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DEVELOPMENT OF PORTABLE IMPROVED SUGARCANE CRUSHER

PRAKRUTHI N RAJ GANGADKAR,
Ph.D Scholar,
Department of Food Technology,
JNTUA, Anantapuramu 515002, AP, India.

CHOWDE GOWDA. M,
Professor (R&D),
SJCIT, Chickballapur 562101, Karnataka, India.

N. B. L. PRASAD
Senior Chemical Engineer & Officer
Incharge of Examination, JNTUA
OTPRI, Ananthapuramu 515 001, AP, India

ABSTRACT

Traditional power operated 3-Cylinder traditional type sugarcane crusher, 3-Cylinder heavy duty sugarcane crusher and 3- Cylinder gear box type sugarcane crusher commonly used for crushing sugarcane in the jaggery making cottage industries and power operated 2-Cylinder power driven sugarcane crusher used by road side venders for extraction of juice for local consumption have been evaluated for their performance. Among the four types of sugarcane crushers evaluated, power operated 3- Cylinder gear box type sugarcane crushers was found to be more effective in crushing of sugarcane with respect to higher crushing efficiency, higher output capacity and less power consumption. Based on the feedback from locally used power operated 3-Cylinder sugarcane crushers, portable improved sugarcane crusher was developed and fabricated. It consists of M.S. frame to hold the mechanism including 5-crushing cylinders, 1.0 HP electric motor, power transmission systems, juice collection tray and casing. The improved 5- Cylinder sugarcane crusher developed was evaluated under actual field conditions and its performance was compared over the performance of 3- Cylinder gear box type sugarcane crushers used in the study area. The experimental data indicates that the performance of improved 5- Cylinder sugarcane crusher was found to be superior with respect to higher percent of juice extraction, higher output capacity of crushing sugarcane per unit time with less power consumption as compared to 3- Cylinder gear box type sugarcane crusher which is found to be the best among the locally used sugarcane crushers evaluated in the present study.

Key words: Traditional Sugarcane Crusher, Improved Sugarcane Crusher, Juice Extraction Efficiency, Output Capacity, Power Consumption

I. INTRODUCTION

Sugarcane is an important member of the plant kingdom and it is a species of herb belonging to the grass family (*Poaceae*). It has the pride of place among the commercial crops in India and provide raw material for the second largest industry in the country. In sugarcane production, India is No.2 in the world after Brazil (Table 1.0) cultivating in an area of over 4.83 million hectares, with an annual production of over 341 million tons of sugarcane. Sugarcane grow typically up to the height of 6 meters having clumped up, cylindrical, stout jointed fibrous stalks of 1.25 cm to 7.25 cm diameter (Munoz et al, 2007) & (FAO, 2015).

Table 1 Top ten sugarcane producers in the world

Sr.No	Country	Production(TMT)	Productivity(Tons/ha)
1	Brazil	7,39,267	72.30
2	India	3,50,200	62.80
3	China	1,25,536	65.50
4	Thailand	1,00,096	66.40

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5	Pakistan	63,750	47.90
6	Mexico	61,182	70.60
7	Colombia	34,876	84.10
8	Indonesia	33,700	73.10
9	Philippines	31,876	67.10
10	United States	27,906	77.50

Source: FAO:2015

Fifty percent of the sugar cane produced in the country is used for production of sugar, 40 % for jaggery and khandsari making and 10 % for seed and chewing purpose. This crop is highly adequate in the provision of energy for the nutritional requirement of both livestock and humen. Based on its land use factor, its value of calories per unit area is highest for any plant (Heiser,1981). Furthermore, a matured stalk is typically composed of 63-73 % water, 11-16 % fibre, 12-16 % soluble sugars and 2-3 % non-sugars. Sugarcane provides 60% of the world's sugar production (World Bank, 1998).

