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Research paper

Performance Evaluation of a small-Scale Motorized Mango Pulp Extractor

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Mango pulp extraction is a process of crushing and scraping of whole fruit in order to separate the juice from fruits pulp. The essence of processing the fruit using this machine can easily help to store, preserve, package, transport or consume the product by adding value with high quality juice and reduce the postharvest loss. The aim of this study was to conduct a performance evaluation of the small-scale mango juice pulp extractor. The operation of the pulper was the screw conveyor conveys and the screw blade impacted the mango fruits against a drum perforated on the inside. The extracted juice was drained through the perforated mesh of the juice channel into the juice outlet from where it is collected while the residual waste is collected at the waste outlet. The operating factors considered during the evaluation were feed rate and the extracting retention time. The machine was tested using freshly harvested mango fruits and results obtained an average extracted capacity, extraction efficiency and extraction loss of 86.41l/hr.,78.94% and 11.18%, respectively operating at 400 rpm speed. Allowing a 40sec processing retention time is recommended to separate and well drained the edible part of the mango so as to minimizing loss.

Keywords: Extractor, Feed Rate, Mango Pulper, Retention Time

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INTRODUCTION

Mango is a very important fruit, cultivated in several tropical and subtropical regions, and its distribution in world trade is expanding. Mangoes are an important part of the diets in Ethiopia. The highest and lowest edible portion 79.49 % and 65.61% respectively were found (Ara R. et al.,2014). Post-harvest losses of fruits and vegetables are more severe in developing countries than in well developed countries. Most of the time observed that 30% up to 50% of different kinds of fruits produced by fruit farmers in the country is usually wasted yearly due to lack of management and efficient storage facilities after those fruits have been harvested (Sonar D. J. et al ,2018). The main causes of postharvest losses include mechanical damage, physiological deterioration and biological (i.e., postharvest diseases and insect pests). Besides, the fruits are exposed to the mechanical, chemical, and environmental impacts which contributes greatly to the degradation and deterioration of PHL after harvest. Rapid growth has been achieved in small-scale fruit farming technology, whatever which has little record in such fruit storage facilities. This luck of storage facility problem resulted enormous loss of mango fruit in Ethiopia. A study carried out on fruits indicated that the losses were up to 30% during the rainy season (Aviara et al., 2013). This problem leads to scarcity as well as high cost of fresh fruits during the off season.

Mango processing presents many problems as far as industrialization and market expansion. Due to the perishable nature, the farmers record abundant wastage during the production season and extreme scarcity during the off season. Processing the fruit into the form that can easily be stored, preserved, packaged, transported or consumed is crucial to having the product all the year round. Besides, mango juice can be consumed freshly, processed into dry powder, mixed or blended with other juice to make fruit jams, or evaporated to concentrates. These products have a lot of potential in food and beverage industries for export and foreign exchange earnings.

The solution to alleviate the problem of mango fruit storage facility is developing juice extraction or pulping technology. Manual Fruit extraction methods in our homes usually is crude. FAO,1995 stated that Most of the time people apply pressure to peeling and squeezing fruits with hand and mouth in order to get the juice out of the fruit. These methods are primitive and consume both time and energy.

Some of the researchers who have an experience in the past have developed mango juice extraction technologies are (Sonar D. J. et al ,2018 and Boakye O, 2014). The skills, knowledge and understanding of the importance of hygiene is also a valuable factor (Bamigbade, 2002).

Jackson (1988) worked on an electrically powered juice pulping machine. The machine is a lever operated press that grinds and crushes in one operation with an output of about 25 liters of juice per hour when operated by one person. The first attempt in the design of the Fruit Juice Extractor was carried out by Onyene, (2007). Adewumi (1998) were developed an orange juice extractor with a capacity of 5.1lit/hr. and extraction efficiency of 78.78%. The extraction capacity of the machine was found to be better than 280 % of the manual extraction method and 304% of the value obtained using the domestic hand peeling and extraction. Adewumi and Ukwenya (2012) designed and fabricated an extractor for the juice with a power of 1.42 horsepower, highest juice extraction efficiency of 76 % and highest juice extraction capacity of 26.67 liters/h was recorded at shaft speed of 300 rpm. Olaniyan and Obajemihi (2013) were designed, fabricated and evaluated of a small-scale mango juice extraction with a result of average juice yield, extraction efficiency and extraction loss of 34.56 %, 55.14 % and 10.15 % respectively by using a 2.5 HP electric motor.

Hence, Fruits are seasonal, there is a need to avail a machine that can efficiently extract juice in order to enable availability and storage in the form of powder or juice at all time. Still, there is a need for developing a medium scale mango pulp extractor because of its high consumption need and lack of high capacity technology.

