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Sreedevi Pandraju
Reginal Agricultural Research Station, Anakapalle, Andhra Pradesh, India

Madhava M
Dr. NTR College of Agricultural Engineering, Bapatla, Andhra Pradesh, India

Amit Padhi
Reginal Agricultural Research Station, Anakapalle, Andhra Pradesh, India

Gangadhar G
Reginal Agricultural Research Station, Anakapalle, Andhra Pradesh, India

Indira M
Reginal Agricultural Research Station, Anakapalle, Andhra Pradesh, India

Lavanya T
Reginal Agricultural Research Station, Anakapalle, Andhra Pradesh, India

Pavan Kalyan K
Reginal Agricultural Research Station, Anakapalle, Andhra Pradesh, India

Sandhya M
Reginal Agricultural Research Station, Anakapalle, Andhra Pradesh, India

Subramanyam Sarma A
Reginal Agricultural Research Station, Anakapalle, Andhra Pradesh, India

Lakshmi Durga M
ICAR- CIAE, Bhopal, Madhya Pradesh, India

Corresponding Author:
Mattaparthi Lakshmi Durga
ICAR- CIAE, Bhopal, Madhya Pradesh, India

Development of low cost sugarcane peeler for small vending's

Sreedevi Pandraju, Madhava M, Amith Padhi, Gangadhar G, Indira M, Lavanya T, Pavan Kalyan K, Sandhya M, Subramanyam Sarma A and Lakshmi Durga M

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Abstract
Sugarcane is the most common commercial crop grown worldwide, which is grown in tropical and subtropical countries of the world. Sugarcane is the world's second largest crop in production with about 188.25 million metric tonnes of cane during 2018-19 and provides 60 to 70% of the world sugar. Sugarcane is a common raw material for sugar and jaggery. As the production is high, the development of sub products from sugarcane is also high where juice has its equal importance. Additionally, cane juice is mostly used as a "refreshner" during summer to replace the artificial beverages. The sugarcane juice can be obtained by squeezing through extractors. Apart from that, as per health point of view many of consumers show more interest on sugarcane juice than other cool drinks. In major countries of South Asia, sugarcane juice extraction is the main occupation for small scale road side venders. The extracted juice quality can be improved by separating the sugarcane peel prior to juice extraction. The ancient method of sugarcane peeling is done manually with help of knife. But this method is more tedious, ineffective and prone to injuries. Moreover, the extracted juice contains a lot of suspended solids and impurities, which affects the quality, taste and colour due to presence of wax and other plant impurities. To reach the above limitations, a low cost sugarcane peeler for small scale venders was developed. The maximum value of machine production efficiency obtained as 74.9% with the peeling capacity of 3 canes per minute.

Keywords: Sugarcane, sugarcane juice, sugarcane peeler and peeling efficiency

1. Introduction

Sugarcane (*Succharum offcinarum* L.) is the most common commercial crop grown worldwide, which is grown in tropical and subtropical countries of the world. Sugarcane is the world's second largest crop in production about 188.25 million metric tonnes of cane during 2018-19 and provides 60 to 70% of the world sugar (Statista, 2019). India occupies 2nd place after Brazil in area of cultivation with 18.49% and with production of 348.45 Mha of sugarcane (FAOSTAT, 2016). Its by-products are also used as a fodder to feed livestock in many countries. In India, sugarcane being grown as a Kharif crop. It grows well in hot and humid climate with an average temperature of 21 ºC to 27 ºC in deep rich loamy soil.

Sugarcane juice is sweet in taste and is full of natural sweetness, which have a low glycemic index (GI) hence it works very well for diabetic patients. It also prevents heart diseases as it helps decrease the levels of unhealthy or cholesterol and triglycerides. Sugarcane is a common raw material for sugar and jaggery. Typically, out of the total sugarcane produced in India, about 74% is processed into white sugar, 15% into jaggery and khandasari which is an unrefined sugar with strong molasses content and the remaining 11% is utilized for extracting juice as well as seed material (Rao and Sreedevi, 2016) [6]. Sugarcane juice is used as an alternative for synthetic beverages which will give the refreshness during summer. Apart from that, as per health point of view many of consumers show more interest on sugarcane juice than other cool drinks. In major South Asian countries, the highway roads, streets are crowded with sugarcane juice vending shops in informal markets under unhygienic conditions by arranging small scale crushers and getting more economical benefit from them. The process of extraction of sugarcane juice from small scale units involves manual peeling with help of conventional knife which gives the uneven peeling, which is more tedious and drudgery process and the efficiency of peeling is not satisfactory which remains unpeeled portions, this may reduce the quality of juice.

