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Design and development of sugarcane peeler-cum-cutter machine

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Abstract
A dual-purpose machine engineered for stripping the outer rind from sugarcane stalks and subsequently chopping them into smaller segments was developed during this study. This equipment is composed of three main subsystems: the peeling mechanism, the slicing assembly, and the drivetrain. The outer husk is stripped away through the frictional contact generated by three sets of opposing wire-brush rollers. These brush units are mounted onto a revolving disc connected to a central hollow spindle, which receives its mechanical power from a D.C. motor via a V-belt drive system. At the terminal end of this hollow spindle, a specific opening is maintained. As cane stalks are fed through this opening, the rind is removed, and the separated waste material is subsequently expelled through a designated outlet port. This gap can be modified to accommodate variations in the thickness of different sugarcane stalks. A series of preliminary trials were undertaken to establish the most effective rotational speed and clearance setting for the rollers. Following this, the system's operational effectiveness was assessed by examining several key metrics, including the rind-removal rate, the overall processing throughput, and the proportion of damaged produce. The equipment demonstrated a processing rate of 90 kilograms per hour, and when operating under the ideal parameter settings, the rind-stripping efficacy was recorded at 58 percent.

Keywords: Sugarcane, peeler-cum-cutter, rollers, peeling unit, cutting unit, peeling efficiency

Introduction

Globally, India holds the top position both in sugar production and consumption. The sugarcane sector supports roughly 45 million growers, along with their families and a vast rural workforce, accounting for 7.5 percent of the country's village population. This extensive involvement in farming, harvesting, and related operations has propelled India past traditional giants like Brazil and Cuba to become the world's foremost sugarcane and sugar producer. Within the country, the primary regions for sugarcane cultivation include Uttar Pradesh, Bihar, Assam, Haryana, Gujarat, Maharashtra, Karnataka, and Tamil Nadu. Beyond its agricultural output, the sugarcane industry and its associated sugar manufacturing significantly contribute to rural socioeconomic progress by tapping into local resources and creating substantial avenues for income generation and job creation (Krishnamoorthy, 2017) [8].

A popular refreshment across Southeast Asia, South Asia, Latin America, and other regions where sugarcane is cultivated on a commercial scale is sugarcane juice. Despite its widespread appeal and palatable taste, this beverage is seldom found in prepackaged retail forms. The liquid is obtained by feeding cane stalks through roller-type crushers, and it is typically served either over ice or without any added chilling. In terms of its nutritional makeup, the juice consists predominantly of moisture, ranging from 75 to 85 percent, alongside non-reducing sugars chiefly in the form of sucrose at levels between 10 and 21 percent. It also contains reducing sugars namely glucose and fructose in amounts of 0.3 to 3 percent, organic compounds constituting roughly 0.5 to 1 percent, inorganic mineral components from 0.2 to 0.6 percent, and nitrogen-containing substances falling within the 0.5 to 1 percent range (Krishnakumar *et al.*, 2013) [7].

Commercially packaged sugarcane juice is a product that is seldom encountered in the market. The final grade of jaggery is significantly influenced by how effectively the juice is purified and clarified during processing. Sugarcane stalks commonly carry a range of adhering contaminants, including plant debris, dust, root remnants, waxy coatings, gums, withered foliage, soil particles, chlorophyll pigments, and various coloring compounds. In traditional jaggery production, the cane is typically crushed straightaway, causing all these extraneous substances to pass directly into the extracted juice.

Although subsequent clarification of the juice often employs plant-based clarifying agents, it remains good practice to wash and clean the stalks thoroughly before they undergo crushing (Tupkar *et al.*, 2023) [10].

Within India, large-scale industrial juice extraction typically involves feeding unwashed sugarcane through shredders and presses, after which the resulting turbid liquid undergoes filtration. This process causes waxy substances to become trapped within the filter cake, necessitating their subsequent recovery and refinement before they can be utilized. In contrast, for sugarcane juice destined for direct retail sale, the outer rind is stripped off prior to pressing. Based on this distinction, it was deduced that performing the peeling operation at the very beginning of the processing line would make the recovery of wax significantly more uncomplicated and produce a purer end product (Inarkar and Lele, 2012) [4].

Currently, the stripping of sugarcane rind is predominantly carried out by hand, a practice that proves to be physically strenuous, offers poor productivity, and yields inconsistent results. In response, mechanical peelers are increasingly being adopted to shorten the operational timeframe, thereby enabling vendors to lower their expenses and enhance their profits. This decortication step is performed after the foliage has been removed and represents the second stage in readying the stalk for juice extraction. The cane itself is structurally composed of an outer protective cover, a pulpy inner core, and the sweet liquid contained within. In actual practice, manual trimming demands substantial muscular effort coupled with an extremely sharp blade, rendering it a risky activity. Additionally, this traditional approach suffers from further drawbacks, such as a lack of trained workers and the prolonged duration required to complete the trimming process (Asim *et al.*, 2014) [1].

