# Fabrication and Performance Evaluation of a Portable Motorized Pineapple Juice Extractor

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## ABSTRACT

A motorized Juice extractor was designed, fabricated and its Performance Evaluation was carried out to determine the best extracting operating factors for the prototype. The two operating factors used for evaluating this machine are extraction speed (S) at three levels (i.e. $S_1$=565 rpm, $S_2$=478 rpm and $S_3$=380 rpm) and Feed rate (F) at three levels (i.e. $F_1$=0.5kg/min, $F_2$=1.0kg/min and $F_3$=1.5kg/min). Each of these factors was replicated thrice, which resulted into 3X3X3 factorial experimental design. In addition, the performance parameters used for evaluating this prototype are the Extraction efficiency $\varepsilon_f$(%), Extraction losses $\varepsilon_l$(%) and Extraction capacity $C_{ex}$(lit/hr). The performance evaluation results obtained from this experimental design shows an optimum Juice Extraction Efficiency, $\varepsilon_f$=87.50%, Juice Extraction Capacity $C_{ex}$=26.70lit/hr with Juice Extraction Losses, $\varepsilon_l$=12.50% at $S_3F_2$ operating factors (i.e. $S_3$=380 rpm and $F_2$=1.0kg/min). The optimum output of this prototype was compared with that of manual extraction method which was evaluated to have manual Juice Extraction Efficiency, $\varepsilon_{fm}$=97.00%, manual Juice Extraction Capacity $C_{exm}$=5.25lit/hr and manual Juice Extraction Losses $\varepsilon_{lm}$=3.08%. Hence, this prototype was rated to be five times faster than human method of extracting juice from fruits. Although, the extraction losses of this prototype was observed to be slightly higher than that of manual extraction method. This suggests there is need to further improve on this prototype for higher extraction efficiency, $\varepsilon_f$(%) close to that of human beings.

**Keywords:** Feed rate, Extraction losses, Extraction Efficiency, manual extraction efficiency, performance parameters, Operating factors, proto-type and fruit pulp.

## 1.0 INTRODUCTION

In Nigeria, several varieties of fruits like Orange, Pineapple, Pawpaw, Mango, Apple, Grape, Pears and Watermelon are available in large quantities during their various harvesting seasons. Aikhonbare and Badmus (2003) observed that over 50% of different kinds of fruits produced by fruit farmers in Nigeria is usually wasted yearly due to lack of efficient storage facilities after those fruits have been harvested. In addition to this, susceptibility of fruits to mechanical, chemical and environmental factor contributes to high wastage due to spoilage during the harvesting seasons of such fruits. However, rapid progresses have been made in fruit farming technology over the years with little success recorded in storage facilities of such fruits. All this contributes to enormous wastage of fruits all over Nigeria.

The only solution to fruit storage problem is the extraction of juice from fruits. After extraction, the juice may be stored in rubber bottle or any other neat packaging, with or without preservative chemicals. According to Bhatia (1989), the most important steps in processing fruit juice are selection, extraction, de-aeration, filtration, preservation and packaging. To achieve this, some researchers in time past have developed machines for extracting juice from fruits, among these researchers are Badmus and Adeyemi (2006), Ishiwu and Oluka (2005) Olowonibi and Ozumba (1999) and Bites,

Morris and Grand (2001). Most of these juice extractors are for medium and large-scale fruit juice extractors. However, there is need for developing a portable pineapple juice extractor because of its sweet juicy taste that makes so many homes to prefer it to other fruits.

## 1.1 Importance of fruits

In recent time, nutritionists in Nigeria began to emphasise on the importance of fruits to the growth of human beings and animals. According to Kintinga & Kader (1995), fruit acts as catalyst when combined with protein in the body to activate the production of some active enzymes, which in turn produce hundred of important chemical reactions in the body. Fruit and their juices are believed to contain vital food nutrients for both man and animals such as vitamins, minerals and fibres which, in turn, make fruit and its juices to have medicinal and nutritional values and at the same times act as appetizers (Ashurt, 1991). Again, rapid growth of population in Nigeria with her elite gradually discovering importance of fruits in recent times has led to increase in demand for fruits and its juices. The demand for different fruits during and out of the season is increasingly high on a daily basis. Therefore, fruit juice, because of its importance as highlighted above, has to be hygienically extracted and then preserved in its natural form. The extracted juices of different fruits can be neatly packaged and made available to the teeming Nigerian populace in cities and urban regions who are hungry and thirsty for fruit juices during the off-season of such fruits.

