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SUGARCANE PROCESSING AT THE VILLAGE LEVEL

Part V. An Evaluation of the Sugarcane Crusher (Belna, Trapiche)* and Some Suggestions to Improve Juice Extraction.

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The small sugarcane crusher *(belna, trapiche)* introduced in the sub-continent some hundred years ago has been thoroughly studied and evaluated. Its efficiency has been compared with the big sugar mill. The factors which affect the extraction of juice have been studied. Proper alignment and roll setting improve the juice percentage-cane upto 5%. The "feeler gauge", a small instrument has been introduced to achieve the suitable roll setting. Animal driven crusher operates at face speed 7 feet per minute but the electrically driven crusher operating at 42 feet per minute causes substantial loss in juice extraction. An optimum face speed of 20 feet per minute for the electrically driven crusher has been recommended. Face configuration also plays an important role in the juice extraction, while roll size has insignificant effect on the juice extraction. Proper maintenance and education of farmers in handling this machinery is very important for the proper working of this cottage industry.

Technical results of "gur" processing technology of Pakistan have been determined. Juice percentage cane varies from 52 to 60 percent as compared to that of the mills (74 - 77%). Purity of juice (77 to 90%) at village level is better than the mills (77 to 84%). Bagasse percentage (30 to 50%) and pol percentage bagasse (7 - 12%) are far more than at the mill level (bagasse percentage 30%) and pol percentage (bagasse 2.5%). This village level industry gets better quality of cane (pol percentage cane 13.7) than big sugar mills (pol percentage cane 11.5).

Introduction of feeler guage, leveller and proper maintenance is recommended for the "gur" technology. Improvement in harvesting techniques and infra-structures for the transportation of sugarcane have also been recommended for the big mills.

INTRODUCTION

Sugarcane is composed of 80-85% of juice and 15-20% of cellulosic material[1]. Function of a crushing mill is to extract the maximum possible of this available juice in the sugarcane. In the villages, sugarcane is crushed in a small mill *(belna, trapiche)*, driven by a tractor or animal power, usually a pair of bullocks. This small mill is unable to extract juice beyond a certain extent. Thus, it appears to suffer from enormous economic set-back when compared with mill tandem, usually an integrated group of four to seven crushers with imbibation. Despite various draw-backs, use of this small mill has not been eliminated even by the introduction of large crushing mills. Majority of the sugarcane crop is still crushed with this small mill in the sugarcane growing countries all over the world.

So far only the comparative studies on the efficiency of such small mills have been made during the past several years. Unfortunately, this small crushing mill, itself, has not been subjected to a thorough study and evaluation.

Elaborate research[2] is being carried out in several countries to achieve good milling on large scale. There is hardly any organization in the world which has ever paid serious attentions to this small machine. Main objectives of the milling either on large or on small scale are as follows:

i. To extract highest amount of sucrose from the cane.
ii. To obtain final bagasse with minimum moisture content which will burn readily in furnace.
iii. To achieve increased crushing capacity.

Evaluation of the cane crushers was carried out keeping in view the above qualities.

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

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MATERIALS AND METHODS

Field study was carried out according to the method reported [3]. Laboratory studies were carried out with an electrically driven (5 Horse Power) crusher operated at a speed of 21 feet per minute. The crushers used had the drainage grooves on the king and the bagasse rolls 1/16" wide and 1/16" deep.

Ridges or pitch between the grooves is 7/16" or 1/2". Circumferential grooves or threads were sixteen per inch. Feed roll had only longitudinal grooves 3/8" wide and 3/8" deep and ridges or pitch between the grooves was 1/2".

Freshly harvested sugarcane was taken and was cleaned properly to remove the soil and trash. Sample of 2 to 20 kg. were weighed on a balance (Sartorius-Werke GMBH and RHEWA made in Germany) and the juice was filtered through muslin cloth and weighed. Results have been recorded.

RESULTS AND DISCUSSIONS

Present crusher used in the Indo-Pak sub-continent was introduced more than 100 years ago by Messrs Thomson and Mylne [4], England, who had much practical experience in the cultivation of sugarcane and its processing. This crusher became common all over the sub-continent within a few years of its introduction. By 1880 there were over 250,000 sugarcane crushers in the sub-continent which completely eliminated the age-old wooden crushers which were in common use at that time.

