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SUGARCANE PROCESSING AT VILLAGE LEVEL

Part VII. A New Face Configuration for Rolls of the Vertical Sugarcane Crusher (Belna, Trapiche)*

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The modified and improved compression roll (1/16" x 1/16" x 1/4" or 3/16") breaks up the redesigned and modified to increase the juice extraction.The principles applied are better sugarcane preparation before compression, maximum drainage of juice from the compression rolls and minimum reabsorption of juice by the bagasse etc. The modification of the feed roll affects the sugarcane preparation. The redesigned feed roll in combination with the original king roll and bagasse roll has given well shredded and dried bagasse and increased the juice extraction by 2 %. To improve the cane preparation, circumferential grooves having threads 4 per inch have been added on the drainage grooves (3/8" x 3/8" x 1/2") of the feed roll.

The modified and improved compression roll (1/16" x 1/16" x 1/4" or 3/16") breaks up the sugarcane, separates the fibre from the pith completely and increases the juice extraction from 10-15 % on the juice weight as compared to the old village crusher. The compression roll (8.5" x 8.5" or 9.5" x 9.5") shows no appreciable difference in juice extraction. Observations, tests, experiments and field work suggest that the compression roll (8.5" x 8.5") with face configuration of 1/16" x 1/16" and 3/16" circular threading 24 per inch and feed roll with threading 4 per inch wide is the most suitable crusher for processing at the farm level.

A special compression roll with a face configuration right angled to the shaft size and spaced 7/16" ridge to ridge and grooved 1/4" deep with the internal angle 90° has been tested. The juice percentage on cane dropped significantly.

Key words: Village sugarcane crusher; Face configuration of rolls; Field evaluation.

INTRODUCTION

Sugarcane is processed into gur, jaggery or panilla at farm level in most of the sugarcane growing countries of the world. Nearly 50 % of the crop in these countries is crushed at farm level. On the introduction of the plant it was considered that farm crushing would be eliminated but still a major portion of crop in Pakistan, India, Columbia, Indonesia and Africa is crushed at the farm to make gur and allied products [1].

Recently [2], it has been established that gur, jaggery or panilla is far better nutritionally than white sugar. In the scientifically advanced countries, white sugar is being replaced by brown sugar in daily diet due to its nutritive and medicinal values.

In some of the sugarcane growing countries, sugarcane fields are of small size and are owned by individuals. Here the processing of sugarcane at farm level is technically feasible as compared to the supply of sugarcane to the big mills. Farmers not only make gur and its products but also get fodder for their animals. Moreover, the buying power of the masses of these countries is very low, so the prefer to purchase gur and its products than the comparatively costlier sugar manufactured at the big mills.

In our previous papers, we have suggested a number of improvements and precautions for manufacturing the final products. These improvements have been suggested in juice extraction [3] and the clarification and concentrac-

*Small cane-crusher is called *belna* in the whole of Indo-Pak sub-continent and *Trapiche* in the South America.

tion [4] procedures. It has been estimated that, as a result of these improvements, there would be 5-10 % rise in juice extraction in animal driven and 35-45 % rise in the mechanically driven crushers. These suggestions, if implemented, can save a considerable amount of sugar from burning. A farmer generally processes a ton of sugarcane daily. As it is a relatively small quantity so he feels less attracted towards the suggestions which can improve his yield substantially.

To attract the farmers, it was decided to look for a technology which could be introduced in the villages for better extraction of sugarcane juice. The Indian and Columbian crushers [5] and other equipment used for cane crushing were imported and evaluated under the conditions existing at our farms. It was observed that the juice extraction results were either lower or similar to those of the crushers made in Pakistan. It was however, considered proper to further improve the design of the century-old sugarcane crusher for still better extraction of the sugarcane juice. The present study describes the efforts made to increase juice extraction by redesigning and modification of our traditional sugarcane crusher.

MATERIALS AND METHODS

For comparing various crushers sugarcane of the same variety and the same size was harvested at the same time and in the same field. The crushers were operated at the same speed and in most of the cases rolls of the same crusher were replaced with modified rolls. The experiments were carried out at different rpm, on the same day with the same sugarcane. Soft, hard and extra hard sugarcane was tested and crushers were operated at the same speed. For evaluation, the crusher were installed in December, and percent juice recorded was 62-68. The same crusher yielded 62.0 % in April with poor quality sugarcane.