In view of the above importance of fruits to man and animals, farmers in recent times have made series of efforts in extracting juices from fruit manually and then preserving it for off-season consumption. Also, some researchers have constructed some machines that can be used for extracting juice from fruits. The traditional or manual method of extracting juice from fruit is observed to be unhygienic, with slow extraction rates. Apart from unhygienic nature of the traditional extraction methods, it is also associated with several physical stress of the body.

## 1.2 Objectives of the study

The main objectives of this study are:
(i)      To fabricate a functioning portable motorized pineapple juice extractor for home use.
(ii)     To carry out the performance evaluation of the pineapple juice extractor.

## 2.0 MATERIALS AND METHOD

The various parts of this motorized juice extractor are the hopper, barrel, shaft with auger, juice outlet, fruit pulp-outlet, pulley and frame. These parts are clearly displayed in the assembly drawing in Fig 1. Apart from the pulley and the frame all other parts were fabricated from stainless steel. The main reason for the choice of costly stainless steel is to ensure that the extracted juice is free from contamination. The major aim of this design is to fabricate a portable and affordable motorized pineapple fruit juice extractor for home use in Nigeria. Also, another reason for this design is to make it portable and affordable for an average family in Nigeria.

## 2.1 Description of the components of the juice extractor

Fig. 1 shows the exploded assembly drawing of the motorized juice extractor. The average weight of this prototype was measured to be 6.45kg. Careful selection of materials for each part of the juice extractor was made with the aim of reducing the weight of the machine. The rotor type can be described in three compartments: the hopper, the extracting compartment and the outlet compartment.

**(i)    The hopper**
   The hopper is essentially the part of the machine that contains and retains fruit to be process for a short time. The hopper acts as a container and at the same time helps in gradually introducing the fruit material in to the juice-extracting compartment. The trapezoidal shaped hopper is fabricated from stainless steel and welded to the barrel of the proto type. The dimension of the hopper is as shown in the orthographic views presented in Fig 2.

**(ii)   The Extracting compartment**

The extracting compartment of this proto-type comprises the extracting shaft with auger, the barrel, and the pulley with bearing. The extracting shaft with auger is housed in a barrel and supported by the bearings at both ends, as shown in Fig. 1. The extracting shaft and the barrel were both fabricated from stainless steel with their sizes and dimensions shown in Fig. 2. The pulley is mounted on the extracting shaft with the main function of transmitting the rotary power or (torque) from the Electric Motor to the juice extracting machine through the V-belt connection. The pulley was fabricated from mild-steel with its dimension shown in Fig 2.

**(iii) The outlet compartment of the juice extractor**

The outlet compartment comprises two major outlets, that is: the juice outlet and the fruit pulp outlet. The two outlets are welded to the posterior end of the barrel as shown in Figs. 1 and 2. The two outlets were designed to discharge the extracted fruit juice and the fruit residue (or fruit pulp) at the same times. The outlets were fabricated from stainless steel.

**(iv) The frame and stand of the juice extractor**

The frame and the stand are the parts of the machine that provide supports for  both the juice extractor and the Electric motor as shown in Figs. 1 and 2. The material used for fabricating the frame and stand was mild steel angle bar.

**2.2 Principle of operation of the juice extractor**

The multi-juice extractor can be powered by either electric motor or small petrol engine. Inside the juice extractor is a screw-like auger fitted on a shaft that rotates inside a fixed tube called the barrel. When the fruit material comes into the extracting compartment via the hopper, the screw-like auger pushes the fruit-material against the wall of the barrel. The forward motion caused by the auger on the extracting shaft subjects the fruit-material to a certain degree of pressure sufficient to extract the juice from the fruit-pulp. The juice comes out from the juice outlet, while the fruit-pulp comes out from the pulp outlet. Advantage of this juice extractor is that, it is a continuous feed extracting    system capable of handling about three types of fruit materials continentally with good flowability characteristic of fruits like pineapple, pawpaw, and Orange. The juice extraction commences immediately after peeling and washing of the fruits.