Farmers in Ethiopia do not utilize the mango fruit to the optimum after harvesting because of poor postharvest practices. Government of Ethiopia has been making intensive efforts to encourage local production of agricultural equipment but have been faced with some problems. Because agro-processing machinery depends largely on imported technologies. Apart from the massive related cost, the issue of unavailability of spare parts for the sophisticated imported equipment and in some cases lack of relevant skilled manpower to operate and repair the equipment has given rise to the need to look inward for locally fabricated equipment. Therefore, it is important to produce a machine that can aid in the extraction of mango juice in an efficient way in the country to boost the income of the farmers and the industry sector.

OBJECTIVE OF THE STUDY

The main objective of this study is to conduct the performance evaluation of the mango juice pulper machine.

MATERIALS AND METHOD

The motorized mango pulp extractor was designed and fabricated in the Agricultural Engineering Research workshop. The juice extractor is designed to work on the principle of chopping, crushing and scraping of the mango to separate the pulp and the bush. Extractor consists of the hopper, barrel, shaft with auger, juice outlet, fruit pulp and bush outlet, pulley, electric motor, top cover, collector, motor stand and frame. The feed hopper is essentially the part of the machine through which the fruit is fed into the machine. The hopper acts as a container and at the same time helps in gradually introducing the fruits into the chopping and juice-extracting sections. The extracting section of the machine comprises a screw beater conveyor, and the pulley with bearing. The outlet section comprises two major outlets: the juice outlet and the residual outlet. The juice outlets are perforations drilled below the cylindrical barrel unto which a sieve made of stainless steel for juice collection attached. The residual outlet is joined at the right-side end of the cylindrical barrel. The power unit consists of a 1 hp single-phase electric motor with belts and pulleys. 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 and rust formation. The major aim of this design is to fabricate a portable and affordable motorized mango fruit juice extractor for small scale and medium mango fruit growers and processors.

The operation of the mango pulper, the screw conveyor and the screw blade impacted the mango fruits against a drum perforated on the inside. The extraction chamber consists of a perforated cylindrical drum which houses a uniform diameter and equal-pitch screw conveyor. The perforated drum is essentially a cylindrical drum on which series of perforated holes were drilled in an orderly manner. The perforations are roughened in the internal surface of the drum to form an abrasive surface for tearing the fruit mesocarp and enhance the flow of juice. The shaft rotates at its required 400rpm speed, the screw blades hits the mango fruits against the roughened/abrasive drum surface in such a way that the mango mesocarp is softened. The pulp that has been conveyed to that end is crushed and scraped by the rotating action of the auger against the wall. The juice extracted drops on the collector and is drained through the juice channel into the juice outlet from where it is collected while the residual waste is collected at the waste outlet.

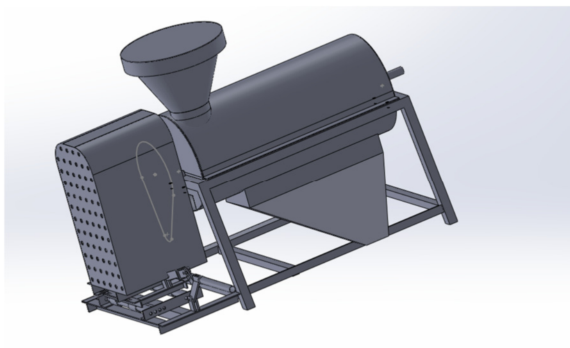

Figure 1. Isometric view of electric motor driven mango pulper

Figure 2. Mango pulp extractor prototype
Experimental Procedure

The juice pulper was tested and evaluated with fully matured mango fruit. The prototype was evaluated, using a 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 feed rate FR at three levels (F1=4kg, F2=6kg, F3=8kg) and the retention time of juicing at three level (i.e. RT1=20sec, RT2=40sec and RT3=60sec). Each of the factors was replicated three times to arrive a factorial design. Performance parameters used for evaluating the juice extractor are the extraction efficiency (εf), %, extraction losses (εL), % and extraction capacity (Cex), lit/ hr. using equation 1.1,1.2,1.3 and 1.5. The evaluation results showing the different interactions between the operating factors. Testing procedure was carried out at Agricultural Engineering Research Process Laboratory. Freshly harvested and ripe mango fruits were purchased from Adama fruit merchant market. The mango fruits were washed, weighed and prepared ready for juice extraction. The machine was set into operation and known weights of the fruits were fed into the machine through the hopper. In the extraction unit, the screw conveyor conveyed the mango fruit, scrapped and softened the mesocarp, beaten the mesocarp against the perforated cylindrical drum in order to extract the juice. The juice extracted was drained through the stainless-steel screen/hole into the base collector, discharged through the juice channel and weighed while the residual wastes were collected and weighed separately and obtained values of juice yield, extraction efficiency and extraction loss.