Studies were carried out with crushers, Fig. 1(a) and 1(b), drainage grooves on the king and bagasse rolls 1/16" wide and 1/16" deep. Ridges or pitch between the grooves is 7/16" or 1/2", circumferential grooves or thread were sixteen per inch. Feed roll had only longitudinal grooves 1/2" Fig. 2.

Power from the drive was transmitted to rolls through a master shaft of the prime roll with a gear and teeth arrangement. The three rolls were mounted in a steel frame with a metal base. At the base, a collector tray for the extracted juice was provided. It had a run off spout below. A section of the juice extracting unit is shown Fig. 3. The modification of feed roll Fig. 4(a) and 4(b) had been made such that in combination with the king roll, sugar-

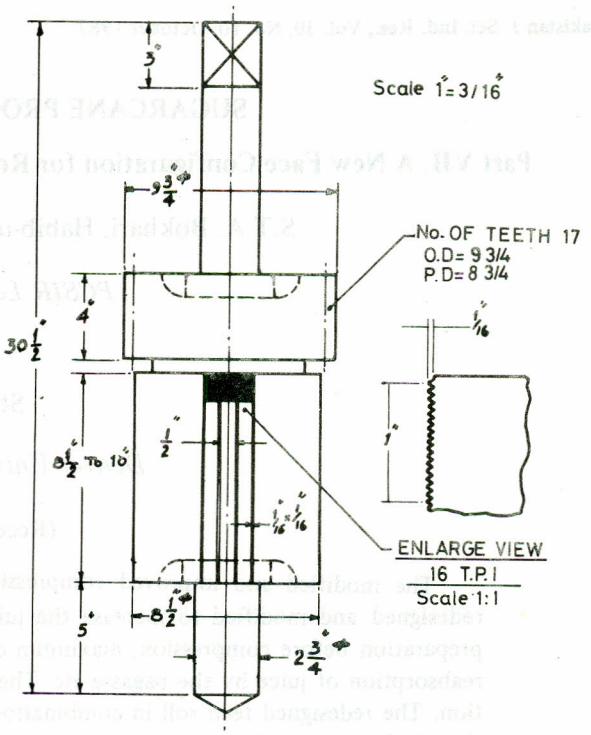

Fig. 1(a)

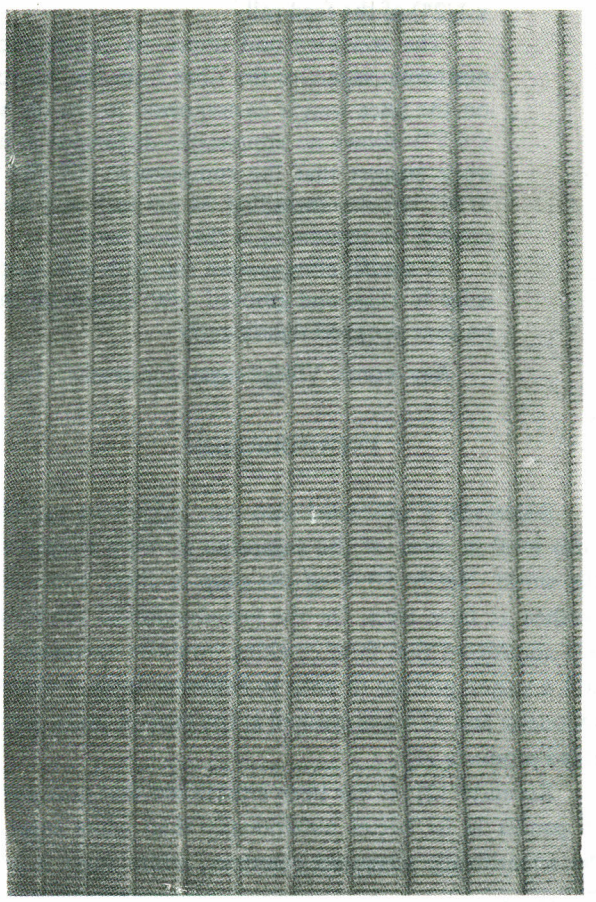

Fig. 1(b)