Table.1 shows the comparison between 2 and 3-roll wooden mills and a 3-roll steel mill (Thomson & Mylne)

Table 1. Comparison between 2 and 3 roll mills

Thomson & mylne mill	2-Wooden roller mill	3-Wooden roller mill
	percentage of gur on cane	
9.5	7.6	–
8.8	–	8.1

Comparison was carried out upon the introduction of the Thomson and Mylne Mill. This table indicates 25% increase in gur as compared to the 2-rolls and 8.6% increase as compared to the 3-rolls wooden mill.

It was, however, interesting to note that the crusher developed by Thomson and Mylne worked 12% slower in face speed than the 2-rolls wooden mill and 25% slower than the 3-rolls wooden mill. Despite this drawback, 25% improvement in gur extraction was considered attractive and the new crusher eliminated the wooden mill totally.

The crushers of various manufacturers both at home Table 2 and 3 and abroad were thoroughly investigated and no standardization was found in these machines, nor was there any information available regarding the suitable materials of construction. This was due to the fact that when the original patent of Thomson and Mylne ran out, such mills, including the rolls, with shafts, pinions, etc., began to be manufactured on large scale in the sub-continent in small native foundries and workshops. This practice has continued even today. There is an open competition and every manufacturer shows interest in cost reduction and therefore no standard material and design is kept in view. A cast iron crusher cost Rs.120, 1875 [5] and was sold at Rs.325 in 1960 while the current price is around Rs.2400. This price-hike of the cane crusher is less as compared to the other commodities.

Cane Crushers. These crushers are made of cast iron. They are mounted on a wooden or angle iron foundation with bolts, nuts, and screws of mild steel and dug in the earth. They do not require heavy foundations of concrete or bricks. Transportation of the units from one place to another is not difficult. They do not require highly-skilled craftsmen to instal, operate, or maintain them properly. The current crusher meets the needs of the farmers and the village level processors. These are easy to maintain and depreciation is low or insignificant. They are run by animal power and can be operated by unskilled workers. These will last about 10-20 years and will return three-fourths of the original cost when sold as scrap. However, maintenance can be an important factor in improving the output.

This is, perhaps, the only study which concentrates upon the crusher driven by the animals. Technical results of gur industry are given in Table 2. Various factors which affect the juice percentage cane extraction are:

1. Proper alignment and mill setting; 2. the face speed of crusher; 3. face configuration and roll size; 4. proper maintenance.

Mill Setting. Most of the animal driven crushers are installed on soft ground and their alignment invariably changes during operation. The villagers must keep a leveller to control the alignment.

The villagers are ignorant about the effect of roll-setting and space between the compression rolls. During our survey not a single unit was observed all over Pakistan where roll setting of the cane crusher was proper. Some of the observations are given in Table 4. To solve this problem an instrument was required which was cheap and easy to handle and operate. This instrument, feeler guage (Fig.1) worked very well in the field and improvement was observed in the juice percentage recovery as is evident from the

Table 2. Technical results of gur (panila*) technology at village level of Pakistan