Different machines that are locally fabricated and available in the market are used for extracting sugarcane juice from the cane. The incursion of rust and surrounding debris into the extraction process of the locally fabricated sugarcane crushers has been an issue to which one needs to proffer solution to. The new technologies and new materials has been used in the latest machines for better performance to make better extraction. In the past, sugarcane juice was extracted from the sugarcane crusher run by bullock power whichwas the traditional practice of extracting juice from sugarcane. In India many road side venders engaged in extracting juice form the sugarcane as it is a main occupation for their livelihood. Hand rotated machines were developed which were made of metal. The rollers are strong enough to extract juice from sugarcane when the wheel is rotated manually. Later, the machines that worked on electricity with the help of motors were developed. Then emerged the problem of electricity and danger of hand injuries. Taking all these into considerations, the sugarcane extraction machines with inbuilt motors have been developed to produce hygienic juice, with increase in extraction efficiency of juice, consuming less man power and energy. These inbuilt machines have been developed using materials that prevents rust during cane crushing process. Even though the inbuilt machines were emerged in the market, the road side venders use only the two roller machine which runs on electricity / fuel.Crushing of sugarcane is one of the main unit operations in Jaggary making cottage Industry. The traditional used mechanically driven sugarcane crushing units in the Jaggary industries require high energy with less efficiency and unhygienic in operation. An improved and economical sugarcane crushing machinethat extracts maximum juice from cane with reduced energy consumption and hygienic in operation is required to meet the needs of the small scale jaggery industries and for road side venders (Olaoye, 2011). [3] discussed about Intelligent Sensor Network for Vehicle Maintenance System. Modern automobiles are no longer mere mechanical devices; they are pervasively monitored through various sensor networks & using integrated circuits and microprocessor based design and control techniques while this transformation has driven major advancements in efficiency and safety. In the existing system the stress was given on the safety of the vehicle, modification in the physical structure of the vehicle but the proposed system introduces essential concept in the field of automobile industry. It is an interfacing of the advanced technologies like Embedded Systems and the Automobile world. This "Intelligent Sensor Network for Vehicle Maintenance System" is best suitable for vehicle security as well as for vehicle's maintenance. Further it also supports advanced feature of GSM module interfacing. Through this concept in case of any emergency or accident the system will automatically sense and records the different parameters like LPG gas level, Engine Temperature, present speed and etc. so that at the time of investigation this parameters may play important role to find out the possible reasons of the accident. Further, in case of accident & in case of stealing of vehicle GSM module will send SMS to the Police, insurance company as well as to the family members.

Karnataka is one of the major sugarcane growing states in the country producing over 42 million tones of cane and ranking third in the production, and second in the productivity (Table 2). Mandyadistrict is one of the major sugarcane growing districts in Karnataka where sugarcane is predominantly cultivated was selected for the presented.

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Table.2 Top ten sugarcane production states in India

Sr.No	State / UT	Production (Thousand Tons)	Productivity (Tons/ha)
1	Uttar Pradesh	138481	60.70
2	Maharashtra	81870	63.20
3	Karnataka	41895	80.20
4	Tamil Nadu	24463	100.80
5	Bihar	14131	39.50
6	Gujarat	14060	74.10
7	Andhra Pradesh &Telangana	13150	74.90
8	Haryana	7650	62.00
9	Punjab	7039	60.10
10	Uttarkhand	6135	60.20

Source: Directorate of Economics and Statistics, Ministry of Agriculture GOI, (2014-15)

Preliminary field survey was conducted in Mandya district of Karnataka to study and understand the merits and demerits of the indigenous sugarcane crushers which are used for crushing sugarcane in the jaggery making cottage industries and also roadside venders for extracting cane juice for public consumption. Since juice is a liquid in nature and it contains good amount of moisture (70 %), leads to the corrosion of the material used in the locally fabricated sugarcane crushers during crushing operations. The cane stalk are crushed or macerated between heavy grooved cast iron rollers to extract the juice. Use of power driven three roller sugarcane crushers in the jaggery industries and two-roller sugarcane crushers by roadside venders are common in the study area.The conventional sugarcane crushers required repeated crushing of cane to reach maximum juice extraction limit of up to 55 - 60 per cent thereby losing considerable amount of quality juice with bagasse, which later burnt as fuel in the jaggery industry.