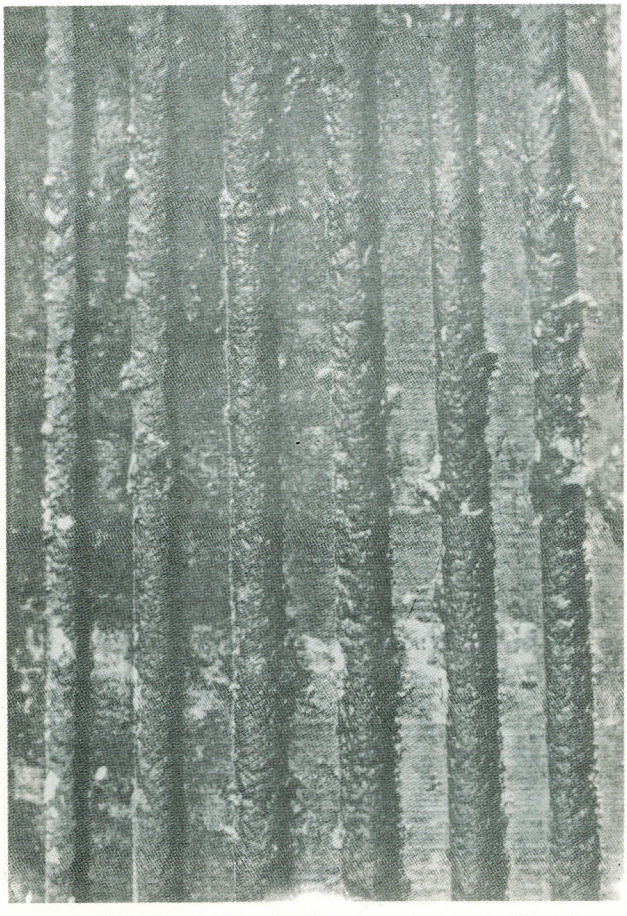

Fig. 2.

Fig. 3.

cane was crushed effectively and an improvement in juice extraction has been confirmed (Table 1). Detailed experiments were made in the field and it was found that modified feed roll along with a king roll and bagasse roll gave well shredded and dried bagasse.

The original feed roll (Fig. 2) had drainage grooves 3/8″ wide and 3/8″ deep. The pitch or face width was 1/2″ and there were no circumferential grooves. The recommended face configuration is as shown in Fig. 4(a) and 4(b):

(a) Longitudinal grooves 3/8″ wide by 3/8″ deep and pitch between grooves 1/2″.

(b) Circumferential grooves or thread four per inch.

Original Pakistani and Indian (Fig. 1a, 1b) crushers have drainage grooves on the king and bagasse rolls 1/16″ wide and 1/16″ deep, and ridge or pitch between the grooves is 7/16″ or 1/2″. There were sixteen circumferential grooves or threads per inch.

The recommended face configuration of the king and the bagasse rollers are as follows (Fig. 5 and Fig. 5b):

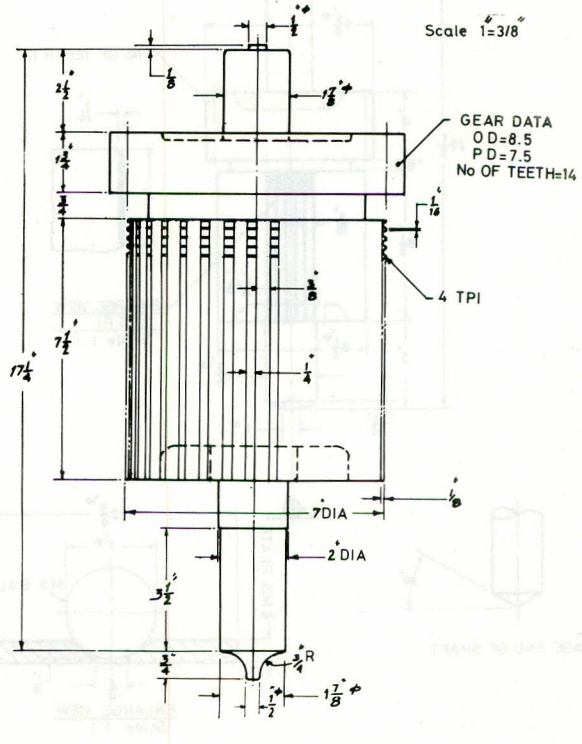

Fig. 4(a)