	JUICE				BAGASSE				GUR
Sample No.	Rec. % Cane	Brix	POL%	Purity%	Extrac-tion	% Cane	POL %	Mois-ture %	Rec. %
1.	59.72	17.61	14.36	81.55	71.73	40.28	8.4	58.00	10.52
2.	62.50	18.90	16.70	88.35	68.50	37.50	12.80	51.80	11.81
3.	60.00	19.50	16.43	84.26	56.99	40.00	18.60	53.00	11.70
4.	68.06	17.60	14.97	85.06	75.28	36.94	8.40	58.90	11.10
5.	61.25	19.02	16.82	88.25	74.26	38.75	9.20	54.00	11.67
6.	59.38	19.80	17.13	86.52	71.47	40.62	10.00	56.00	11.76
7.	61.25	17.64	14.43	81.80	67.84	38.75	10.80	55.00	11.50
8.	58.75	18.24	15.63	85.69	69.28	41.25	10.40	55.50	10.94
9.	57.00	23.00	20.10	86.60	70.36	43.00	10.00	54.00	12.50
10.	62.50	21.70	20.54	94.60	78.28	37.50	7.60	51.30	10.00
11.	60.00	17.00	14.00	87.90	75.38	40.00	7.00	48.60	10.00
12.	55.00	20.00	14.90	74.50	62.61	45.00	6.90	52.70	10.00
13.	68.00	17.80	13.50	75.80	85.00	32.00	10.10	54.10	9.50
14.	67.50	18.60	17.00	91.40	84.37	32.50	7.90	51.20	10.00
15.	56.25	18.50	17.50	94.60	68.75	63.75	10.30	54.00	10.00
16.	67.50	21.00	19.30	91.90	67.07	32.50	7.20	48.60	10.00
17.	50.00	18.00	15.20	84.40	81.30	50.00	8.70	52.70	10.00
18.	53.75	18.00	14.85	85.50	82.30	46.25	7.80	54.10	10.00
19.	69.50	18.90	17.10	89.90	83.42	30.50	9.40	49.70	10.00
20.	58.75	18.60	17.00	91.40	75.50	41.25	8.60	51.60	10.00
21.	58.94	17.71	14.62	79.34	–	41.06	6.59	49.00	–
22.	62.84	17.04	13.52	79.30	–	37.16	5.69	48.05	–
23.	64.15	15.74	12.66	80.40	–	35.85	6.36	49.00	–
24.	59.03	16.30	12.93	79.30	–	40.97	5.53	45.00	–
25.	63.04	14.49	11.26	77.70	–	36.95	5.61	52.05	–
26.	60.91	18.02	15.95	84.62	75.41	39.00	8.10	55.50	–
27.	63.57	17.46	14.46	82.81	79.50	36.43	6.50	54.00	–
28.	66.90	16.62	14.27	85.86	81.62	34.10	6.50	52.00	–

* Inspissated juice expressed from sugarcane is known as Gur in Pakistan Jaggery in India and Panila in South America.

Table 4. Spacing between the compression roll should be 0.2 to 0.4 mm. subject, however, to the physique of the animal used for driving the crusher.

Mill Speed. It is well established in the large sugar industry that slower the face speed of the roller, better is the juice recovery. It has been verified that the number of mills required to extract the same amount of juice at lower speed is less than the number of mills required to do the same job at higher speed [2]. Results determined by using the same variety of sugarcane, harvested and extracted at the same time at different face speeds on the same day showed that higher the face speed of crusher, lesser is the amount of juice extracted (Tables 5A & 5B). A village farmer runs his crusher at an ideal face speed of about 7 feet per minute. In the North Western Frontier Province of Pakistan the electrically driven units are operated at 40 feet per minute. The mill we selected was running at 42 feet per minute and yielded only 43% juice on cane. This low extraction of juice was due to the fast speed of the machine. When the speed was reduced to 20 feet per minute, the same cane variety gave 67% juice. Even big mills do not run at such a high face speed of 42 feet per minute. Running the small crushers at such a high face speed has no logic and it is a major contributor to the reduced gur yields in the

north-western region. 20 feet per minute face speed is recommended for electrically driven crushers. At this speed juice extraction is around 60% as against 43% at 42 ft/ minute.

Results obtained from freshly-harvested sugarcane of the same size but crushed at different face speeds clearly indicate, that with the increase of face speed, extraction of juice drops. These results are in agreement with the IIT

Table 3. Cane crushers available and their general characteristics.

