



Comparative study on cane cutter / juice expeller and roller model

Sugarcane juice extraction systems

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Abstract

Two types of cane juice extraction systems have been developed through research efforts to extract sugarcane juice in the small scale sugar processing technology in Nigeria. The first type of juice extraction system that was developed is the roller model where whole sugar cane stalks of 3 to 4 are fed into rotating rollers to extract juice from the canes. The two juice extraction systems were roller cane crusher and cane cutter/juice expeller. About 1000 kg of approximated quantities of sugar cane samples in three replications were crushed to extract the juice in each juice extraction system. The brix of the juice and quantity collected were recorded and weighed for each sample. The baggasse were subjected to sun and oven drying in order to expel the remaining moisture. The weight of moisture left in the baggasse, juice extraction efficiencies and machine capacities were computed in order to determine the process parameters. Results indicated that the cane juice cutter and expeller system which is the new model performed better than the roller cane juice extractor as the new model recorded higher average juice extraction efficiency of about 98% with corresponding higher sugar recovery of about 9% which are comparable with results obtained by the 3-4 sets of multiple roller juice extraction system usually adopted in crushing sugarcane in large scale sugar manufacturing factories. The extraction efficiency of the roller model juice extractor was found to vary from 55-65%. Also, unlike the low baggasse temperature of about 28^oC obtained with the roller juice extraction system, the baggasse temperature of the cane cutter juice expeller immediately after juice extraction recorded over 65^oC, therefore was utilized as source of heat energy for the open pan boilers without additional energy requirement for drying.

Keywords: Processing, technology, efficiency, brix, baggasse

Received: 14th March; Revised: 16th April; Accepted: 25th May; © IJCS New Liberty Group 2013

Introduction

Juice extraction is one of the major processes involved in the manufacture of sugar from sugarcane. Basically, two major methods with some variations are reported to have been widely adopted in extracting the juice. These are the roller mills and diffusers (Bhagatt, 2004). However, the technology being used for over 35 yrs

is the roller model extractor which has multiple (3 to 6) sets of corrugated rollers rotating at recommended speeds of 60-80 rpm. The combined action of the corrugated structures of the rollers and the opposite vertical pressures applied on the canes by the top and lower rollers enables the canes to be bruised and pressed for the juice to be expelled (James et al., 2000). In order to achieve high

juice extraction efficiency, the whole canes are preliminarily reduced to smaller fragments by hammer roll shredders with the aid of revolving knives before introducing them into the multiple rollers. Also, a process of imbibition whereby water is sprayed on the baggasse as they pass from one set of rollers to the next in order to leach out the sugar from the baggasse is usually done to extract more sucrose. Cane diffusers technique which involves the use of water as a major medium of extracting the cane juice has been adopted in several sugar producing countries since the early 1969. However, the final baggasse from the last mill contains the un-extracted sugar, woody fibre and 45-50% water. More modification of the multiple roller juice extraction being adopted in China and East Africa have been reported (Jia-Jionglu et al., 2000), where multiple train of 3-6 sets with each set having 3-6 rollers and individual cane feeding mechanisms are used.

For over 35 yrs each mode of these juice extraction has claimed superiority over one another but it has been asserted that the juice extraction systems account for 35% of the cost of the entire sugar manufacturing equipment, 35% of the total energy requirement and 35% of the total maintenance cost in addition to 35% total sugar losses in the factory (Bhagatt, 2004). As a result the small scale sugar processors cannot afford the cost of multiple roller juice extractors required for efficient juice extraction. Therefore, only a single set of small sized roller juice extractors being driven by animals, electric motors or diesel engines of varying capacities are being used in most developing countries. The juice extraction efficiencies of this type of extractors have been found to vary from 55-65% hence losing a lot of juice to the baggasse (Gbabo, 2004). Consequently, the overall sugar recovery rate of these plants was also adversely affected as low values of 5-

6% are often times recorded. In order to solve this problem of low juice extraction rate of the small scale single roller mills, research efforts were focused by engineers and sugarcane scientists towards the development of a simple system that can extract juice efficiently at minimal cost. Thus, the cane cutter/juice expeller was developed in the National Cereals Research Institute, Badeggi, Nigeria. The system can be effectively utilized for extracting sugarcane juice in cottage sugar industries in developing countries. This paper therefore, is a presentation of the comparative study of the technical process parameters of the old (roller) and the new (cane cutter/ expeller) juice extractors.