As sugarcane juice contains lot of nutritional qualities apart from that the extracted juice also contains a lot of suspended solids and impurities, which affects the quality, taste and colour due to presence of wax and other plant impurities. In the present market different models for peeling machines are available, which includes fully automatic and semi-automatic peelers, which are more expensive and cannot afford by small scale venders. Hence this paper lights on the development of low cost peeling machine for sugarcanes especially for small venders.

Gadekar *et al.*, (2017) [2] designed and developed sugarcane peeling machine and their aimed to provide a commercial platform for production of sugarcane peeling machine. The main working principle involved in this study is when sugarcane is passed through the rotating hollow shaft, comes in contact with brushes. Hence with the developed machine 59.6 percentage of peeling-efficiency obtained. In other hand, to defeat the drudgery of manual peeling, Kadam *et al.* (2018) [3] have designed the peeling machine for sugarcane crop and they adopted the orbital motion shaped peeling action. Yamani and Basiouny (2016) evaluated the prototype version of small-scale peeling machine of sugarcanes. To evaluate the quality of peeling machine they have compared the different machine and crop parameters. The authors obtained with results of zig-zag pattern type brush giving better performance. Finally, they concluded that maximum peeling efficiency is 88.85% achieved at peeling drum speeds of 9.18 and 3.53m s^{-1} and peeling drum clearance of 2 cm and number of feeding canes per minute of 3 canes. Bagher *et al.* (2008) [1] developed a mechanical peeling of pumpkins by using an abrasive brush.

Automatic-sugarcane peeling machine was designed by Xinfeng (2014) and they have adopted the slider-crank mechanism, which is reliable with drudgery reduction and with high efficiency. Manjunatha *et al.* (2012) [5] explained about development and performance evaluation of a power operated garlic peeler with a cylinder-concave mechanism with peeling efficiency, yield of peeled garlic and unpeeled garlic, damage and peel separation were 86.6, 86.2, 4.7, 9.15and 96%, respectively with a machine throughput capacity of 27 kg/h.

2. Materials and Methods

In the present work, the variety of 93A145 sugarcane (S*acharam Officianarum*) was selected. The length, diameter, weight of sugarcane were crucial for designing of peeler for sugarcane in terms of clearance between the two brushes, stiffness of the brush for clearing the peel over the cane. The physiological characteristics of the cane like length, mean diameter are measured with help of cloth tape and Vernier calliper up to an accuracy of 0.02 mm.

2.1 Development of low cost peeling machine

A low cost sugarcane peeler was designed and developed for peeling the sugarcane. The mechanical peeler is mainly for (peeling the sugarcane) small scale cane crushing units. It consists of frame, two rotating brushes and power transmitting unit. The frame is used to support all the integral components of the mechanical peeler. The frame columns are put at an angle to increase the ground contact area in terms to stabilizing the whole machine while machine in working condition. A motor is main source for development of rotational power. In this present investigation, two stainless steel zig-zag wire brushes (Yamani and Basiouny, 2016) was taken and these were procured from Bosch Brush Ltd. And these wire brushes have groove on them for fine peeling of sugarcane. Four stud rods are fixed between the frames to adjust the clearance between two brushes which is suitable for peeling various sizes of sugarcane. v-belt type transmission was adopted because it is less critical to misalignment than other types of drives and there is no need to maintain exact speed ratio and does not require lubrication (Kepner *et al.*, 1987).

In this machine three pulleys (Motor, 1st shaft and for 2nd shaft) are selected for facilitating the speed variation between the pulleys. A steel dome was mounted over the top of the brushes for preventing the sugarcane dust falling on to the operator during operation. This dome is portable for cleaning in side of the machine.