	Crushing capacity tons in 8 hours	Horse power requirement	Roll dimensions	Juice % on cane	Gur production per 100 tons cane	Sugar per ton of cane No. SO_2	Sugar per ton of cane with SO_2
3 Roll Vertical	.8 to 1	Animal	8 x 10	55-60	9.5-9.7	5-5.5	6.2-6.8
3 Roll Horiz.	1.5	7.5	8 x 10	55-60	9.5-10.0	5-5.5	6.2-6.8
3 Roll Horiz. Mech. Adj.	2.0	10.0	8 x 10	58.62	9.5-10.0	5-5.5	6.2-6.8
3 Roll Horiz. Mech. Adj.	3.5	15.0	10 x 12	58-62	9.5-10.0		
3 Roll Horiz. Mech. Adj.	8	20.0	12 x 15	58-62	9.5-10.0		
5 Roll Horiz. Mech. Adj.	8	20-25	10 x 15	60-62	10		
3 Roll Horiz. Hydraulic Adj.	10	35_3	10 x 15	62-64	10	6.0	6.8
6 Roll Horiz. Hydraulic Adj.[6]	12	50_4	10 x 15	64-66	10.5-11	6.3	7.0
6 Roll Horiz. Hydraulic Adj.[6]	30-35	75_5	13 x 18	64-66	10.5-11	–	7.0-7.5
6 Roll Horiz. Hydraulic Adj.	60-65	100	16 x 24	64-66	11	–	7.0-7.5
Expeller*	15	75^7	Dia 270mm	70-73	12-12.5		

1. These are averages – cane varities, % fiber, Time from harvest to crushing can cause variations in these numbers. Early and late season crushing is a variable.
2. The roll face speed must be kept between 27-32 ft./Minute.
3. An additional 15 H.P. required for cane preparation.
4. An additional 15 H.P. required for cane preparation.
5. An additional 25 H.P. required for cane preparation.
6. Experimental models by the National Cane Institute – Kanpur.
7. Additional H.P. -2 cane cutters 7.5 H.P., screw conveyor (leveller) 2 H.P., elevator 1.5 H.P.
8. Improved expeller will be in operation Ganona – Smark – Niohi Khandsari Unit in January 1979. The spindle operates at 32 R.P.M.

Table 4. Compression roll spacing in the field

Cane crusher	Top	Middle	Bottom	% Juice on cane as such	% Juice on cane after adjustment.	Improvement in juice % cane
I	0.40	0.50	0.30	56	61; 59.2; 62 (avg. 60.7)	+4.7
II	0.20	0.30	0.30			
III	0.65	0.95	0.30			
IV	1.00	0.95	0.30	56-60		
V	0.55		0.25			
VI	–	0.70	–			
VII	–	1.15	–			
VIII	0.65	0.65	0.65 original	60	62; 64	+3.0

graph (Institute of Industrial Tormometal, Columbia.) (Fig.2). At lower face speed i.e. 3-8 feet per minute, the difference in extraction is not as evident as between 8 to 20 feet per minute. This can be easily explained that at lower face speed, reabsorption of juice by the bagasse takes place, which reduces the benefit of lower face speed, Table 5-B.

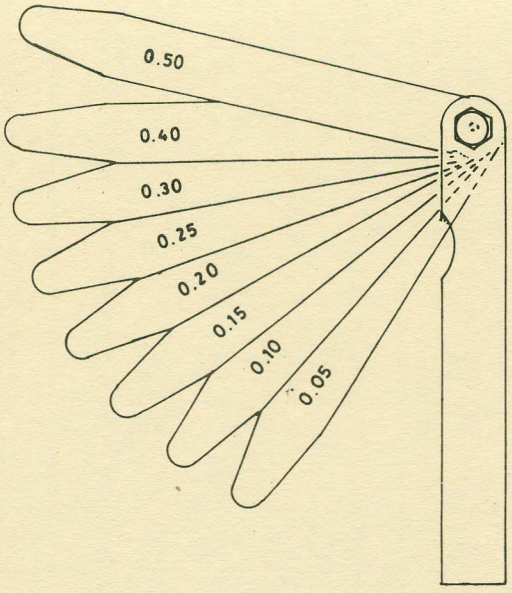

Fig.1.