Description of the two juice extraction systems

Roller Juice extractor: The roller juice extractor (Fig. 1) is mainly made of three grooved rollers suspended on bearings. They are arranged triangularly with two rollers of dimension 300 mm (length) and 180 mm (diameter) each which are placed below a top roller with dimension 300 mm (length) and 300 mm (width). A minimum clearance of about 1 mm is maintained between the grooves when the top and lower rollers are in meshed position.

Fig. 1. Roller Juice expeller



A 15 hp electric motor or 16 hp diesel engines depending on location supplies power to the rollers through belts, pulleys and gears to actuate the movement of the rollers at 60 rpm for the top roller and 70 rpm for the lower set of

rollers. About 4 to 5 canes stalks are fed into the clearance between the top and lower rollers.

ii) Cane Cutter/Juice Expeller: The cane cutter/ juice expeller (Figs. 2 and 3) is comprised basically of two units: cane cutter and juice extraction assemblies. The cane cutter is made up of horizontal knife assembly having about 75 knives that rotate at a speed of 1,650 rpm within a concave sieve which is placed at the bottom and upper solid stainless iron casing. A grasshopper conveyor is also incorporated directly under the sieve to transport cut and fragmented canes into the cane juice expeller. The juice extraction unit is an expeller which extracts the juice from the fragmented canes. It is made up of a conical worm with conveying attachments that conveys the cane fragments from the anterior to the posterior end within a cage barrel made of square iron bars placed at pre-determined clearances.

Fig. 2. Sugarcane cutter



About 3-4 canes are thrown into the hopper of the cane cutter which is cut into fragments of about 3-7 mm sizes. These fragments pass through the sieve on to the grasshopper conveyor by gravity as they are brushed against the sieve by the rotating knives. They are then transported by and fed into the expeller through the hopper. The rotating worm of the expeller conveys the cane fragments and subjects them to compressive forces as they

are forced to pass through diminishing clearance in the cage barrel. These compressive forces on the cane fragments results to the squeezing out of the juice from the cane fragments which is released through the barrel clearances while the baggasse is forced out through the posterior end of the barrel.

Fig. 3. Sugarcane juice expeller



Comparison of performance between the roller cane juice extraction and cane cutter /juice expeller

Materials and Methods

Three samples of sugarcane variety BD 96-001 weighing approximately 1000 kg were used for the study. Approximate weights of sugarcanes were used because it was impossible to obtain exactly the same weight during the weighing process. Three (3) to four (4) stalks of the canes are fed into the roller cane juice extractor and cane cutter/juice expeller system separately. For the roller juice extractor, the canes are crushed and the juice is squeezed out as the canes pass through the rollers while in the case of the cane cutter/juice expeller, the fed canes are cut by the rotating knives and delivered to the expeller by the grasshopper conveyor. The extracted juice from each system are collected through the juice collector with a graduated bucket and weighed with a scale. The brix of the juice were taken while the baggasse were weighed and dried in the sun to loose the initial moisture. They were

then finally dried in an oven until a constant weight was recorded. The following parameters were then computed (Gbabo, 2008) and results presented in table 1.