The engineering, fabrication, and operational testing of this dual-purpose peeling and chopping apparatus can adequately address the demands of street-side vendors, jaggery processors, and packaging entities. By utilizing this mechanical device, unsanitary practices, manual workforce requirements, and physical strain are effectively reduced, all while achieving a superior level of operational efficiency. In turn, this equipment guarantees an elevated standard of product quality and yields greater profit margins for its users.

Materials and Methods

Design Considerations

The act of peeling involves eliminating the outer inedible layer from the underlying consumable flesh. The design of this equipment was rooted in the mechanism of frictional force. As the produce passes through a designated opening between multiple abrasive revolving rollers, the scrubbing action successfully removes its external covering. For the subsequent operation of sectioning, a blade-type arrangement was employed. Ultimately, the individual parts of this apparatus were established based on a comprehensive review of these underlying operational principles.

Following are some design considerations of the components of the machine:

Determination of Torsional Moment:

Torsional moment is expressed by the Equation (Killedar *et al.*, 2019) [6].

$$T = \frac{P \times 60}{2\pi N}$$

Where, T = torsional moment (Nm)
P = power of prime mover (Watts)
N = rotational speed of pulley (rpm)

Force required to peel the Sugarcane:

The force required to peel the cocoyam is expressed by the equation (Pandey *et al.*, 2020) [9]

$$F = \frac{T}{r}$$

Where, F = Force (N)
T = Torque (Nm)
r = Radius of disk having peeling rollers (m)

Determination of length of Belt:

The length of belt was determined by the equation (Dehui *et al.*, 2015) [2]

$$L = 2C + \frac{\pi(D + d)}{2} + \frac{(D - d)^2}{4C}$$

Where, L= Length of belt (m)
C= Centre distance bet. the two pulleys (m)
D= Dia. of peeling disk shaft pulley (m)
d= diameter of prime mover pulley (m)

Description of the Machine

The machine described here was designed and fabricated with the specific aim of stripping the tough outer layer from sugarcane stalks and subsequently chopping them into smaller segments. This equipment is mounted onto a supporting structure fabricated from angle iron. Its primary assembly comprises six cylindrical rollers arranged in three matching pairs. These rollers are linked to a revolving disc featuring adjustable slots, into which roller pins are fitted. A blade mechanism is also incorporated into the unit to facilitate the chopping operation. Power is supplied by a single electric motor that drives the system through a beltand-pulley arrangement. The specific measurements and constructional features of each part of this peeling and cutting assembly are presented in Figure 1.

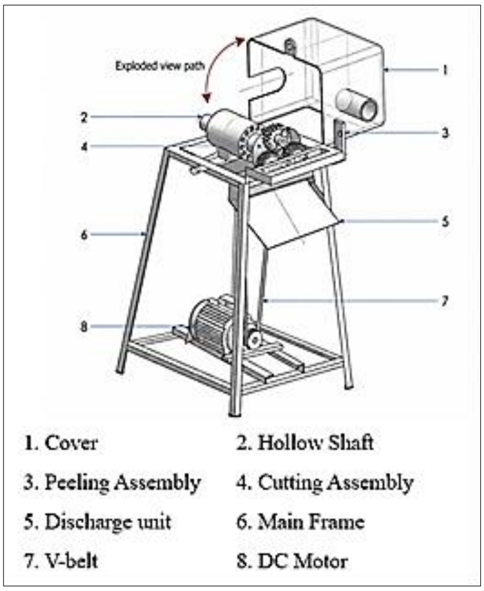

Fig 1: Isometric View of Sugarcane Peeler cum Cutter Machine

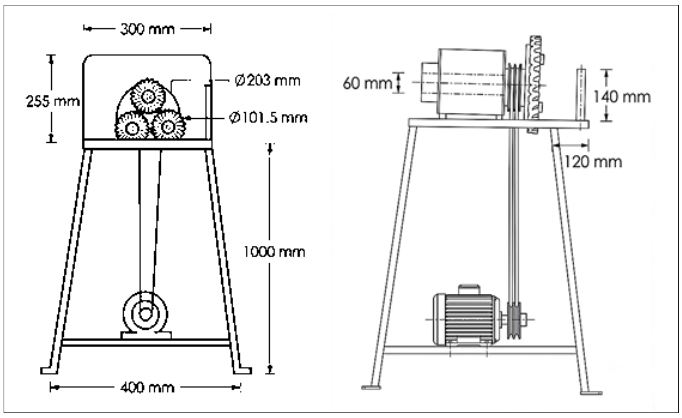

Fig 2: Front view and side view of Sugarcane Peeler-cum-cutter

Frame Assembly

To provide a sturdy base for all the machine's subassemblies and to absorb operational shocks and oscillations, a robust supporting structure was essential. This chassis was constructed from mild steel angle sections, each measuring 25 mm by 25 mm with a 5 mm thickness, providing a stable platform to accommodate the peeling rollers, the chopping mechanism, and the drive arrangement. The overall footprint of this structure was 440 mm in length and 310 mm in width, while its total height reached 1115 mm. A shaft bearing support was permanently affixed to this frame using welding techniques, whereas the cutting segment and the power transmission system were fastened securely by means of bolts and nuts, as clearly depicted in Fig 2.