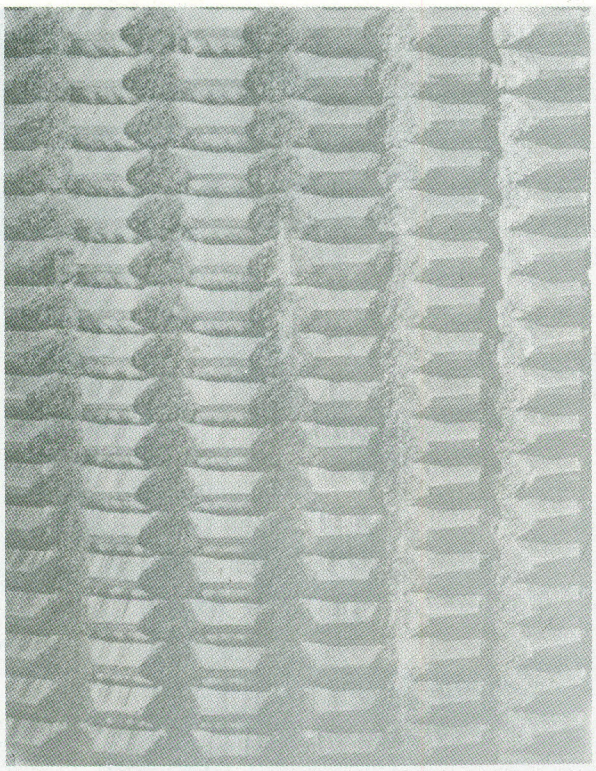

Fig. 4(b)

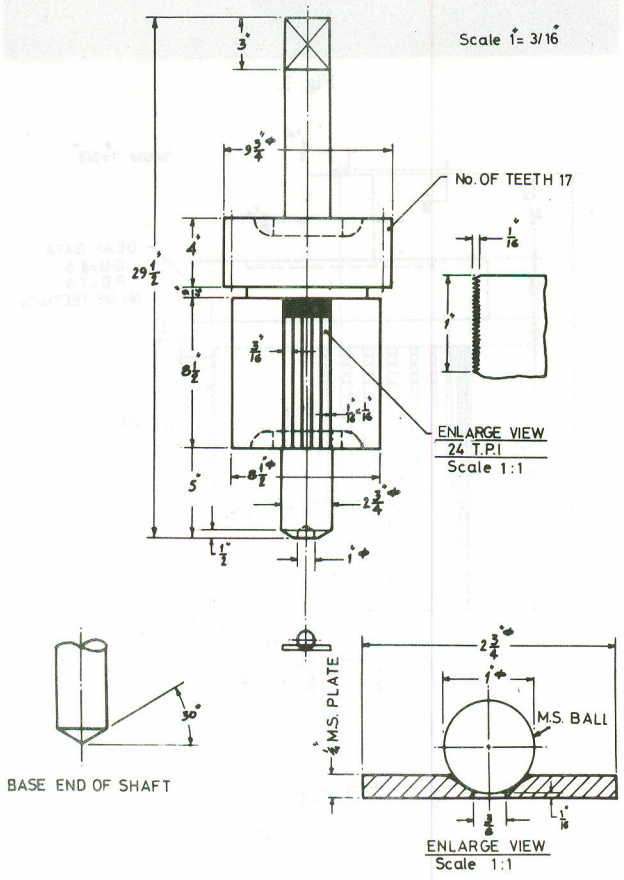

Fig. 5(a)

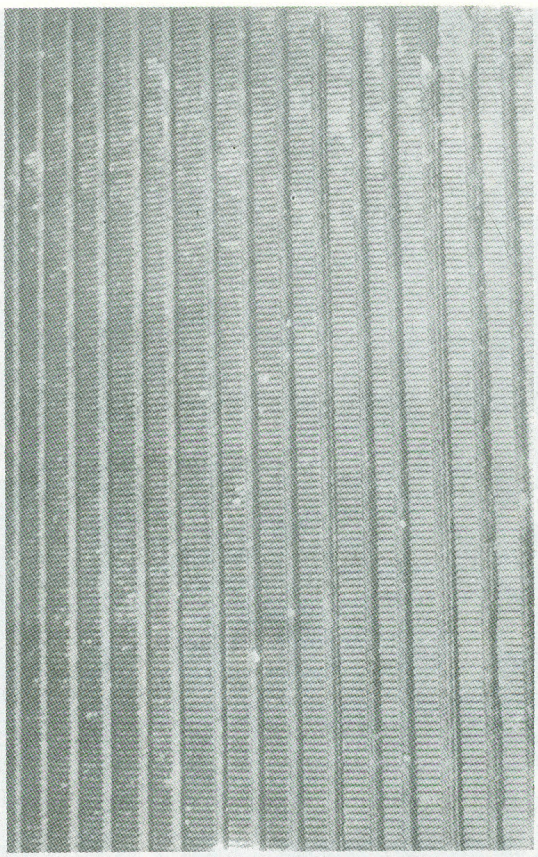

Fig. 5(b)

(a) Drainage grooves 1/16" wide and 1/16" deep and ridge or pitch between the drainage grooves of 3/16".