Iqbal (2007) designed and developed a proto-type model of 5-cylinder sugarcane crusher and evaluated its performance. He stated that juice extraction rate and crushing capacity of the 5-cylinder sugarcane crusher found to be better than the traditional 2 to 3 cylinders sugarcane crushers.

In the present studythe development of 5-Cylinder sugarcane crusher was taken up as an improved crusher over existing sugarcane crushers for increasing the juice extraction efficiency with hygienically extracting of juice from sugarcane.. The additional features to the existing crusher includes (i) replacing of 3-cast iron cylinders with 5- steel cylinders to improve the juice extraction efficiency and to prevent rust and (ii) providing safety protection cover to the crushing unit to prevent incidental accidents and contamination of juice during operation. This improvement helps to upgrade jaggery industry and crushing of cane by roadside venders to minimize the loss of juice in the extraction process. Also covering of the moving parts of the crusher such as gears etc improve the aesthetics appearance of the crusher apart from preventing the introduction of dust, flays and other contaminants with the extracted juice. This unit (Fig.1) is compact, portable and cost affordable by small-scale jaggery industries and roadside venders.

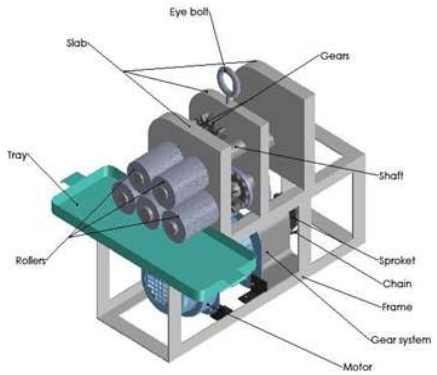

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Fig.1: Compact and portable 5-Cylinder sugarcane crusher

II. PERFORMANCE EVALUATION

A. Parameters Considered: All the 4-selected traditional sugarcane crushers and the improved 5 cylinder sugarcane crusher were subjected to performance evaluation study under actual field conditions with respect to their efficiency of crushing, power consumption, output capacity etc. Six varieties of high yielding sugarcane cultivars predominantly cultivated in Karnataka particularly in the study area were selected as feeding materials for performance evaluation of sugarcane crushers. The juice extracted from each method of crushing and the cultivar was analyzed for its quality.

B. Power consumption (watts): Energy meter was used to record the energy consumed by the crusher per unit time of crushing sugarcane during operation.

C. Weight of bagasse: The bagasse came out after crushing was collected at outlet and its weight was noted down. The juice left over in the bagasse was estimated by drying a known quantity of bagasse in the oven at 105oC for 24 hours (AOAC, 1980).

D. Brix content (%): The composite sample of filtered juice was filled in a cylinder jar into which Brix hydrometer was suspended and its reading was recorded along with temperature of juice and corrected Brix value was computed (Anon, 1986). The experiment was repeated thrice and average reading was computed.

E. Reducing sugars (%): The reducing sugars was estimated by titrating the sugarcane juice and clarified with lead sub acetate with 10 ml of Fehling's (A+B) solution according to Lane and Eynon Volumetric method.

$$\text{Reducing sugars percent} = \frac{(0.05 \times \text{Volume of juice})}{(\text{T.V.} \times \text{Wt. of juice})} \times 100$$

Where T.V. is the Titrate value

F. Sucrose content (%): One hundred ml of filtered juice was transferred to 250 ml conical flask to which one gram of basic lead acetate was added. Stirred well and allowed to stand for about an hour until clear supernatant was obtained. This supernatant was filtered through Whatman No.40 filter paper and clarified juice was filled into succhroliser tube and pol reading was recorded. The corrected pol reading were obtained by comparing the pol reading measured with the corresponding corrected Brix reading referring to Schmitz table (Anon, 1986).