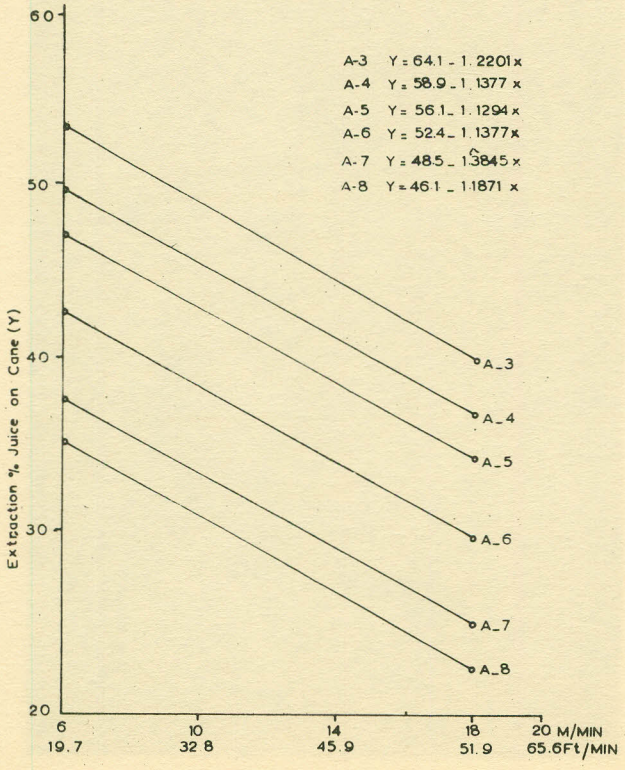

Fig.2. Effect of face speed on extraction roll diameter 9.5 inch.

Table 5.A. Effect of face speed on extraction compression roll diameter 9.5 inch

No.	Face speed	Juice % cane
1.	3.7	62.50
2.	3.7	61.40
3.	3.7	64.00
4.	8	61.17
5.	8	59.56
6.	8	63.50
7.	8	62.70
8.	8	65.66
9.	21	53.80
10.	21	56.18
11.	21	62.60
12.	21	62.50
13.	21	60.30

Table 5.B. Effect of face speed on extraction compression rolls diameter 9.5 inch

No.	Face speed	Juice % cane
1.	3.7	62.50
2.	8	62.00
3.	21	56.80

Role-size. Crushing rolls of sizes (12" x 12"), (9.5" x 9.75"), (9" x 9"), (8".5 x 8".5) manufactured by the different firms of the sub-continent have been evaluated. The rolls of sizes (12" x 12"), (9.5 x 9.75) are hard for the animals to drive. Moreover, their percentage of juice on cane is not better than that of the (8.5 x 8.5) crusher which is easier to work and better to handle. This is in agreement with the graphs showing effect of roll diameter on extraction (IIT*, Fig 3). The roll size (8.5" x 8.5") with proper configuration gives better extraction than roll size (9.5" x 9.5") (Table 6).

Maintenance. Compression rolls of a new crusher has drainage grooves on the king and bagasse rolls 1/16 ' deep. Pitch between the grooves is 7/16" or 1/2". Circumfrential grooves or threads are sixteen per inch (Fig 4). This confi-

guration wears out with the passage of time. The villagers get their crushers repaired by the local blacksmith who just evens the surface of the rolls and makes 6 to 8 irregular lines on the compression rolls (Fig 5).

Table 6. Effect of diameter of roll on juice extraction

Dia x length 8.5" x 8.5"	Dia x length 9.5" x 9.7
Juice % Cane	Juice % Cane
60.00	59.00
59.00	62.00
61.00	60.10
Average 60	60.40

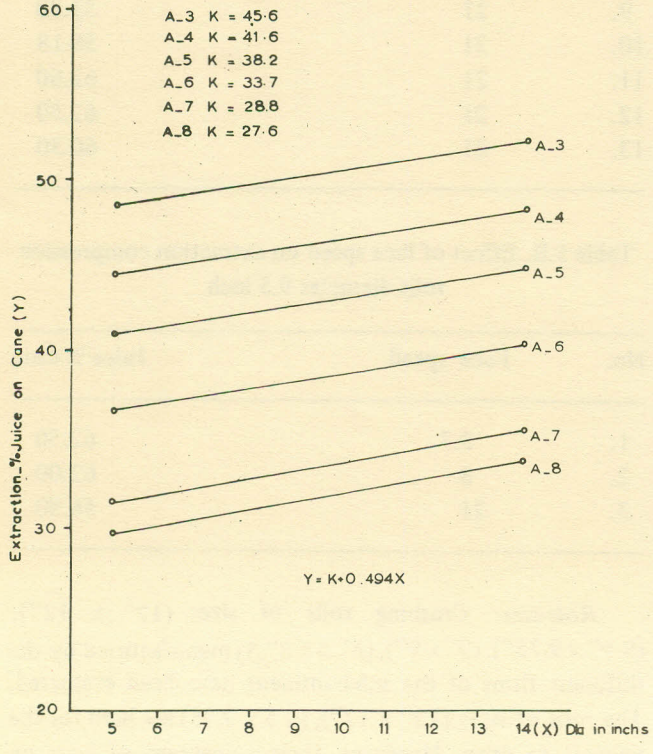

Fig.3. Effect of roll diameter on extraction.