(b) Circumferential grooves of 24 threads per inch. Paramenters recommended in the new design are given in Table 2, Fig. 6.

Rolls of sizes 12" x 12" x 9.75", 9" x 9" and 8.5" x 8" manufactured by different firms in Pakistan and India were evaluated 12" and 9.5" rolls were hard for the animals to drive. Moreover, their juice percentage was no better than that of the 8.5" x 8.5" crusher, which is easier to work with and better to handle. Farmers were not satisfied with 9.5" and 12" rolls sugarcane crusher, as the animals soon gave signs of exhaustion. The base of the shaft of the roll was modified and a 1" diameter steel ball was inserted and this made work easier for the animals (Fig. 5).

Farmers felt satisfied with this modification as the crusher not only crushed more sugarcane but also gave 62.70 % juice on cane extraction throughout the season (November-April). The rolls were tightened metal to metal and the crusher was worked with a tractor. It was found that more than 70 % juice on cane was extracted (Tables 4,5,6,7).

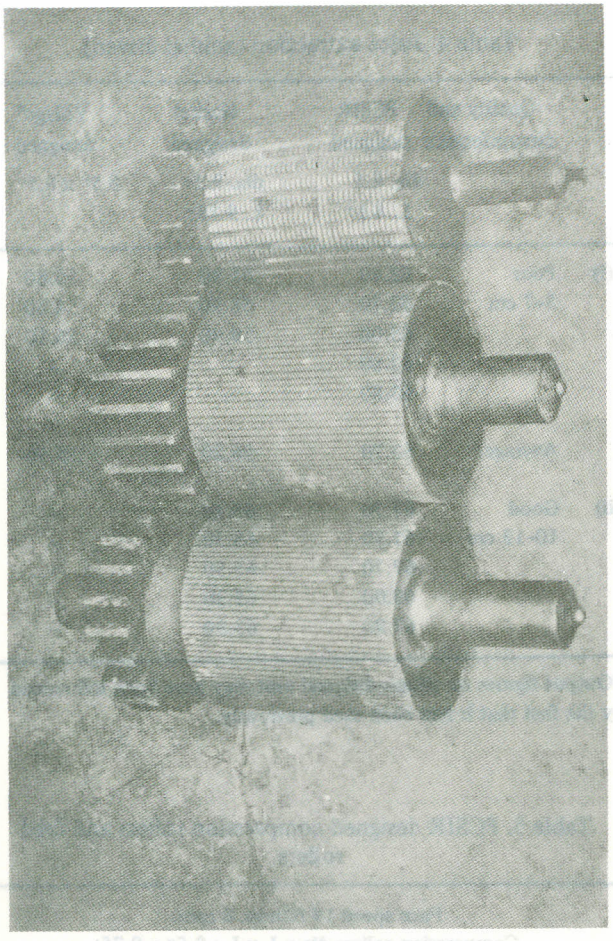

Fig. 6.

Fig. 7.

A special compression-roll face configuration was made and tested; the grooves were at a right angle to the shaft size and were spaced 7/16″ ridge to ridge. The grooves are 1/2″ deep, and the internal angle was 90°. The juice percentage dropped considerably.

These were tried on low fibre sugarcane. The test data obtained are shown in Table 3.

RESULTS AND DISCUSSION

Our objective was to find or devise a simple, inexpensive crusher with high juice extraction. The capacity objective was 1 TC/hr for mechanically driven crushers and 0.1TC/hr for the animal driven crusher. This (0.1 TC/hr) is a reasonable size for Pakistan farmers, most of whose farms are small with a low sugarcane density. From a mechanical standpoint, however, the size (0.1 TC/hr) of the crusher was not so favourable. One TC/hr crush is too big to be considered small and yet too small to be called a large crusher.

Vertical crushers (1 TC/hr) are simple to fabricate, operate, and maintain. The largest unit found had compression rolls of 14″ dia. and the more sophisticated ones are difficult to adjust and maintain. The current crusher (0.1 TC/hr) is ideal for the farmers and village level processors. Its depreciation value is low and insignificant. It is run by animal power and can be operated by unskilled workers. These crushers last for about 20 years and will return three-fourth of the original cost when sold as scrap.

