit juice extractor was devised and built by Badmus and Adeyemi [8]. Beater blades and a shaft, as well as a driven screw pressing mechanism, make up the machine. The machine reduced 8 liters of pineapple juice from 12 kg of ripe pineapple fruit. Ishiwu and Oluka [9] constructed and tested a juice extractor's extraction efficiency as a function of its performance. Screw jack, frame, connecting screw rod, pressing mechanism, interlock, feeding pot, reception pot, and discharge mechanism made up the extractor. Their research demonstrated that the created juice extractor performed admirably.

This research therefore focused on the design and construction of an automated and manual new-fangled fruit juice extractor

2. MATERIALS AND METHODS

Mild steel, stainless steel, polymers, and other materials were used in the design and construction of the juice extractor.

Construction Material: Plastic and stainless steel were chosen for the shaft, hopper, press cage housing, and gear to avoid contamination of citrus or orange fruit juice due to mild steel corrosion. The extractor stand was made of mild steel (steel with a carbon content of up to 0.25 percent) since it is easy to weld and fabricate [9]. They are not hardened by heat treatment due to their low carbon content, and as a result, weld and heat affected zone (HAZ) do not have hardened zones despite rapid cooling [10]. Mild steel is also recognized for its ductility and plasticity, which allows it to be rolled, bent, or pressed into a variety of shapes. It has strong malleability, allowing it to be hammered vigorously without losing too much energy [9].

Design concept: The goal of this project is to create an optimal and reliable design based on the following calculations: power calculation, shaft design, belt selection, and hopper volume calculation.

Frame: The fundamental criterion in the design of the machine's frame is that it maintains the right relative position of the units and parts installed on it during an extended term of operation in all working situations. The strength factor is the second aspect or need. The frame measures 840mm×300mm×551mm and was designed to withstand the various weights installed on it.

2.1 Fruit Juice Extraction

The process of crushing, squeezing, and pressing whole fruits in order to obtain juice and reduce the bulkiness of the fruit to liquid and pulp is known as fruit juice extraction. According to Badmus and Adeyemi [4], the several procedures involved in fruit processing include: sorting, ashing, pressing, lcing, cruhing, and extraction, addition of additives, homogenization, and pateurization. The processing tages entails cutting, cruhing, squeezing, pulping, and pressing (Figure 1). Extraction can be done manually or mechanically, depending on the volume of fruit to be processed. Fruit juice can be obtained from a variety of fruits, including pineapple, apple, citrus, orange, ginger, and cashew.

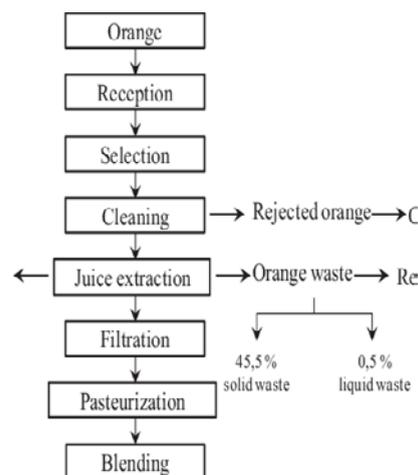


Figure 1: Flow chart for juice processing source: Abulude,2007

2.2 Efficiency of Extraction

The yield of juice obtained and the time taken to obtain it determine the efficiency of the extraction process. It is determined by the following factors: viscosity of the juice to be removed; persistence of the creation of the old pulp phase; pulp property; and pressure or force used. These factors are depending on the physical characteristics of the pulp to be extracted and are liable to change during the extraction process [11]. Separately, the extracted juice and the leftover waste were collected and weighed. The Tressler and Joslyn equation was used to calculate juice yield, extraction efficiency, and extraction loss based on the values obtained (Equation 1-3).

$$Ey = \frac{W_1}{W_1 + W_2} \times 100\% \quad (1)$$

$$\epsilon e = \frac{W_2}{W_3} \times 100\% \quad (2)$$

$$E_L = \frac{W_{FE} - (W_{JE} + W_{RW})}{W_{FE}} \times 100\% \quad (3)$$

where ϵy = Juice yield; ϵe = Extraction efficiency; E_L = Extraction loss; W_1 = Weights of juice extracted, W_2 = Residual waste; W_3 = Feed sample; g and x = The juice content of orange in decimal.

2.3 Design Analysis / Specification

Following a compression test in which the fruits were pushed by a sliding parallel plate, we discovered that the highest fruit rupturing force was 220N [11] with an average mass of 272g per fruit (some fraction higher than experimental value). Solidworks was used to create the design. We may deduce that the machine is operational and that it is fully loaded with half the mass of each fruit in order to receive 272 grams². When you multiply this by four cups, you get 544 grams. The fruit recipient weighs 220 grams (for a size of 0.14m).