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

1. Input capacity, C_i, (kg/hr.)

$C_i = \frac{W_i}{T_i}$-----------------------------1.1

Where:

C_i=Input capacity.kg/hr.
W_i=weight of input material, kg
T_i=time required to empty the hopper of the input material, hr.

2. Extraction Rate, E_r, (kg/hr.)

$E_r = \frac{W_f}{T_t}$ --------------------------1.2

Where
E_r =Extraction Rate, kg/hr.
W_f =Weight of juice collected, kg
T_t = Total Operating Time, hr.

3. Extraction Loss, E_L (%)

$E_L = \frac{W_L}{W_{TJ}}$-----------------------------1.3

Where

E_L=Extraction loss, %
W_L= weight of juice collected other than from juice outlet, kg
W_{TJ}= Total Weight of Extracted Juice, Kg =$W_f + W_L$

4. Potential Juice Content, P_{JC}, (kg)

$P_{JC} = \frac{MC_i}{100} \times W_i$----------------------1.4

Where
P_{JC}=Potential Juice Content, kg
M_{Ci}=Initial moisture Content of crop, %
W_i=weight of input material, kg

5. Extraction Efficiency, E_{ff}, (%)

$E_{FF} = \frac{W_{TJ}}{P_{JC}} \times 100$---------------------1.5

where
E_{ff}=extraction efficiency
W_{TJ}= Total Weight of Extracted Juice, Kg = $W_f + W_L$
P_{JC}=Potential Juice Content, kg

6. Moisture Content, MC, (%)

$$MC = \frac{W_{im} - W_{fm}}{W_{im}} \times 100 \text{-------------} 1.6$$

Where

M_C = Moisture content, %
W_{im} = initial weight of sample, kg
W_{fm} = Final Weight of samples, kg

RESULT AND DISCUSSION

The performance evaluation of the small-scale mango juice-pulp extractor was carried out and its results presented as below. The operating factors considered during the evaluation were feed rate, (F) and the extracting retention time (RT) for the prototype. The three levels of feed rate (F1, F2 and F3) and three levels of extracting retention time RT (i.e.RT1, RT2 and RT3) were considered good for this study with each run replicated three times. Also, the performance parameters considered in this study were extraction efficiency, (Eff, %), extraction loss (E_L, %% and extraction capacity ($C_{ex,\ lit}$/hr.). Mmechanism of mango fruit extractor machine. It was found out from the tests that the machine when operating at 400 rpm has obtained the efficiency of 78.94%, extraction loss percentage of 11.18%.and extraction capacity of 86.41L/hr using 1hp electric motor as noted in Table 1.

Table 1. Performance result of the extractor

PARAMETERS	Efficiency, (%)	Ext_Capacity (L/hr.)	Ext_Loss, (%)
N	27.00	27.00	27.00
MEAN	78.94±2.37	86.41±3.79	11.18±1.51
MEDIAN	77.00	90.92	12.43
SD	7.12	11.36	4.54
MINEMUM	70.30	66.90	7.22
MAXIMUM	92.14	97.47	20.35
CV	9.00	13.15	14.44

Figure 3. juice processing and pulping

Earlier, Adewumi and Ukwenya (2012) found a result of juice extraction efficiency of 76 % and juice extraction capacity of 26.67 liters/h was recorded at shaft speed of 300 rpm using a power of 1.42 horsepower. Besides, Olaniyan and Obajemihi (2013) were evaluated and found a result of average juice yield, extraction efficiency and extraction loss of 34.56 %, 55.14 % and 10.15 % respectively by using a 2.5 HP electric motor. The 400rpm is not an indication of the best speed to use in mango juice extraction using this machine, it needs further test varying the speed of electric motor. The stage of ripening of the mango can also directly affect the amount of juice extracted from the fruit.

Allowing the processing retention time until the edible part of the mango well drained has been essential for minimizing loss. During testing, the edible part of mango is well drained at 40 sec processing retention time. At this time, it has an extraction capacity of about 86.41 liters per hour. Increasing the retention time beyond 40sec to extract the edible mango juice can no longer increase the juice capacity. Already the edible part of the mango well drained at this time limit. Increasing the feed rate has not a significant effect. Therefore, the optimum retention time for mango juice processing is 40 sec as shown in the Fig.4. The figure reveals that above 40 sec, the capacity become more or less similar while at 20 sec retention time found lower capacity but varying the feed rate has not a significant effect.

Fig:5. shows that the mango juice extraction efficiency of the machine when tested using mango. It can see that the efficiency of the extraction for mango increased to a maximum value of 70% up to 85% at operating speed of 400rpm and feed rate of 6kg/min. The average efficiency of the machine is 78%. Naturally, the mango fruit is less succulent to extract like orange. This has an effect on juice extraction efficiency.