Table 1. Juice % on cane (under similar conditions).

Traditional design of feed roll	PCSIR design of feed roll
–	69.30
–	67.40
–	67.70
67.37	68.45
64.70	66.70
65.40	64.59
62.56	65.50

Table 2. Parameters recommended for animal powered crushers.

	Rollers	King	Bagasse	Feed
1.	Diameter	8.5"	8.5"	7.0"
2.	Height	8.5"	8.5"	7.5"
3.	Number of teeth	17	17	14
4.	Face speed ft/min	6.74"	6.75"	6.68"
5.	R.P.M.	3	3	3
6.	Longitudinal groove	1/16"x1/16"	1/16"x1/16"	3/8"x3/8"
7.	Pitch	3/16"	3/16"	1/2"
8.	Circumferential groove	24 inch	24 inch	4/inch
9.	Rollers setting	(0.2mm for animal driven metal to metal with tractor)	–	1/mm

Table 3. Comparison of juice % cane.

Indian		Pakistani	
Horizontal sugarcane	Vertical sugarcane crusher	vertical sugarcane crusher	Vertical sugarcane crusher
January 1980	January 1980	April 1980 old designed	April 1980 grooves 90^0 pitch 2"
60.4	63	66.7	61.6 Soft cane
52.1	56.8	57.5	55.0 βL-4 medium
52.9	58.7	57.0	
56.9	62.4		
52.2	57.8		
60.5	66.62		
(best quality cane	(best quality)		
cane L-29	L-29		

The compression rolls of the vertical sugarcane crusher were replaced with the grooved compression rolls having groove 90^0, pitch 1/2", similar to horizontal cane crusher. For the above data, freshly harvested sugarcane was brought from the field and tested under the identical conditions on the same day. Juice % cane is dependent on the following parameters: (1) Cane veriety; (2). Cane size; (3) Time lapse between harvesting and crushing; (4) Time of the season; (5) Face speed of the roller or RPM; (6) Design and mechanical condition of the crusher.

In addition to good sugarcane quality, the extraction has been improved by proper sugarcane preparation, high roll compression and good roll drainage. Proper roll spacing, face speed and roll face configuration directly affected juice extraction. Improper roll spacing reduced the amount of juice to as low as 56 % in the field. When the rolls were properly aligned and spaced, the yield was increased to an average of 64 %. Maintenance and good sugarcane feeding techniques, even a simple stalk-size grading procedure and proper cleaning of the crusher definitely improved extraction [3]. It was observed that the following variables are essential for the better juice extraction.

Table 4. Juice extraction (animal driven).

	Quality and circumference	PCSIR designed	Market designed	Village* designed
		dia. 8.5 L. 8.5"	dia. 9.2" L. 9.75"	8.5" x 8.5"
(i)	Poor	62.40	55.90	55.80
	5–7 cm	62.70	58.90	54.80
		65.00	59.90	56.10
		62.60	–	–
		63.80	–	–
	Average	63.70	56.20	55.50
(ii)	Good	67.70	65.10	–
	10–13 cm	67.30	65.30	–
		67.70	65.50	–
		69.00	65.30	–
		67.90	65.30	–

*Output figures on village-disigned unit may have been influenced by the fact that it had been used previously.

Table 5. PCSIR designed compression rollers and feed rollers.

Face speed 19 ft/min, 8 rpm.
Compression rollers dia x L x L : 9.5" x 9.75'

Quality and circumference	Juice and cane	Remarks
	65.00	Extra hard and
	63.70	dry cane
	68.70	
	67.00	Extra hard and
	66.00	dry cane.
7–10 cm	66.30	
	66.50	
	68.80	
	69.50	
	69.60	Comparatively
	67.80	hard cane.
	65.80	
	66.40	
Less than 7 cm	62.00	
	64.00	
	61.50	
Less than 5 cm	57.90	Extra hard cane.
	56.00	

Table 6. Cane tests in Peshawar

Juice % cane	Birx
70.00 thick	14.6
68.00 "	14.4
64.30 thin	14.4
67.60 thick	16.4
67.30 thin	16.4
64.50	21.0
66.00	

Table 7. PCSIR compression rollers.