Total mass = 544 + 220 = 764g (fruit receiver with all four cups fully loaded)
About 0.764kg

And thus, the weight of the fruit receiver loaded is approximately 7.5N.

A rupture force of 220N was required to shear the fruit, as previously indicated. The resultant force applied on the shaft passing through the fruit recipient is shown in the free body diagram below. The force for compression of the fruit should be sufficient and able to cut (shear).

Radius of the crusher = 0.12m

$$\text{Torque} = F \cdot r \text{ (Nm)} \quad (4)$$

Thus it has been chosen to use a force of 225N.

$$\text{Torque required} = 225 \times 0.12 = 27 \text{ Nm}$$

Thus any motor we select should be able to provide this minimum output torque requirement to impart on the fruit while at the same time causing rupture of the fruit.

Now using a motor of the following specification

Power = 120W

Voltage = 12V/24V

Speed = 55rpm

$$\text{Power (P)} = \frac{2NT}{60} \quad (5)$$

The input torque T, from this motor is

$$T = \frac{60P}{2N} \quad (6)$$

$$T = \frac{60 \times 20}{2 \times 55} = 20.835 \text{ Nm}$$

This torque will be supplied by the motor shaft to the input gear which is to drive the output gears.

Now we know

$$\text{Velocity ratio } (V_r) = \frac{T_o}{T_i} \tag{7}$$

$$\text{Velocity ratio } (V_r) = \frac{27}{20.835} = 1.3$$

This is the marginal number for design purposes, thus a bigger value is chosen to account for unforeseen pressures that we may have neglected during the computation. As a result, the velocity ratio should be considered as 2. Where Z_2 = number of teeth on output gear.

So, with a selection of input gear and knowledge of the velocity ratio as calculated above, we may select appropriate output gear on the market from any of the figures below.