2.2 Performance evaluation of sugarcane peeler

a) Speed

The speed of the drive shaft was measured by a digital tachometer. The measured speed was obtained in revaluations per minute and converted into meter per second.

$$\text{Speed (m/s)} = \frac{\pi D N}{60} \quad \ldots. \quad \text{Eq (1)}$$

Where,
D = Diameter of the drive shaft, m and
N = number of revolutions, rpm

b) Power consumption of developed machine

It was calculated according to the following formula (Yamani and Basiouny (2016)),

$$\text{Power consumption} = \sqrt{3}\,(I.V.\cos\theta.\ \eta)/1000,\ \text{kW} \ \ldots. \ \text{Eq (2)}$$

Where,
I = Current intensity, Amperes;
V = Potential difference, Volts;
cos θ = Electrical power factor, decimal (being equal to 0.71), and
η = Mechanical efficiency of motor assumed to be 80%

c) Peeling efficiency

The peeling efficiency of mechanical machine was calculated by the following formula (Yamani and Basiouny (2016)),

$$\text{Peeling Efficiency (\%)} = \frac{\Delta d}{i} \times 100 \quad \ldots. \ \text{Eq (3)}$$

Where,
Δd = Difference between sugarcane diameters before and after peeling (thickness of sugarcane peeled by machine), mm and
i = Ideal thickness to be peeled by machine, mm

d) Machine production efficiency

It was calculated according the following formula

Machine production efficiency = (Actual machine capacity, kg/h/Theoretical machine capacity, kg/h) x 100 ….Eq (4)

e) Cane stalk weight loss

It was calculated as difference between weight of cane before and after the peeling with developed machine.

2.3 Quality parameters of peeled cane juice

a) Total soluble solids

Total soluble solids of extracted juice measured by a Refractometer. It is a simple machine used for measuring concentrations of sugarcane juice. It requires only a few drops of solution. Degree Brix (ºBrix) is the sugar content of an acqueous solution. One degree brix is 1gram of sucrose in 100 grams of solution and represents the strength of the solution as percentage by mass. If the solution contains dissolved solids other than pure sucrose, then the ºBrix only approximate the dissolved solid content (Sirichai and Jittani, 2010) [7]. In this determination, few drops of sugarcane juice were placed on the sensor of Refractometer. Due to of light refraction through sugarcane juice, it gives direct measurement of total soluble solids present in the juice.

b) pH

A pH meter is a scientific instrument that measures the hydrogen – ion activity in water based solutions, indicating its acidity or alkalinity expressed as pH. In this study, the pH level of extracted juice of canes obtained from mechanical peeling, manual peeling and control.

c) Photo colorimeter

The colour of extracted juice (canes obtained from mechanical peeling, manual peeling and control) was measured by using colorimeter (Make: Eliico) in terms of absorbents present in the extracted juice obtained from 4-roller SS crusher. A colorimeter is a device used in colorimetry. In scientific fields the word generally refers to the device that measures the absorbents of particular wave lengths of light by a specific solution.

2.4 Cost economics

In order to evaluate the effectiveness of the treatments and to ascertain the most remunerative treatment, the cost incurred for the peeling under each treatment were computed and added. The cost analysis is divided under two heads known as fixed cost and operating cost which is as follows

Fixed cost/year

i. Fixed cost of unit = $\frac{i\ (i+1)^N}{(i+1)^N - 1} \times C$ …. Eq (5)

Where,
i = Interest rate (10% per annum)
N = Life span of unit
C = Cost of unit

ii. Housing, insurance & taxes = 3% of initial cost

Fixes cost/year = (i) + (ii)

Variable cost/year

i. Repair and maintenance = 5% of initial cost of unit
ii. Electricity charges = 6 /- per KWh
iii. Labour charges per person at the rate of 200/day

Total variable cost = (i) + (ii) + (iii)

Cost of operation of machine/h = total variable cost/h + total fixed cost/h

Unit cost of operation = $\frac{\text{total variable cost/year}}{\text{total production/year}}$ Rs/kg …. Eq (6)

3. Results and Discussions

The performance evaluation of the developed low cost sugarcane peeler was conducted as per standard procedures. The length of sugarcane varied from 220 to 255 cm and the diameter of cane varied from 20 to 34 mm. The specifications of developed low cost sugarcane peeler was measured and presented in following table 1 and developed machine was shown in figure 1.