Cane diameter	Dia x length 8.5 x 8.5 Juice % cane	Dia x length 9.5 x 9.75 Juice % cane
	60.00	59.00
	59.00	62.50
	61.00	60.10
Average	60.00	60.40

(1) Good drainage or face configuration
(2) Proper maintenance

We have worked towards the improvement of animal driven crushers by keeping the following principles in mind:

(1) Better sugarcane preparation before compression.
(2) Maximum drainage of juice from the compression rolls and minimum reabsorption of juice by bagasse etc.

An animal-driven crusher must have a surface with the capability of gripping, breaking, tearing up and crushing the sugarcane efficiently. For animal power driven mill, a feed roll is the only part where modification could be effected for sugarcane preparation. These modifications have been made such that in combination with the king roll cane is effectively crushed and an improvement in juice extraction has been confirmed (Table 1).

Detail experiments were made in the field and it was found that the modified feed roll along with a king roll and bagasse roll gave well shredded and dried bagasse.

The original feed roll has drainage grooves 3/8" wide and 3/8" deep, and the pitch or face width is 1/2" with no circumferential grooves. The recommended face configuration is:

(1) Longitudinal grooves 3/8" wide by 3/8" deep and pitch between grooves 1/2"
(2) Circumferential grooves or threads four per inch

Big mills have shredders to prepare the cane. The object of the shredder is to complete the preparation and defibrication of the sugarcane so as to improve the juice yield in the mills.

In village-level crushers the feed roll is also the cane preparation device. This roll, no doubt, feeds the sugarcane, but also does a little sugarcane preparation. The defiberized sugarcane requires less power to extract the juice. This modified feed roll has increased the juice. This modified feed roll has increased the juice extraction by 2 %, as the sugarcane goes to the compression rolls in a more uniform manner. This modification is expected to have other beneficial effects like reduction of the power necessary to drive the crusher; such benefits have improved the efficiency of the animal. The modification we made requires no precision machine work and can be done in an ordinary workshop.

Originally, the compression rolls of the sugar mills were of various designs. Some had smooth rolls while the others had grooved rolls. It was observed that the mills with smooth rolls gave much less juice extraction than those grooved rolls, but were equal in all other respects. Grooved rolls break up the sugarcane, separating the fibre from the pitch completely and facilitate juice extraction. The coefficient of friction depends mainly upon the roll surface. The drainage grooves increase the unevenness and this increases the the friction coefficient from 0.40 to 0.55, 0.40 is the coefficient for the polished surface of cast iron and 0.55 is the coefficient of friction for the grooved metal. Grooved rolls are more effective with low moisture and high pressure. It should be kept in mind that high face speed lowers the coefficient of friction so the speed should be kept optimum. The desired roll face speed can be calculated using the following formula [6].

$$\phi = 0.43 - .002U$$

Where ϕ is the coefficient of friction of bagasse.
U= is the face speed of the rolls in ft/min.

We improved the face drainage by groovings of compression rolls (1/16" x 1/16" x 1/4" or 3/16") for the animal-driven cane crusher (Fig. 5). The yield had increased from 4-10 % on juice weight (Table 4), when compared to

the newly cast traditional sugarcane crusher (Fig. 1). This increase was, however, 10-15 % on juice weight in comparison with the old crushers that are generally found in our villages.

It has been found that the normal life of a traditional crusher is about 15 years. It is remachined by a local blacksmith every 2-3 years. After machining, extraction is lowered by 10-30 %. A newly cast cane crusher extracts 60-62 % juice during the first two years. This percentage falls to 55 or even lower in the subsequent years when the machining is done by the village blacksmith (Fig. 7). All such rolls can be modified to the improved face configurations. Such modified crushers will increase juice extraction by 15 % or more.

Our modified compression rolls have extracted 60-64 % (Table 5) juice out of poor quality sugarcane. Good quality sugarcane yields 67-70 % juice (Table 7). Our survey in 1978 revealed that villagers extract 55-65 % juice with their crushers. After our modification these machines are expected to give 60-70 % juice or from 5-15 % more than they now realize. The bagasse from the modified rolls contains less moisture and can be used as fuel the next day.

We have also observed (Table 7) that there is no appreciable difference in juice extraction if we use a 8.5" x 8.5" crusher or 9.5" x 9.5" crusher. The working of 8.5" x 8.5" crusher is handy and easy. The animals have to use less energy to operate the crusher so they can crush more cane in a day. The recommended paramentes for the animals driven farm crusher are given in Table 2.

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