This affects the extraction very much. (Table 7). Repair and maintenance is the most important factor in gur-making technology. The farmers should be educated to have their crusher rolls repaired at a proper workshop.

Technical results recorded in the Table 2 were determined in the sugarcane processing seasons of 1975-80 at the fields in the different part of Pakistan.

Juice percentage cane varies from 52 to 66% and in exceptional cases goes upto 69%. These values are well

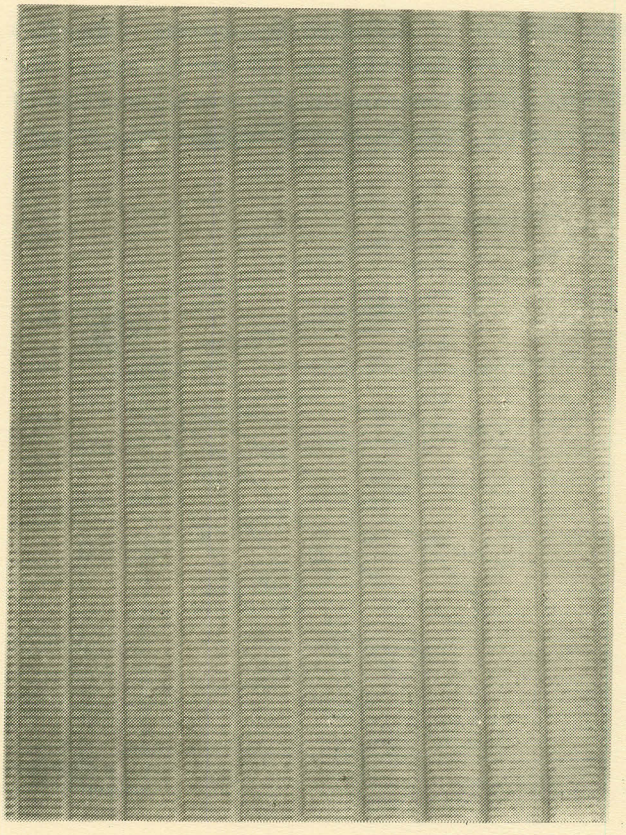

Fig.4.

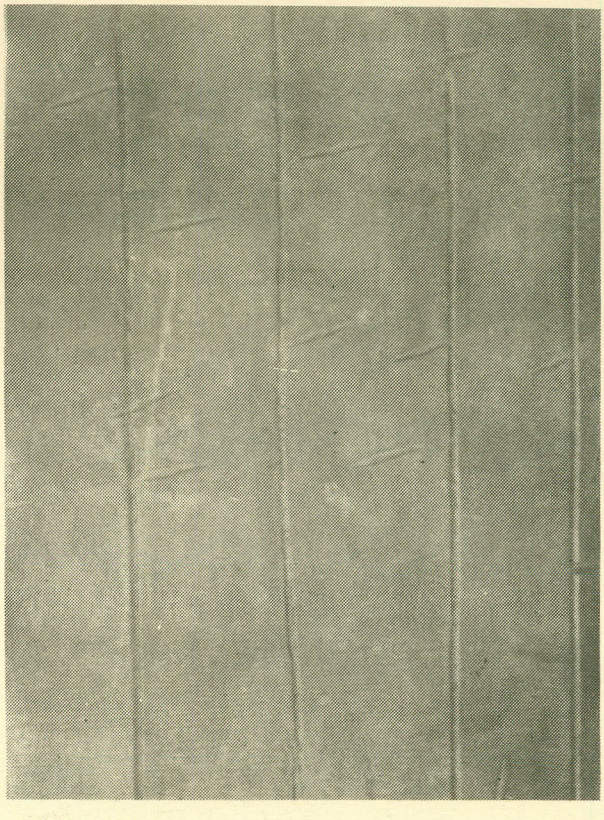

Fig.5. Configuration of the villagers compression rollers (in use).