G. Purity percent (%): The purity of sugar cane processed stream products (e.g., cane juice, molasses, raw sugar etc.) is a measure of product quality and was determined by calculating the ratio of %Sucrose and %Total Solids as a percentage which were measured by double polarization and dry substance measurements respectively.The ratio of sucrose percent to the corrected Brix was expressed as purity of the juice, which indicate the proportion of sucrose in the total solids present in juice (Anon, 1986). The experiment was repeated thrice and average reading was computed.

$$\text{Purity percent} = \frac{\text{Sucrose percent}}{\text{Corrected Brix}} \times 100$$

III. PERFORMANCE EVALUATION OF SUGARCANE CRUSHERS

The identified sugarcane crushers are 3-cylinder traditional sugarcane crusher, 3-cylinder heavy duty sugarcane crusher and 3-cylinder gear box type sugarcane crusher commonly used by the jaggery making cottage industries and 2-cylinder sugarcane crusher used by the roadside venders. All the sugarcane crushers identified and selected for evaluation study are power driven and fabricated by local industries. The stalks of sugarcane cultivars selected as feeding materials were fed to individual sugarcane crushers under evaluation study.

A. Power consumption: The power consumption varies from crusher to crusher depending upon their design

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factors and fabrication skills. All the traditional sugarcane crushers under study are locally fabricated by different industries and hence design and fabrication skill vary from industries to industries. It is seen from the Tables 3 and illustrated in Fig. 2 that the simple designed 2-cylinder sugarcane crusher consumed 240 kWh of power per unit of crushing cane. The 3-cylinder traditional type sugarcane crusher consumed 620 kWh of power per unit of crushing cane which is 15.32 % and 26.13 % higher than that consumed by 3-cylinder heavy duty sugarcane crusher (525 kWh) and 3-cylinder gear box type sugarcane crusher (458 kWh) of power per unit of crushing cane respectively. This variation may be due to the design factors, material used for fabrication and skill of the fabricator and also output of cane crushing per unit time. The output of cane crushing per unit time by 3-cylinder heavy duty sugarcane crusher and 3-cylinder gear box type sugarcane was higher than that was recorded in 3-cylinder traditional type sugarcane crusher.

On the other hand the improved 5-cylinder sugarcane crusher consumed 300 kWh of power per unit of crushing cane which is much less than that consumed by traditional sugarcane crushers used in the steady area. This is due to the design factors, material used for fabrication and skill of the fabricator and higher output of cane crushing per unit time by improved 5-sugarcane crusher.

B. Amount of juice extracted (gm/kg): The quantity of juice extracted from each system of crushing sugarcane and cultivarswere recorded and presented in Table4 and illustrated in Fig.3. It is observed that the average amount of juice extracted varies from cultivar to cultivar in each system of crushing. From the data it could be observed that the improved 5-Cylinder sugarcane crusher proved better in extracting juice from the amount of sugarcane crushed (689.80 g/kg of cane crushed) followed by power driven 3-Cylinder gear box type sugarcane crusher (572.33g/kg of cane crushed), 3-Cylinder traditional type sugarcane crusher (499.50g/kg of cane crushed),3-roller heavy duty type sugarcane crusher and (444.83g/kg of cane crushed). The average amount of juice extracted by power driven 2-Cylinder sugarcane crusher used by venders is comparatively less (443.16g/kg of cane crushed) than that of other power driven crushers. The variation in juice extracted from the systems of crushing may be due to their design parameters such as number of cylinders, clearance between the cylinders, serrations made on the periphery of the cylinder, speed of cylinder and quality &quantity of cane fed per unit time. Singh (2004) made similar observations in their study.

C. Weight of bagasse (gm/kg): The weight bagasse available after extraction of juice varies from variety to variety of cane crushed depending upon the fiber content in the cane and the percent of juice extracted. It is clear from the data presented in Table 4 and illustrated in Fig.3 that the average weight of bagasse recorded after extracting juice from improved 5-Cylinder sugarcane crusher is comparatively less (310.20g/kg of cane crushed) followed by 3 Cylinder gear box type sugarcane crusher (427.67 g/kg of cane crushed), 3 roller traditional sugarcane crusher (500.50 g/kg of cane crushed), 3 Cylinder heavy duty sugarcane crusher (555.17 g/kgof cane crushed) and 2 Cylinder sugarcane crusher (556.84 g/kgof cane crushed). Naturally when the juice extraction efficiency is less we could get more weight of bagasse and vice-versa due to the presence of juice in the bagasse. The findings of the present study are holds good with the findings of Hunsugi (2001).