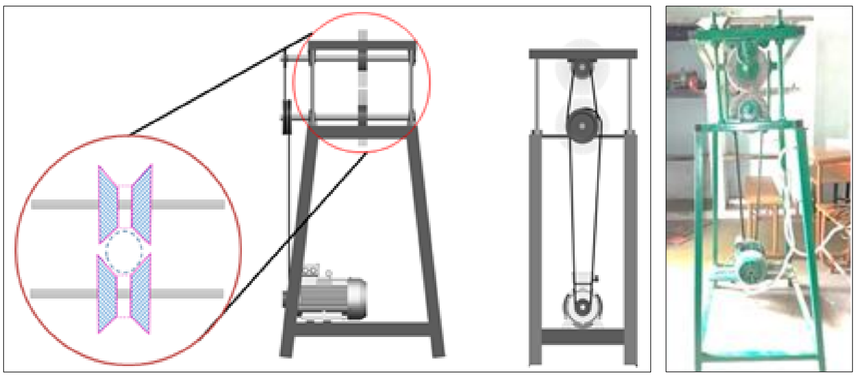

Fig 1: Pictorial representation of developed peeling machine for sugarcane

Table 1: Specifications of mechanical sugarcane peeler

Parameter	Details
Overall height, cm	121.5
Overall length, cm	61
Overall width, cm	48
Weight, Kg	52
Peeling mechanism	Brush type
Power source, HP (electric motor)	1HP, high speed motor (2850 rpm)
Number of brushes	2
Peeler price	Rs. 15, 300

The performance evaluation of peeler was carried out and the operating parameters such as peeling efficiency, machine production efficiency, crushing efficiency, cane stalk weight loss, machine power consumption, and machine unit cost were calculated. The speed of the machine was measured by aforementioned Eq (1) and it was obtained as 3.72 m/s. power consumption of the developed machine (based on Eq (2)) was obtained as 1.47 kWh.

Peeling efficiency

The peeling efficiency of mechanical peeler is calculated at different clearances of 2 cm, 3 cm and 4 cm between the two rotating brushes. The results obtained by peeler at different clearances are presented in table 2. The maximum average value of peeling efficiency is 77% at 2cm clearance and minimum average value of peeling efficiency is 36% at 4 cm clearance. This shows that increasing the clearance between the brushes decreasing the peeling efficiency and vice versa. Hence, the optimum clearance between the brushes is 2 cm.

Table 2: Peeling efficiency at different clearances between brushes

	Peeling efficiency at different clearances between brushes								
	2 cm			**3 cm**			**4 cm**		
	Initial (mm)	**Final (mm)**	**PE, %**	**Initial (mm)**	**Final (mm)**	**PE, %**	**Initial (mm)**	**Final (mm)**	**PE,%**
Average	29.71	28.93	77	27.32	26.82	53	28.21	27.86	36

From the table 2 the optimum clearance between the brushes for effective peeling of the mechanical peeler was 2 cm. So the effect of peeling efficiency on different passes (shown in Fig. 1) of cane at the clearance of 2 cm between brushes are tabulated in table 3. The results indicated that the effect of number of passes per cane on peeling efficiency with the clearance of 2 cm between brushes. The value of peeling efficiency was increased with number of passes per cane and vice versa. The maximum peeling efficiency of 77% was obtained at 3rd pass, this is because of exposure time of the cane in between the rotating brushes is more between the brushes. The minimum value of peeling efficiency was obtained at 1st pass and the value of peeling efficiency was 35%. So by above discussion the maximum peeling efficiency is obtained at 3 passes of cane at a clearance of 2 cm.