Table 7. Comparison of original design with the village design

Quality & circumfrence	Market designed	Village design
Poor		
5-7 cm	55.90	55.50
	58.90	54.80
	59.90	56.10
Average	58.20	55.50

within the range reported by various workers for animal driven cane crushers. When compared to the big mills (74-77%) [6], it appears to be low but the mill values are for the tendum of six mills. Villagers extract juice with one mill and only once. Amount of energy and investment required in case of sugar mills is very high while crushing can be done much more economically at the village level.

Purity of sugarcane juice varies from 77% to above 90% which is better than the purity of the first extracted juice of the sugar mill (77 to 84%). Time from harvesting to crushing at the mill is more than crushing the sugarcane at the village level. So there are more impurities in the juice extracted by sugar mills; than in the juice extracted by the farmer's *belna.* The villagers extract better quality juice but they process the juice in open pan and use hazardous chemicals for clarification. Hence, their product has poor shelf-life and contains dust silica and other organic impurities.

Previously, juice % cane of gur industry was compared with the extraction of the big mills. These results should not be compared because these are totally different from each other. In case of village level processing, the extraction varies from 70 to 80 percent which is not bad. When compared with mills (90-93%), it is only 20% less where the expenditure per ton of the cane crushed is 20 times higher than at the village level [7]. Attention should be paid to make the village level sugar industry work on scientific lines.

Bagasse % cane varies from 35 to 50%. This wide variation indicates that village crushers are poorly maintained. This is high as compared to the mill (30%). Pol % bagasse is also very high (7-12%) when compared with that of mill (2-2.5%). Low pol % and bagasse % in case of big mill is due to the imbibation and the number of mills operated for crushing. It is almost impossible to introduce mill system of juice extraction in village technology due to the non-availability of water, power and fuel.

Gur recovery percentage of cane is 9-12% (Table 2) which is reasonably good as compared to white sugar (8-9%) in case of the big mills. *Gur* contains insoluble materials, moisture and invert sugar. Pol % gur has been reported in the previous paper [8] which varies from 70-80%. On this basis, recovery of sucrose from this village cane crusher is reasonably comparable with mill recovery (8-9%). Most plausible explanation that can be given of the efficiency of gur industry is the availability of fresh cane. Average pol % cane (13.7) as compared to the pol % cane (11.5), supplied to the big mill shows 16% loss. Advantage gained by the big mill at the extraction stage is lost at the recovery stage due to the invert sugar present in the cane and impurities extracted by imbibation.

It has been determined that in Pakistan there is a lapse of 2 to 3 days between harvesting and crushing [3]. It is maximum in Punjab and minimum in Sind. Recoveries of sugar from sugarcane in the mills for 1980-81 explains (Table 8) the broad relationship with the time-lapse of harvesting and crushing.

Table 8. Typical sugar recovery in large mills

Province	Recovery
Sind	8.93
NWFP	8.75
Punjab	8.43

Loss in sucrose content starts almost as soon as the sugarcane crop is cut in the field. This loss is substantial and is mainly due to the enzymatic inversion of the juice and attack of bacteria. This loss was studied in 1978 by determining the sucrose content of the freshly harvested cane within 1-12 hours. Sucrose content of the cane is recorded Table 9.

Table 9. Sucrose % cane province-wise

Province	No. of samples	Sucrose % cane
Punjab	42	13.3
NWFP	30	14.0Average=13.7
Sind	30	13.7
US Aid Estimate	5	13.0
Mills	22	11.5
Loss		13.7 – 11.5 = 2.2

The Table (9) clearly shows a 16% loss in sugar during the transportation of cane from the field to the mill. Inversion of sucrose affects the recovery by two ways.

1. Inverted sugar cannot be crystallised. 2. Inverted sugar affects the crystallisation process. Therefore, harvesting techniques and infra-structure for the smooth supply of sugarcane to mill is most essential to improve the percentage recovery of mills. It has been reported that a loss of 5-10% of the total sucrose occurres in just 60 hours after harvesting.

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