D. Quality of juice extracted: The experiments were conducted to analyze the quality of juice extracted from the varieties of cane crushed and the type of crushers used for crushing sugarcane. The juice extracted from six varieties of sugarcane cultivars using five different type of crushers was analyzed for brix content, sucrose, reducing sugars and purity and presented in Table4. It is clear from the data that the average percent brix content (Gupta 1981), sucrose (Gravios et al. 1991), reducing sugars (Srivastava et al., 2002) and purity (Rekhi and Gil 1987) available in the juice vary from type of crushers used for crushing. This may be due to the characteristics of cultivars and hygienic conditions maintained at the crushing units. Further, it could be seen that the type of crushers used for extracting juice played no role as far as the presence of brix content, sucrose content and reducing sugars in the juice are concerned. However, there is a little variation in the purity percent of juice extracted from different types of crushers used. This variation may be due to the contamination of lubricants with juice and the hygienic conditions maintained around the crushers during crushing operations. Among the crushers used, the purity of juice extracted using improved 5-Cylinder sugarcane crusher found better than the juice extracted from the traditional crushers under. Essentially purity describes how much pure sucrose is present in a sugarcane juice sample.

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Table 3 Performance of 5-cylinder power operated sugarcane crusher over traditional sugarcane crushers in the study area

Sr. No	Parameters studied	Performance of Sugarcane Crushers Studied				
		2-Cylindersugarcane crusher	*3-Cylinder traditional sugarcanecrusher*	*3-Cylinder heavy duty sugarcanecrusher*	*3-Cylinder gear box typesugarcanecrusher*	*5-Cylinder sugarcane crusherdeveloped*
1	Cane crushing capacity/hr/hp at 20 rpm (Kg)	35	80	115	115	120
2	Extraction of juice (%)	55	58	64	65	70
3	Power consumption (watts/hr)	240	620	525	458	300

Table 4 Mean values of parameters studied from six verities of sugarcane crushed from different sugarcane crusher

Sr.No	Type of power operated sugarcane crushers evaluated	Mean values of parameters studied						
		Amount of juice extracted (gm/kg)	Bagasse weight (gm/kg)	Juice extracted (%)	Brix °	Sucrose (%)	Reducing sugar (%)	Purity percent (%)
1	2-Cylinder	443.16	556.84	44.32	20.04	20.22	7.53	98.00
2	3-Cylinder Traditional	499.50	500.50	49.95	20.00	21.18	7.39	98.25
3	3-Cylinder heavy duty Sugarcane Crusher	444.83	555.17	44.48	20.10	21.39	7.24	98.83
4	3-Cylinder gear box type Sugarcane Crushae	572.33	427.67	57.23	20.20	22.60	7.59	99.83
5	5-Cylinder Sugarcane Crusher	689.80	310.20	68.98	20.44	21.60	7.30	99.90

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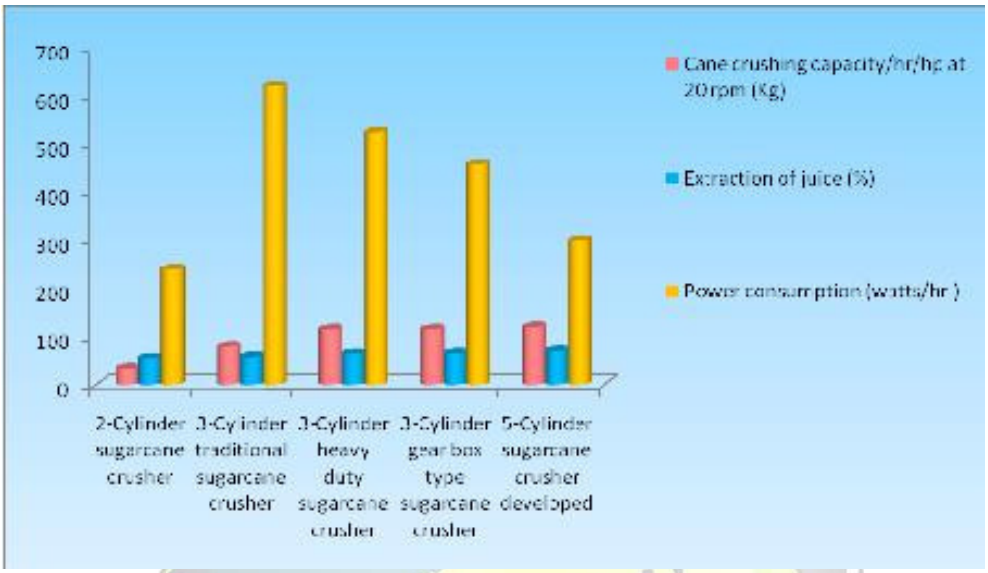