**2.3 Evaluation Methods**

The experimental procedures used in the course of this study and the performance equations used for the various estimations as evaluating parameters are discussed as follows:

**2.4 Experimental Procedures**

The juice extractor, after fabrication, was tested and evaluated with fully matured peeled pineapple fruit. The prototype was evaluated, using a 3 x 3 x 3 factorial experimental design. The aim of using factorial experimental design is to estimate the effect of some operating factors on the performance of the juice extractor. The two operating factors used for evaluation of this machine are the operating speed **S** at three levels (i.e. $S_1$ = 565 rpm, juices $S_2$ = 479 rpm and $S_3$ = 380 rpm) and feed rate **F** of the fruit material at three levels (i.e. $F_1$ = 0.5kg/min, $F_2$ = 1.0kg/min, and $F_3$= 1.5kg/min). Each of the factors was replicated thrice to arrive at 3 x 3 x 3 x3 factorial design. Performance parameters used for evaluating the juice extractor are the extraction efficiency ($\varepsilon_f$)%, extraction losses ($\varepsilon_L$)% and extraction capacity ($C_{ex}$)lit/ hr. The evaluation results showing the different interactions between the operating factors and the performance parameters are shown in Table 2.

Table 1: Juice Extraction Raw Data Measured during the Evaluation of the Prototype

| Operating Factors of the prototype | Mass and Volume of the Extracted Juice from the fruit | | Mass and Volume of the Unextracted Juice from the fruit | | Mass of fruit pulp after extraction | Extraction time, |
|---|---|---|---|---|---|---|
| | $M_j$ (Kg) | $V_j$ (ml) | $M_{uj}$ (Kg) | $V_{uj}$ (ml) | $M_p$ (Kg) | $T$ (min) |
| $S_1 F_1$ | 0.18 | 102 | 0.16 | 100 | 0.14 | 1.00 |
| $S_1 F_2$ | 0.33 | 270 | 0.31 | 270 | 0.34 | 1.00 |
| $S_1 F_3$ | 0.55 | 275 | 0.51 | 368 | 0.42 | 1.00 |
| $S_2 F_1$ | 0.21 | 104 | 0.14 | 98 | 0.14 | 1.00 |
| $S_2 F_2$ | 0.34 | 295 | 0.30 | 248 | 0.35 | 1.00 |
| $S_2 F_3$ | 0.57 | 378 | 0.52 | 373 | 0.39 | 1.00 |
| $S_3 F_1$ | 0.25 | 134 | 0.07 | 67 | 0.16 | 1.00 |
| $S_3 F_2$ | 0.56 | 445 | 0.08 | 69 | 0.33 | 1.00 |
| $S_3 F_3$ | 0.70 | 570 | 0.40 | 290 | 0.39 | 1.00 |
| Manual Juice Extraction method | 0.63 | 558 | 0.02 | 47 | 0.36 | 6.38 |

$S_1$ = 565 rpm.                     $F_1$ = 0.5 kg/min.
$S_2$ = 479 rpm.                     $F_2$ = 1.0 kg/min.
$S_3$ = 380 rpm.                     $F_3$ = 1.5 kg/min.

Table 2: Effect of some Operating Factors on Juice Extraction Performance of the Prototype

| Operating Speed (rpm) | Feed rate (Kg/min.) | Juice Extraction Efficiency, $\varepsilon_f$ (%) | Juice Extraction Losses, $\varepsilon_l$ (%) | Juice Extraction Capacity, $C_{\varepsilon x}$ (lit/hr) |
|---|---|---|---|---|
| $S_1$ | $F_1$ | 52.94 | 47.06 | 06.12 |
| | $F_2$ | 51.56 | 48.44 | 16.20 |
| | $F_3$ | 51.89 | 48.11 | 16.50 |
| $S_2$ | $F_1$ | 60.00 | 40.00 | 6.24 |
| | $F_2$ | 53.13 | 46.88 | 17.70 |
| | $F_3$ | 52.29 | 47.71 | 22.68 |
| $S_3$ | $F_1$ | 78.13 | 21.88 | 08.04 |
| | $F_2$ | 87.50 | 12.50 | 26.70 |
| | $F_3$ | 63.64 | 36.36 | 34.20 |
| Manual Juice Extraction method | | 96.92 | 03.08 | 05.25 |

$S_1$ = 565 rpm.                     $F_1$ = 0.5 kg/min.
$S_2$ = 479 rpm.                     $F_2$ = 1.0 kg/min.
$S_3$ = 380 rpm.                     $F_3$ = 1.5 kg/min.