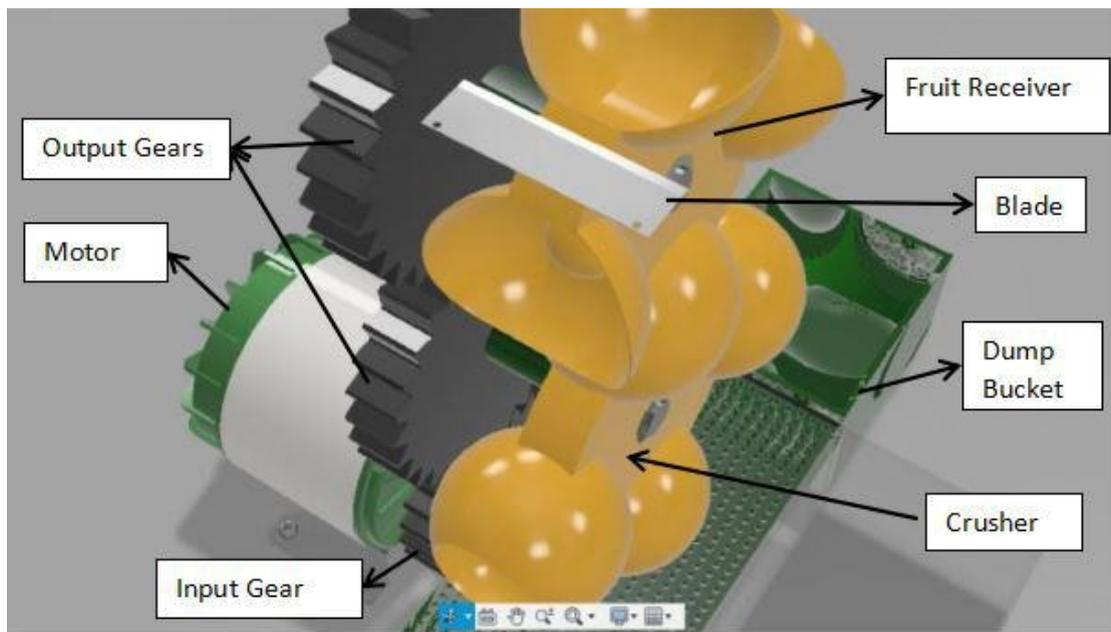


Figure 2. Internal Components of the proposed machine

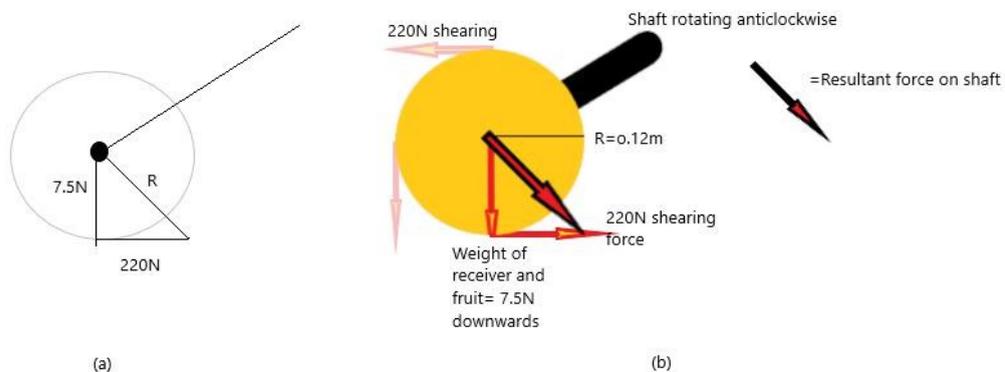
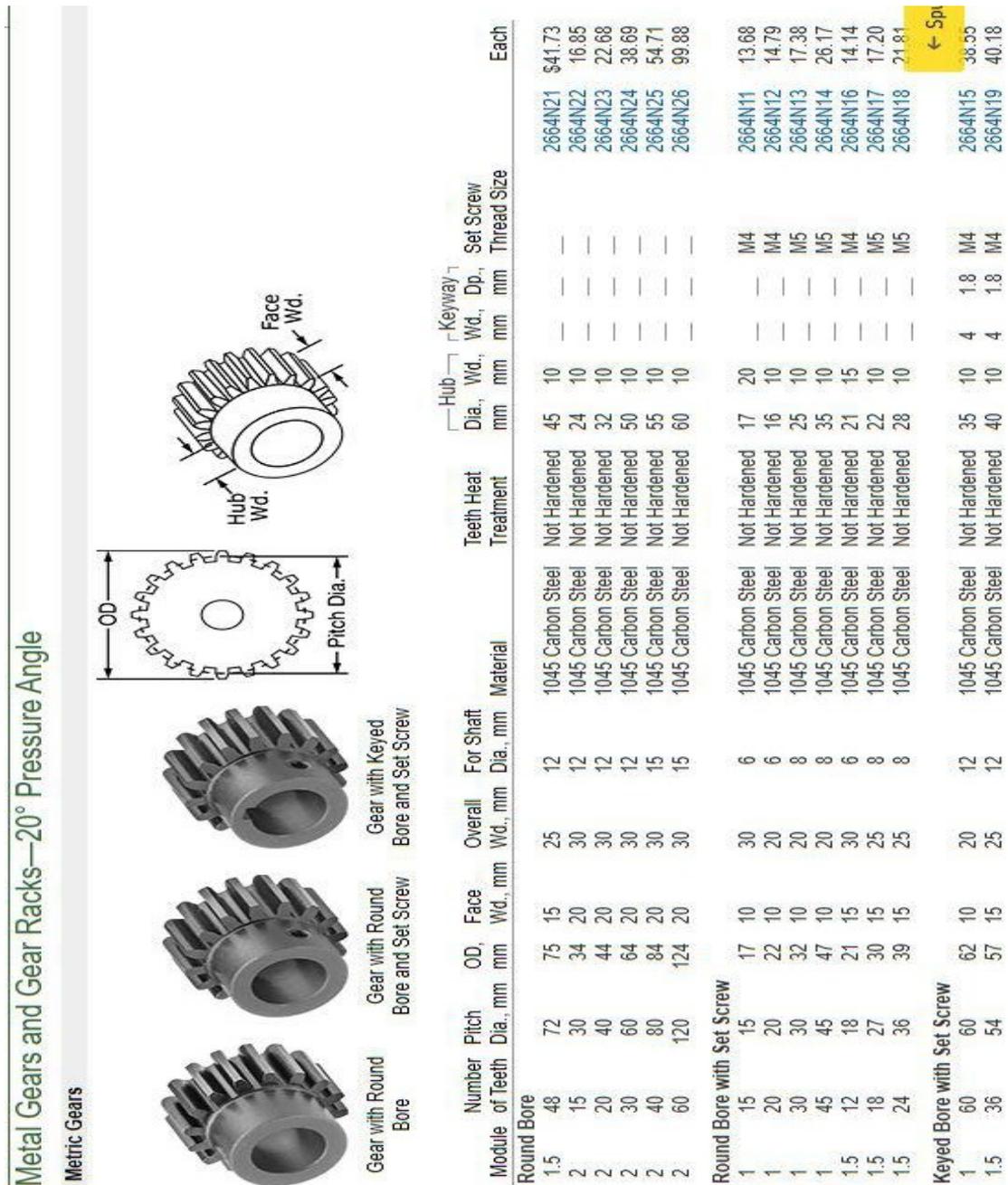


Figure 3. free body diagram and representation of forces on shaft carrying receiver.