Fig. 2: Performance of 5- Cylinder sugarcane crusher over traditional sugarcane crushers

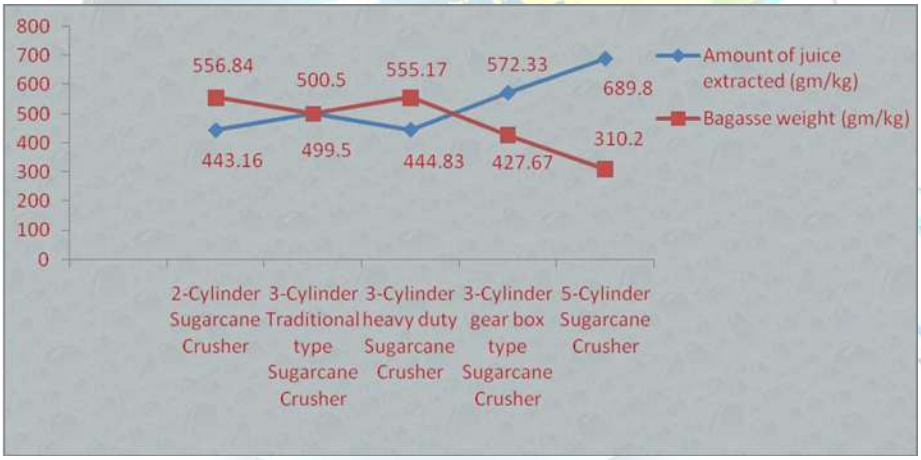

Fig.3: **Amount of juice (gm) and bagasse weight (gm) obtained using different sugarcane**

IV. CONCLUSIONS

Sugarcane crushers identified in the study area were evaluated by feeding the stalks of the sugarcane varieties selected. The performance of sugarcane crushers with respect to crushing efficiency, output capacity, power consumption, quality of juice extracted etc. were recorded, and analyzed. Among the traditional cane crushers evaluated, 3-cylinder gear box type sugarcane crusher found to perform better than the rest of the cane crushers and identified for further evaluation to compare the performance over improved 5-cylinder sugarcane crusher developed.

Three types of power driven horizontal type 3-cylinders sugarcane crushers and power driven horizontal type 2-cylinder sugarcane crusherwhich are designed and fabricated in the local industries and commonly used for crushing sugarcane in the jaggery cottage industries and road side venders in the steady area are identified and evaluated for their performance. The percent of juice extractionand purity of the juice obtained from each crusher and other juice quality parameters studied vary from crusher to crusher due to

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design factors of the crushers evaluated and characteristics of cultivars used as feeding materials.

From the performance study of locally fabricated traditional sugarcane crushers identified in the study area, based on the percent of juice extractionand purity of the juice obtained which are important parameters to improve the economy of the farmer / cottage industry / vender, 3-cylinder box type sugarcane crusher performed better. The 3-cylinder box type sugarcane crusher could extract on an average of 57.23 % of juice from the cane maintaining 99.83 % purity and the 5-cylinder sugarcane crusher could extract on an average of 68.98 % of juice from the cane maintaining 99.90 % purity.

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