**LEGEND**
1. The Hopper
2. The Pulley
3. The Bearing
4. The Barrel
5. The Stand
6. The Shaft
7. The Electric Motor
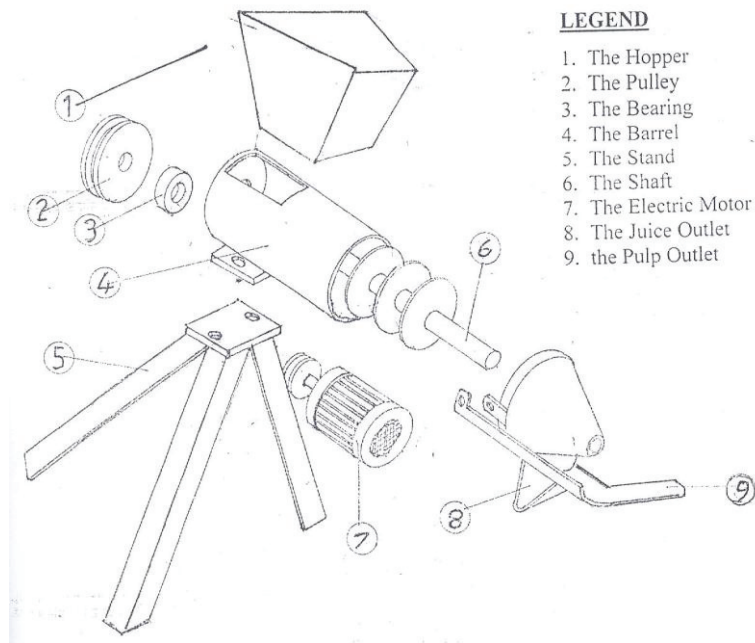8. The Juice Outlet
9. the Pulp Outlet

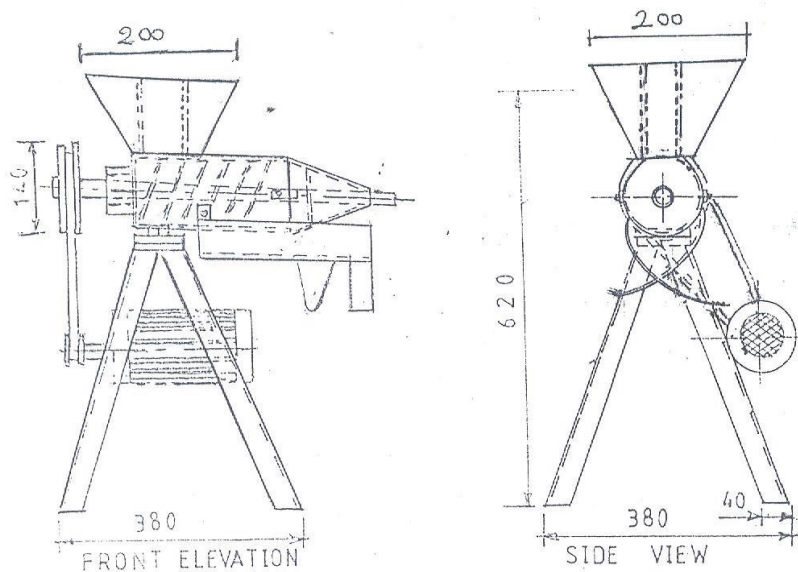Fig. 1: Exploded view of a pineapple juice Extractor



Fig. 2: Isometric views of a pineapple juice Extractor

## 2.5 Performance Evaluation Equations

The various evaluation expressions used for estimating the performance of this prototype are stated as follows:

**(i) Juice Extraction Efficiency, $(\varepsilon_f)$**

$$\varepsilon_f = \frac{m_j}{m_j + m_{jp}} \; x \; 100\% \qquad\qquad \text{Eqn. (1)}$$

**(ii) Juice Extraction Losses, $(\varepsilon_l)$**

$$\varepsilon_l = \frac{m_{jp}}{m_j + m_{jp}} \; x \; 100\%$$  Eqn. (2)

**(iii) Juice Extraction Capacity, $(C_{\varepsilon x})$**

$$C_{\varepsilon x} = \frac{V_j}{T} \; \text{(lit/hr)}$$  Eqn. (3)

Where,

$m_j$ = Mass of Juice Extracted from the fruit material (kg)

$m_{jp}$ = Mass of Juice Extracted from the fruit pulp (kg)

$V_j$ = Volume of Juice Exracted from fruit material (lit)

T = Juice Exraction Time (hr)

## 3.0 RESULT AND DISCUSSION

The measured data obtained from the performance evaluation of the multi-fruit extractor when used for extracting juice from pin apple is as shown in Table 1.