This is the shaft's reference force, which we'll utilize in our computations. Any amount larger than this would be acceptable in calculations, but anything less would be incorrect. As a result, a force of 225N was chosen.

3. RESULTS AND DISCUSSION

The design analysis of the constructed automated and manual new-fangled fruit juice extractor is shown in Figure 4-10. The project is designed so that uncut fruit falls into a revolving receiving component, where it is sheared in half by shear force when it comes into touch with a blade permanently mounted to the machine's side wall.



Plastic Gears and Gear Racks—20° Pressure Angle

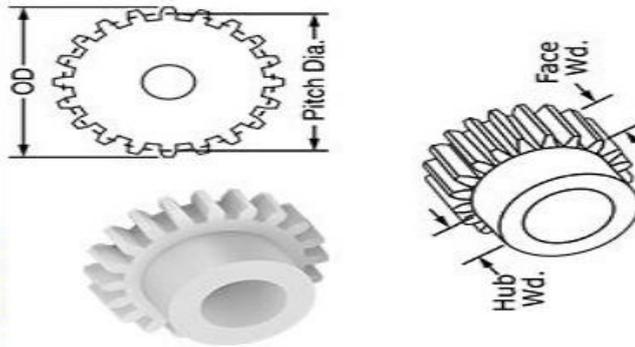
The current industry standard, these 20° pressure angle gears have thicker, stronger teeth than 14½° pressure angle gears. Made of plastic, they run quieter than metal gears and have good corrosion and chemical resistance. They're also known as spur gears.

Combine gears with different numbers of teeth to change speed and torque in your assembly. Combine a gear and rack to convert rotary motion into linear motion.

For components to mesh correctly, they must have the same pressure angle and pitch/module.

 For technical drawings and 3-D models, click on a part number.

Metric Gears



Module	Number of Teeth	Pitch Dia., mm	OD, mm	Face Wd., mm	Overall Wd., mm	For Shaft Dia., mm	Material	Fabrication	Color	Hub		Each
										Dia., mm	Wd., mm	
Round Bore												
0.5	12	6	7	3	7	2	Acetal Plastic	Molded	White	4.5	4	2662N27 \$2.20
0.5	24	12	13	3	7	4	Acetal Plastic	Molded	White	8	4	2662N28 2.31
0.5	36	18	19	3	7	5	Acetal Plastic	Molded	White	10	4	2662N29 2.71
0.5	48	24	25	3	7	5	Acetal Plastic	Molded	White	12	4	2662N31 3.26
0.5	60	30	31	3	8	6	Acetal Plastic	Molded	White	14	5	2662N32 3.69
0.8	20	16	17.6	4	9	5	Acetal Plastic	Molded	White	10	5	2662N33 2.69
0.8	30	24	25.6	4	9	6	Acetal Plastic	Molded	White	12	5	2662N34 3.31
0.8	40	32	33.6	4	9	6	Acetal Plastic	Molded	White	12	5	2662N35 4.14
0.8	60	48	49.6	4	10	6	Acetal Plastic	Molded	White	14.5	6	2662N36 5.14
0.8	80	64	65.6	4	10	6	Acetal Plastic	Molded	White	15.5	6	2662N37 6.39
1	15	15	17	6	12	4	Acetal Plastic	Molded	White	8	6	2662N38 3.43
1	20	20	22	6	12	5	Acetal Plastic	Molded	White	11.7	6	2662N39 4.17
1	30	30	32	6	12	6	Acetal Plastic	Molded	White	14	6	2662N41 5.51
1	45	45	47	6	12	8	Acetal Plastic	Molded	White	16	6	2662N42 7.73
1	60	60	62	6	14	8	Acetal Plastic	Molded	White	18	8	2662N43 10.28