Table 3: Peeling efficiency of mechanical peeler with different number of passes

S. No.	**Sample**	**Initial diameter (mm)**	**Final diameter (mm)**					
			1st Pass	**PE, %**	**2nd Pass**	**PE, %**	**3rd Pass**	**PE, %**
Average		27.81	27.45	36	27.28	53	27.04	77

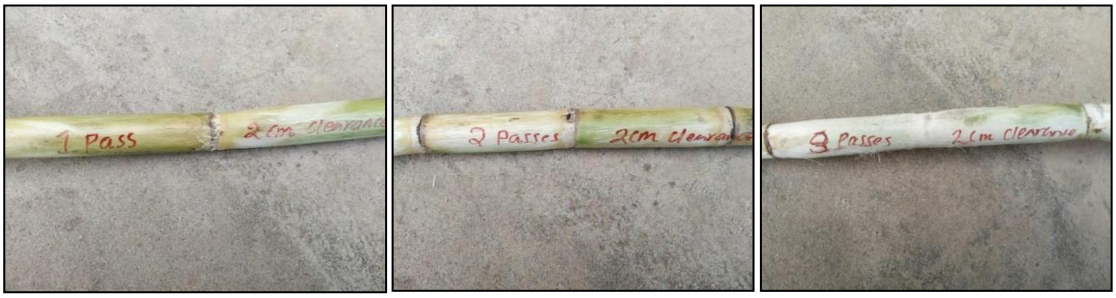

Fig 2: Peeling of cane after 1, 2 and 3 passes

Comparison of peeling efficiency

The peeling efficiency of manual peeling and mechanical peeler are compared with the parameters of thickness removed during peeling and time taken for peeling and the results of the peeling efficiency are calculated by using Eq (3). The comparable data were tabulated in table 4. Figure 2 represents the comparison between manually and mechanically peeled canes.

Table 4: Comparison of peeling efficiency of developed peeler and manual peeling method

Treatment	**Initial diameter of cane, mm**	**Final diameter of cane, mm**	**Thickness of removed bark, mm**	**Time for peeling/ cane (sec)**	**Peeling efficiency, %**
Manual peeling	25.97	25.5	0.42	60	42%
Developed peeler	27.81	27.04	0.77	20	77%

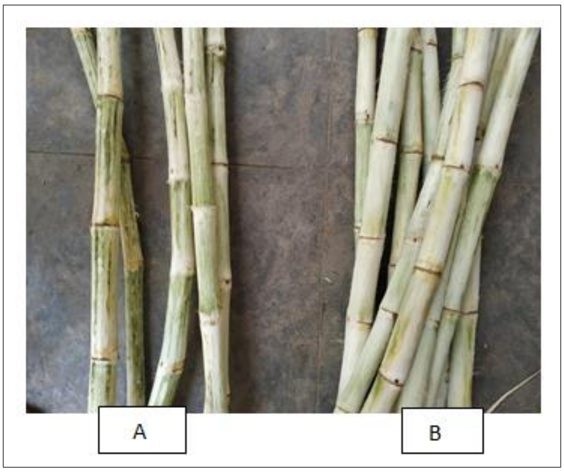

Fig 3: A. Manual peeled canes B. Mechanical peeled canes

From the table 4 the comparison of peeling efficiency of both manual peeling and mechanical peeling are evaluated and the results shows that the peeling efficiency of the mechanical peeler is more, values 77% in 20 seconds and the peeling efficiency of the manual peeling is comparatively less, values only 42% in 60 seconds so the above results shows that peeling efficiency was maximum by using mechanical peeler compared to manual peeling.

Machine production efficiency

The output capacity of the mechanical peeler and manual peeling are compared in the table 5. These were calculated by using Eq (4). The output capacity was calculated with reference of the theoretical capacity and actual capacity of the mechanical. Machine production efficiency of both mechanical sugarcane peeler and manual peeling shows that production efficiency was maximum in mechanical peeler, values 75.4% and the production efficiency of manual peeling is comparatively low, values 60% only. The output capacity also maximum in mechanical peeler with the production of 109.6 kg/h compared to manual peeling with only 28.8 kg/h. The results were coincides with Tagare *et al*., 2013 [8].