The operating factors considered during the evaluation are feed rate, (F) and the extracting speed, (S) for the proto type. The three levels of feed rate ($F_1$, $F_2$ and $F_3$) and three levels of extracting speed (i.e. $S_1$, $S_2$ and $S_3$) are considered good for this study with each run replicated thrice. Also, the performance parameters considered in this study are extraction efficiency, ($\varepsilon_f$)% , extraction loss ($\varepsilon_L$%) and extraction capacity ($C_{ex}$)lit/ hr. The results of the various operating factors on the extraction parameters are displayed in Table 2.

Again, Figures 3, 4 and 5 show the graphical relationship between the investigated operating factors and the performance parameters of the proto-type.
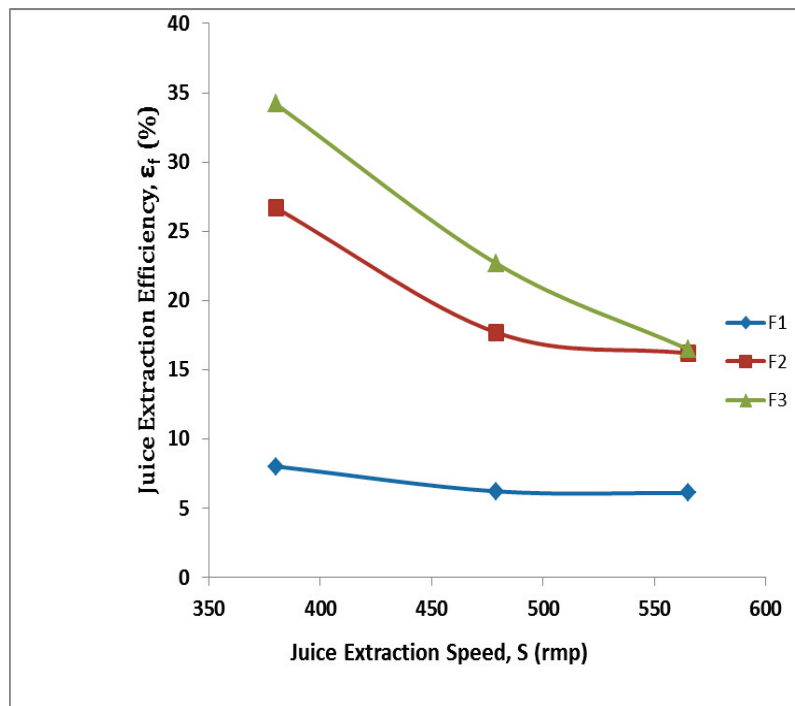


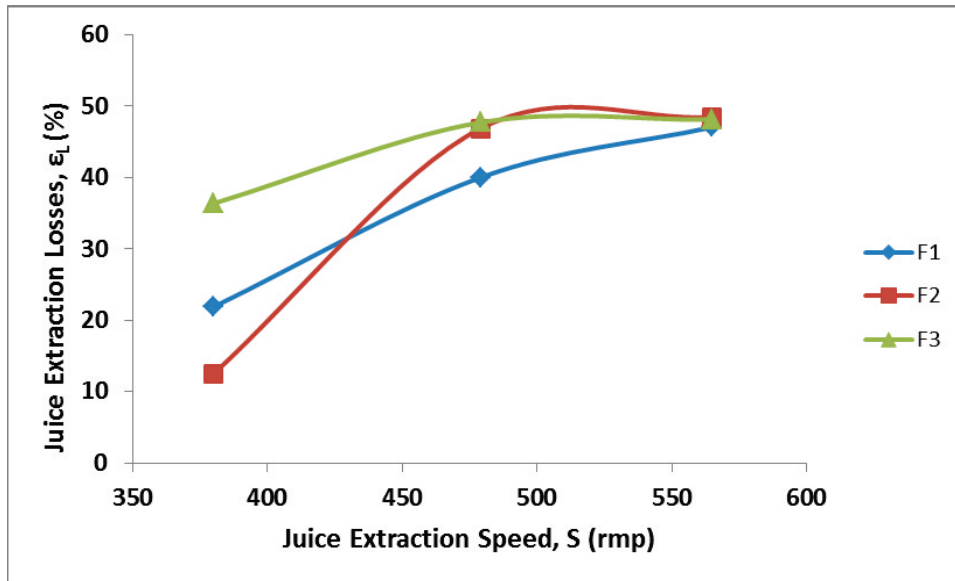**Fig. 3: Effect of Juice Extraction Speed and Feed rate on Juice Extraction Efficiency**