Peeling Assembly

Peeling assembly was consists of hollow shaft, roller disc, roller pins and brush rollers (Ikram *et al.*, 2019) [3].

Hollow Shaft

The central tubular axle was fabricated from mild steel tubing, measuring 229 mm in overall length, with an internal bore of 50 mm and an external diameter of 60 mm. This axle was secured within the circular casing through the use of bearings sized 60×95×18 mm. A 100- mm-diameter cast iron sheave was mounted onto the axle to receive rotational power from the motor via a belt connection. At one extremity, a roller disc was permanently affixed through welding, while the opposite side remained unobstructed to serve as the inlet for inserting sugarcane stalks.

Roller Disc

The roller disc is fabricated from mild steel sheeting with a thickness of 12.56 mm and an overall diameter of 24.84 cm. This component is permanently joined to the hollow axle through welding and includes a central opening whose diameter matches the internal bore of the shaft. As illustrated in plate 3.2, the disc features three radial grooves intended to accommodate the brush rollers via securing pins. These grooves are spaced at 120-degree intervals from the center and provide an adjustable range of 24 mm.

Roller Pins and brush rollers

The roller pins were constructed from mild steel rod, each measuring 86.8 mm in length and threaded on both ends. These pins served two distinct functions: one portion was used to secure the pin to the roller disc, while the other held the brush rollers in position. Through these pins, the clearance between rollers could be varied to accommodate different sugarcane diameters during the peeling process. Each brush roller had a diameter of 104 mm and a thickness of 17 mm. The wire bristles mounted on these rollers were responsible for carrying out the actual peeling action on the sugarcane surface (Jayashree and Visvanathan, 2014) [5].

Cutting Assembly

The chopping function of the equipment is actuated by hand. This section incorporates a straightforward blade made of stainless steel, featuring a cutting edge that extends 160 mm in length and a thickness of 1.5 mm. For operator protection, the blade is fitted with a wooden handgrip. Additionally, the knife is connected to a tension spring that keeps it securely anchored in its resting position.

Power Transmission Unit

The drive power for the system is supplied by a 0.5 HP, 230 V direct-current electric motor, which operates at a top speed of 1500 revolutions per minute. Mounted onto the motor's output spindle is a 51 mm diameter driver sheave. From this pulley, motion is transmitted to the main axle via a V-shaped belt. The receiving pulley, secured to the driven shaft with a fastening bolt, measures 100 mm across (Pandey *et al.*, 2020) [9].

Result and Discussion

The sugarcane peeling and chopping apparatus was conceptualized, engineered, and constructed following the methodology outlined in the materials and procedures section. During operation, the stalks are initially passed through wire brushes that strip away the outer rind, after which they are subsequently severed into smaller sections by the cutting assembly. The detached rind and debris are ejected through the waste outlet. A comprehensive list of all constituent parts along with their respective technical attributes is detailed in Table 1.

Table 1: Technical Specifications of various components

Sr. No.	Component	Sub-component	Technical Specification	Value
1	Main Frame		Length (mm)	440
			Breadth (mm)	310
			Height (mm)	1115
2	Peeling Assembly	Hollow Shaft	Length (mm)	229
			Diameter (mm)	60
		Roller Disk	Diameter (mm)	248.4
			Thickness (mm)	12.56
		Roller Pin	Length (mm)	86.4
		Roller Brush	Diameter (mm)	104
			Thickness (mm)	17
3	Cutting Assembly	Cutting Knife	Length (mm)	160
			Thickness (mm)	1.5
4	Power Transmission Unit	DC Electric Motor	Power (Hp)	0.5
			Max. RPM	1500
		V-belt	Length (inches)	57
		Driving Pulley	Diameter (mm)	51
		Driven Pulley	Diameter (mm)	100

Conclusion

Manual peeling remains the conventional method for preparing sugarcane, demanding both a keen-edged blade and substantial physical exertion. Scant published data exists regarding mechanized solutions for this task. To address this gap, a combined peeling and cutting machine was conceptualized and constructed. Experimental runs were carried out at three distinct roller rotational speeds 200, 300, and 400 rpm and three gap settings of 20, 25, and 30 mm between the rollers. The influence of these operating parameters on both the effectiveness of peeling and the overall processing throughput was examined. The equipment demonstrated a processing rate of 90 kg per hour. Peak peeling performance, reaching 58.8 percent, was recorded at a roller speed of 441 rpm combined with a clearance of 25 mm.

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