Figure 4. Plastic Gear sizes and cost in the market

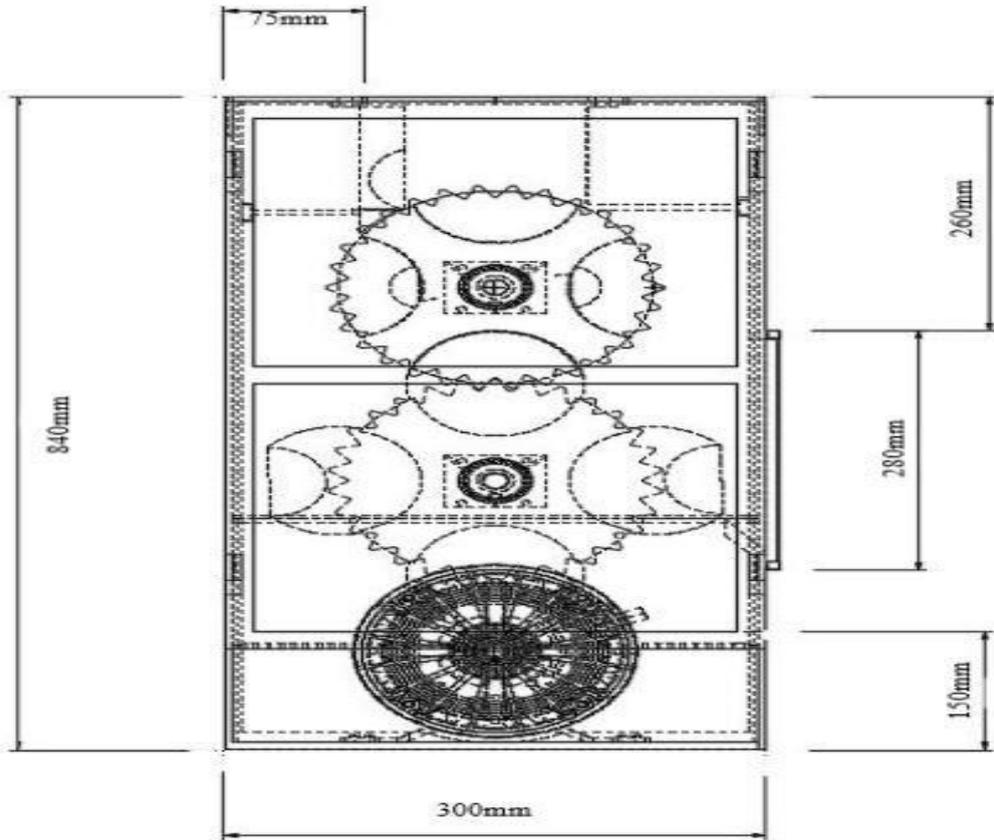


Figure 5. Front View of the model

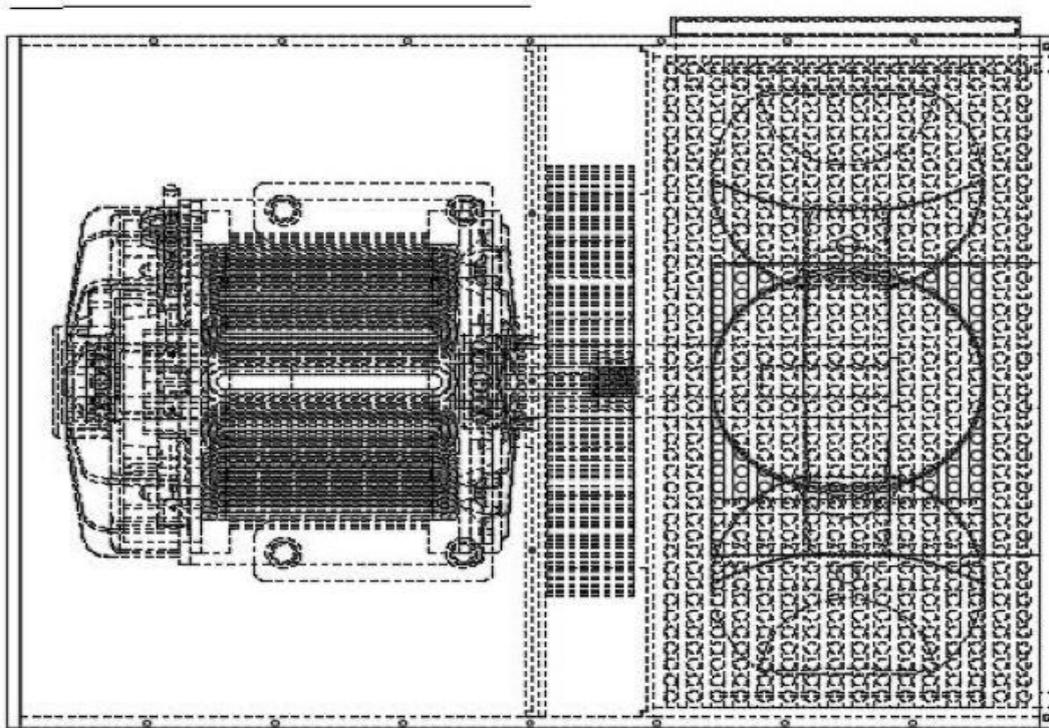


Figure 6. Top View of the model

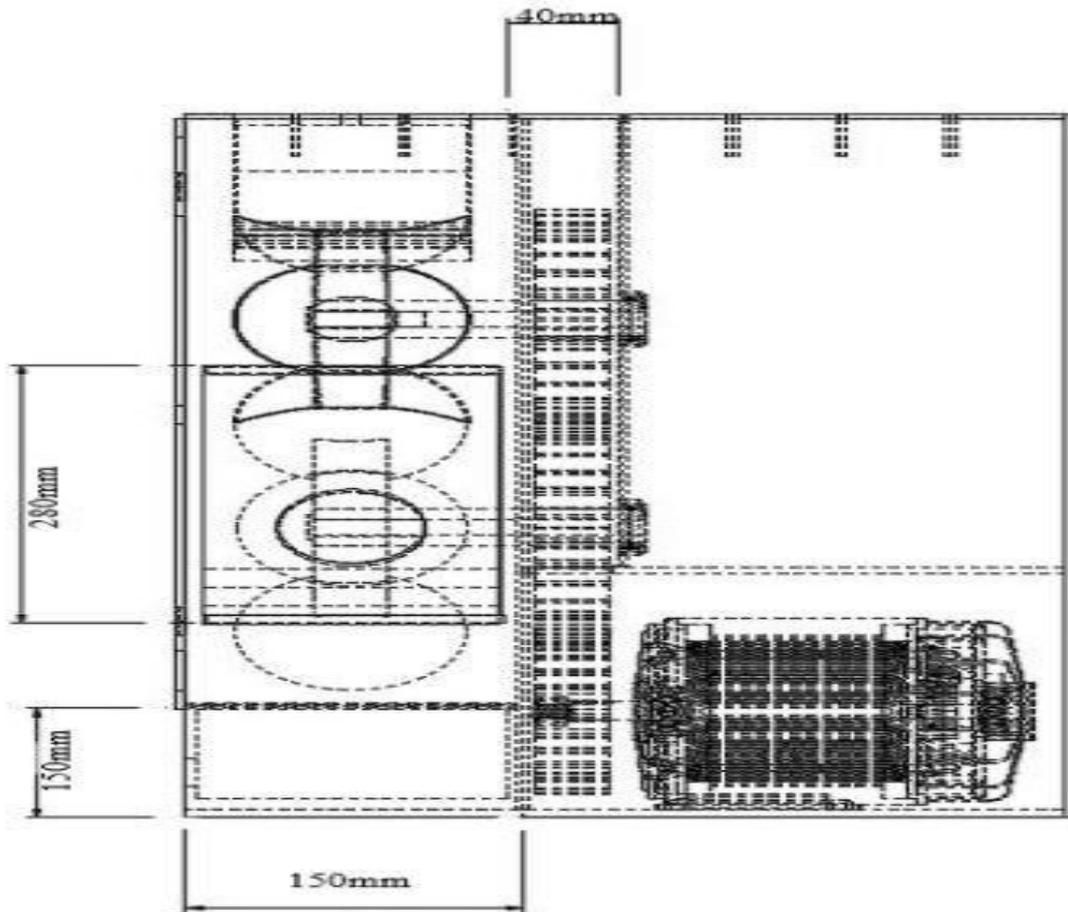


Figure 7. Side view of model

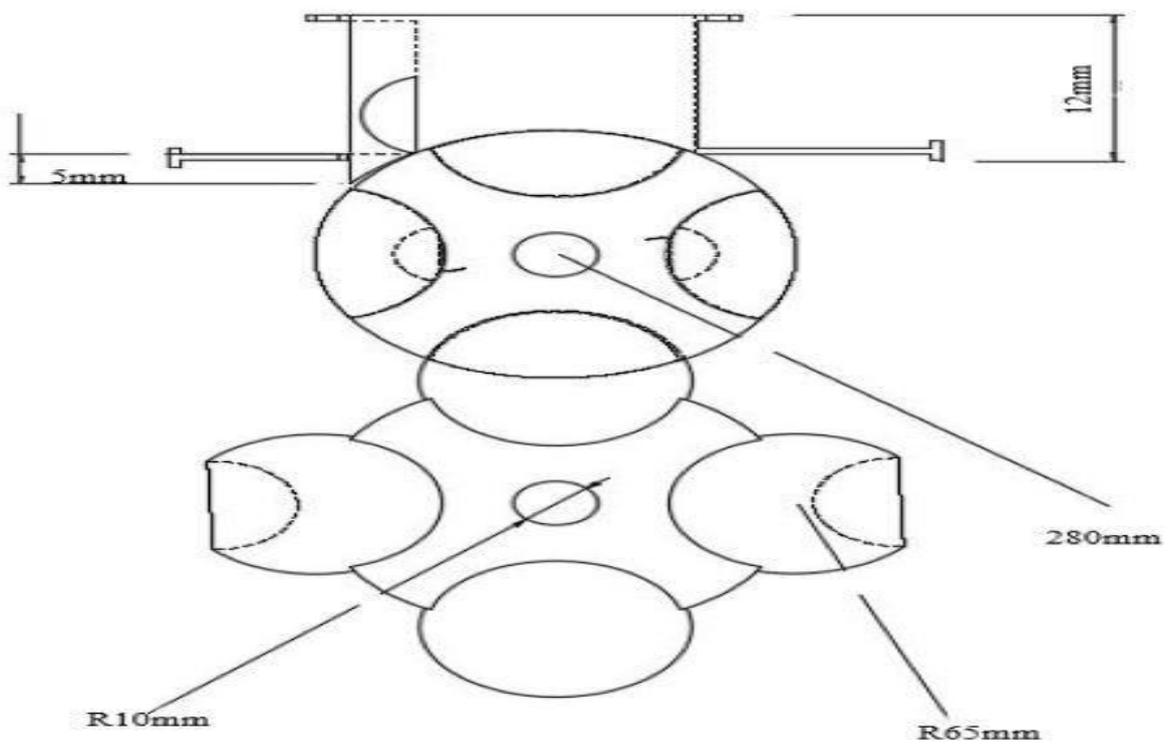


Figure 8. The inlet, fruit receiver and crusher(top-bottom)

Parts List		
Item	Part Name	Material
1	Fruit Inlet	Plastic
2	Fruit Receiver	
3	Crusher	
4	Sieve	Plastic
5	Juice container	Plastic
6	Juicer Body	
7	Electric Power Drive	
8	Shaft	Plastic
9	Mating Gears	Iron, Gray Cast ASTM A48 Grade 20
10	Key	Iron, Gray Cast ASTM A48 Grade 20
11	Power Gear	Iron, Gray Cast ASTM A48 Grade 20
12	Horizontal Closing	Plastic
13	Front closing	Plastic
14	Midway Closing	Plastic
15	Top Cover	Plastic
16	Rear Covering	
17	Blade	Stainless Steel
18	Key	Iron, Gray Cast ASTM A48 Grade 20
19	Glass Door	
20	Screw	Iron, Gray Cast ASTM A48 Grade 20
21	Side exit Cover	
22	Bearing	