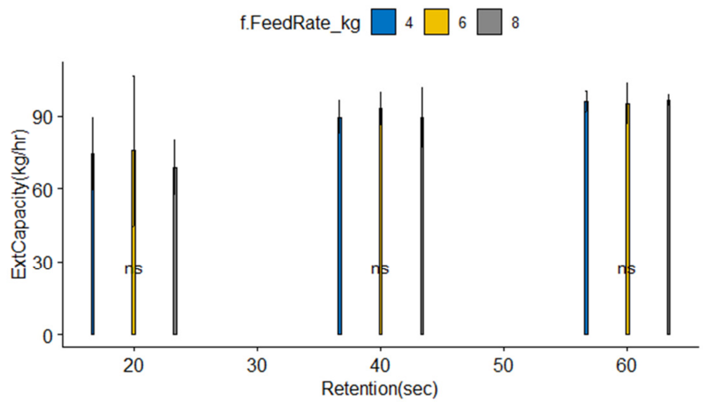

Figure 4. The effect of retention time on feed rate during juice extraction

Thus, it is essential to heating the mango fruit with warm water to loosen and enhance the ease of juice extraction and reduce the roughness of the fruit. This improves the quality and quantity of the mango juice extraction process.

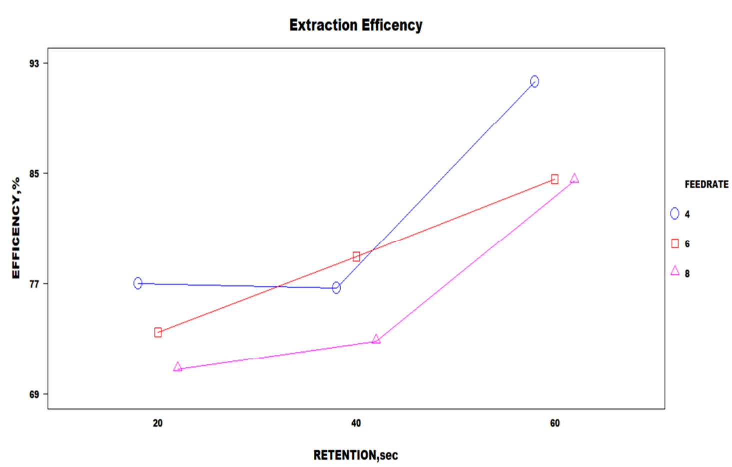

Figure 5. Mango juice extraction efficiency

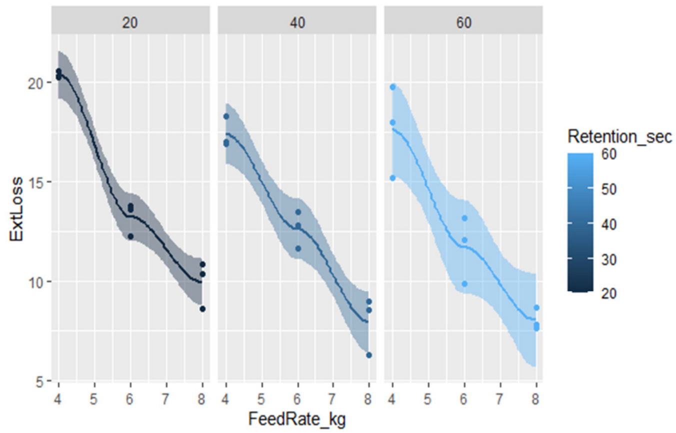

Figure 6. Mango juice extraction loss

Addition of water is not recommended during extraction. Therefore, the performance test shows the optimum extraction efficiency of the motorized mango pulp extractor depends on the ripening stage of the fruit, retention time of fruit extraction and the extraction speed of the machine. The extraction speed design of the prototype was chosen based on the recommendation of (Adewumi and Ukwenya, 2012).

The extraction loss of the machine referring of Fig:6. can be seen that an increase in retention time at 400 rpm machine operating speed, the extraction loses become decreases. This may be due to losses arising from the splashing of the juice at the machine walls as a result of allowing enough time for abrasion and vibration at about 40sec.

Provision should be made for controllable cylinderical hopper and concave is needed for proper discharge of the residual waste from fruits and thus reducing the volume of the juice loss at an average of 11.18%.

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 mango juice Extractor. The extractor was portable enough for local production, operation, repair and maintenance while all the construction materials were available locally with affordable price. The machine was Powered by 1 hp single-phase electric motor. The machine has average juice capacity, extraction efficiency and extraction loss of 86.41 l/hr., 78.94% and 11.18%, respectively. The machine can be used for small scale mango juice extraction in the rural and urban communities and can be scaled-up for industrial application. An improvement in the design of the screw conveyor of the extraction chamber is expected to improve the efficiency of extraction process in terms of juice yield and juice recovery efficiency; hence, this is recommended for further research. The results of the test showed that the machine performed satisfactorily but there is still room for improvement.

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