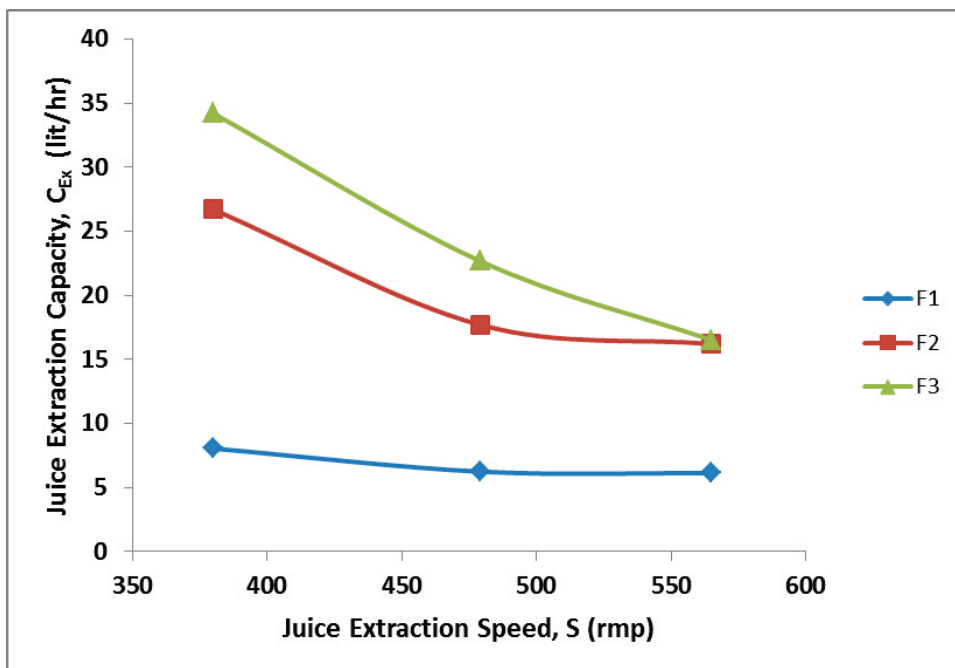**Fig. 4: Effect of Juice Extraction Speed and Feed rate on Juice Extraction Losses**

**Fig. 5: Effect of Juice Extraction Speed and Feed rate on Juice Extraction Capacity**

## 4.0 CONCLUSION

The conclusion of the investigations made in this study shows that good interactions were observed between the investigated operating factors and the performance parameters of the multi-fruit juice Extractor. The summary of results obtained during the investigation are:

(i)   The Average extraction efficiency of the juice extractor was estimated to be about $E_f$ = 72% of at the optimum operating speed $S_3 = 380$ rpm with the feed rate, $F_1$

=0.5kg/min was observed to have the highest extraction efficiency curve. Hence, $S_3$ and $F_1$ are recommended as optimum operatory factors for this proto-type

(ii)     However, juice extracting capacity was observed to be as low as $C_{ex}$=5.4 litre/hr) with $S_3F_1$ but juice extraction efficiency was observed to be very high (i.e $\varepsilon_f = 78.13\%$)

(iii)    Also, Juice losses of $\varepsilon_L$=21% with $S_3F_1$ run was observed with further   improvement on the prototype.

## 5.0 RECOMMENDATION

(i)     Juice losses of about $\varepsilon_L$=21 - 28% with this prototype is still on the high side; therefore, efforts are being made to increase the extraction efficiency to about 90% or more.

(ii)     Additional effort should be made to increase the extracting capacity from $C_{ex}$=5.4 litre/hr to a higher value and at the same times make it a multi-juice extractor.

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