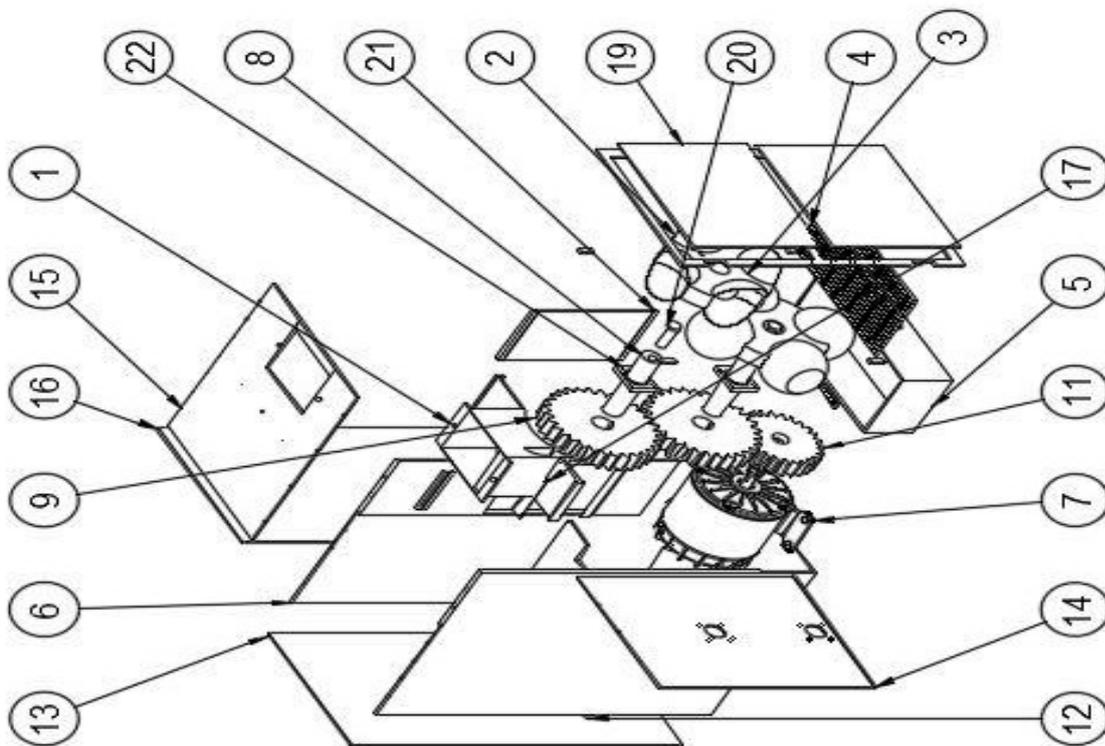


Figure 9. An Exploded View Showing the Component Parts and the Materials used for the Design.



Figure 10. The Design Model (Assembled Parts)

3.1. Discussion

It was important to anticipate the machine's average juicing time for a finite amount of fruits. With the acquisition of 24 citrus or orange fruits, a stopwatch, and a way to record the data from the test run, this goal was set. The goal was to perform three trials of eight fruits each, determining the average time it took to juice each batch.

Table 1: Individual Trial of 8 Citrus Fruits versus the Time Take to Juice in Machine

Trial	Number of Fruits	Juicing Time (s) for Manually Operated	Juicing Time (s) for Automated Operated
1	8	60	25
2	8	56	26
3	8	66	27
Average Juicing Time (s)		60.33	26

From the table in the previous section, the question arose as to why there were some time difference between set runs made. To explain this, some reasonable assumptions have been made below;

1. Timing: The machine did not have an automated timer or a setting for the number of fruits to juice; instead, it was done manually with a stopwatch/clock. As a result, the time difference could be the result of less-than-accurate timing based on eye observation of the eighth fruit being juiced.
2. Time between feedings in each set: For each set of eight fruits, the feed was done by hand to aid the blade's cutting activity at the machine's receiving portion. As a result, it's not unreasonable to consider the tiny time difference between each feed activity.
3. The state of each fruit: The fruits in each trial set of eight may have included, for example, much succulent softer skin fruits in set 1 with a run time of 60 seconds, compared to set 3 with a run time of 66 seconds and fewer fruits as soft and succulent as set 2 with a much

higher percentage of ideal soft and succulent fruits being fed into the machine. Using the data previously created, the average yield time for juicing was anticipated to be around a minute and a third. We have calculated that the yield time for this juicing machine will be one minute for every eight citrus fruits that pass through it.

The maximum juice output, extraction efficiency, and extraction loss were all determined to be 77.6%, 85.3 percent, and 6.5 percent, respectively. For village-level uses, a device of this sort can be made at a small machine plant in an orange-producing developing country. This study's findings were similar to those of Ishiwu and Oluka [7], who reported a juice yield of 76 percent, extraction efficiency of 83 percent, and extraction loss of 3%, respectively. The results show that the newly designed and built juice extractor has a high capacity for extracting juice.

3.2. Cost Evaluation

Table 2. Bill of Engineering Materials and Evaluation

S/N	Materials	Cost(Naira)
1	Alcoboard	3800
2	2 x 1 Angle bar	2200
3	Acrylic	4000
4	A and B Gum	300
5	Silicone Gum	1000
6	Pattern design	6000
7	Gears	3000
8	DC motor with mechanism and driver	10000
9	Bearings	1200
10	Ply board	800
11	8mm bolts	500
12	10mm bolts	10mm bolts
13	1/2'' Square pipe	600
14	Welding electrodes	1000
TOTAL		34900

The cost incurred in the fabrication of the juicing machine have been broken down and outlined as in the table above

4. CONCLUSION

The design and construction of an automated and manual new-fangled fruit juice extractor had been achieved, the newfangled juice extractor operates automatically and manually, it is motorized and also be operated manually. The design of this device was done using solid works version. This device have a high juice production capacity of 42 liters per minute for the motorized powered juice extractor while 20 liters per minute for the manually operated. The machine had a production efficiency of 85.3%. It was possible to design a juicing machine that could both shear the fruit and juice at the same time with minimum contact between the fruit

juice and the unwanted peels from the fruit surface. As such, a juicing machine was designed and fabricated with an average predicted run time of 60.3 seconds and 26 seconds for every 8 citrus or orange fruit specie.

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