Table 5: Output capacity of mechanical and manual peeling

Treatment	No. of canes/min	No. of canes /h	Actual output capacity, Kg/h (x)	Theoretical output capacity, Kg/h (y)	Machine production efficiency, % (x/y)
Mechanical	3	180	109.6	144	75.4
Manual	1	60	28.8	48	60

Table 6: Cane stalk weight loss

S. No.	Sample	Clearance, cm	Initial weight, (g)	Final weight, (g)	Weight loss, (%)
1	R_1	4	1.475	1.435	2.7
2	R_2	3	0.765	0.702	6.9
3	R_3	2	0.930	0.855	7.5

Cane stalk weight loss
The canes stalk weight loss of the mechanical peeler was evaluated with three different clearances between the brushes. The table 6 indicates that the cane stalk weight loss at different clearances between the brushes of mechanical peeler. The maximum weight loss signifies lower peel retention on sugarcane stalks (Xinfeng, 2015) [9]. The maximum weight loss 7.5% was recorded at 2 cm clearance, and the minimum value of weight loss was recorded at 4 cm clearance as 2.7%. This source at 4 cm clearance the maximum peel retention was recorded which is low efficient compared to 2 cm clearance.

Quality analysis of sugarcane juice
The quality parameters of fresh sugarcane juice obtained from canes of manual peeling, mechanical peeler and without peeling were estimated. The Physico-chemical parameters such as pH, TSS and colour of sugarcane juice are presented in table 7. Low value of l (40.) was recorded for juice obtained without peeling indicating darker color. The comparison of extracted juices from three operations are compared in Figure 3.

Table 7: Quality analysis of sugarcane juice

Treatment	Parameters				
	TSS, °Bx	pH	Absorbance		
			L	a	b
Mechanical peeling	19.95	5.28	62.7	1. 7	26.3
Manual peeling	19.25	5.35	48.0	2.0	44.6
Without peeling	19.3	5.33	40.3	7. 7	25.7

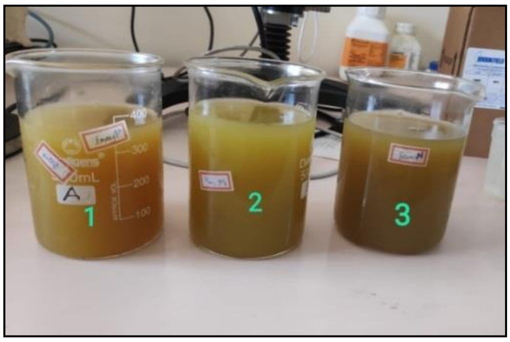

Fig 4: Comparison of sugar cane juice 1) Mechanical peeling 2) Manual peeling 3) Without peeling

Cost economics
The table 8 shows the percentage of labour cost and time saving in developed low cost peeler compared to manual peeling. The results showed that the peeler saves 200% of labour saving, 66.66% of labour cost and 74% of time compared to manual peeling. With help of developed peeler, the production of peeled sugarcanes was about 8.76 q/day.

Table 8: Percentage of time and labour saving of peeler over manual peeling

S. No.	Peeling operation		% Saving
	Manual	Mechanical	
Labour Requirement (per day/8 h)	3	1	200
Quantity of cane peeled (kg)	230	876	
Labour cost @Rs.200/- per day	600	200	66.6
Time per peeling of 100 kg of cane	0.66 hr	0.25 hr	74

In order to evaluate the effectiveness of the mechanical peeler, the cost incurred for the peeling under each treatment were computed and added. The cost analysis is divided under two heads known as fixed cost and operating cost. The cost parameters were considered based on standards. Finally, the cost of operation of the low cost peeling machine was Rs. 292.16/day and unit operation cost of machine was Rs. 0.27/kg (i.e. approx..30 paisa per kg of cane).

4. Conclusions

Low cost peeling machine for sugarcane was developed for small scale vendors. The performance of the machine was evaluated for peeling efficiency, machine production efficiency, cane stalk weight loss, power consumption and speed and the results were compared with manual peeling. After peeling operation, juice was extracted from peeled canes and quality of the juice was compared with manually peeled canes. Quality parameters of the extracted juice determined in terms of total soluble solids, pH, colour and absorbance. Results of the study concluded that, the higher peeling efficiency was obtained from mechanical peeler (77%) compared to manual peeling (42%) and also clearance between the brushes and number of passes of cane for proper peeling was optimized at 2 cm and 3 passes respectively. The output capacity of mechanical peeler was achieved as 109.6 kg/h with machine production efficiency of 75.4%. Percentage of labour and time saving of mechanical sugarcane peeler over the manual peeling was 66.6% and 164% respectively.

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