I) Weight of Moisture left in the baggasse: This is an index of the quantity of un-extracted juice from the sugar cane.

$$W_{mb} = W_w - W_d \text{ ----- (1)}$$

Where

W_{mb} = Weight of moisture in the baggasse (kg)

W_w = Weight of wet Baggasse (kg)

W_d = Weight of dried baggasse (kg)

II) Weight of sugar left in the baggasse: This is the amount of sucrose that could not be released from the baggasse.

$$W_s = \frac{Br \times W_{mb}}{100} \text{ (2)}$$

Where

Results and Discussion

i. *Juice extraction efficiency:* The average juice extraction efficiency of the cane cutter/juice expeller was observed to be as high as 98% while that of the roller juice extractor is 56%. Thus, the variation in juice extraction efficiency between the new and old technology is about 42%. This means that about 42% additional juice was recovered by the cane cutter/juice expeller. The substantially high increase in juice extraction of the cane cutter/juice expeller (new) technology may be as a result of the fact that more surface areas of the canes were exposed to compressive pressures due to the shredding and bruising action of the cane cutter. Also the canes were subjected to more vertical, horizontal and lateral forces as they were conveyed along the cage barrel by the conical

W_s = Weight of sugar left in the baggasse (kg)

Br = Brix of juice

W_{mb} = has been defined in equation 1

III) Juice Extraction Efficiency:

$$E_f = \frac{W_j}{W_j + W_m + W_s} \% \text{ ----- (3)}$$

Where

E_f = Juice extraction Efficiency (%)

W_j = Weight of Extracted juice (kg)

W_{mb} has been previously defined in equation 1

W_s = Weight of sugar left in baggasse (kg)

iv) Machine capacity:

$$C_c = \frac{W_t}{t} \times 60 \text{ mins/hr ----- (4)}$$

Where

C_c = input capacity of the machine (kg/hr)

W_t = weight of crushed sugarcane (kg)

t =Time taken to crush sugarcane (hr)

worm. On the contrary the canes fed to the roller extractor were only subjected to opposite vertical pressures by the upper and lower set of rollers

ii. *Sugar recovery:* The sugar recovered from the processed juice obtained with the cane cutter/juice expeller was about 9% which is higher than the recovery of about 5.5% obtained with the roller model extractor for the same quantity of sugarcane. This is a because of the higher volume of juice extracted from the same quantity of sugarcane by the new model juice extraction system.

iii. *Percentage juice extraction from total cane:* The percentage juice extraction from total cane was also very high (about 74% for the cane cutter/juice expeller compared with the value of about 55% obtained for the roller model extractor. This value, 74% compares very closely with the theoretical

Table 1. Comparison of performance of Roller Juice extractor with cane cutter/Juice expeller system

Process parameters	Roller model			Average	Cane Cutter/Juice Expeller model			Average
	Replications				Replications			
	1	2	3		1	2	3	
Weight of sugar cane (kg)	1000.5	999.2	1005	1001.6	1010.1	1000.8	998.0	1003.0
Brix of Juice	19.5	18.6	20.1	19.4	18.4	19.2	19.7	19.1
Quantity of extracted juice (litres,)	457.5	450.0	462.0	456.5	758.5	760.	762.0	760.2
Weight of wet Bagasse (kg)	540.7	548.0	550.2	546.3	250.0	248.3	249.2	245.7
Weight of dried Bagasse (kg)	241.0	242.3	240.5	241.3	239.1	340.0	238.8	273.4
Weight of moisture in Bagasse (kg)	302.0	300.0	305.5	302.5	9.8	9.9	10.2	10.0
Weight of sugar left in Bagasse (kg)	58.8	55.8	61.4	58.7	1.8	1.9	2.0	1.9
Juice extraction time (minutes)	120	122	119	120.3	130	135	125	130
Percentage Juice extraction from totaling cane (%)	54.8	54.0	55.4	54.7	69.0	76.0	76.3	73.8
Machine Input Capacity (kg/hr)	500.2	91.4	506.7	499.4	507.7	444.8	479.0	477.2
Juice Extraction Efficiency (%)	60.3	60.0	60.2	60.2	98.7	98.7	98.7	98.7
Sugar recovery (%)	5.0	5.5	5.2	5.23	9.0	8.8	8.9	9.2
Average Bagasse Temperature (⁰ C)	28	27	29.5	28.2	65.0	65.0	67.0	65

value of 73- 76% (James et al., 2000) juice level as standard for any given quantity of industrial cane .

iv. Machine input capacity: The input capacities were almost the same for both juice extractors as the input capacity of the roller cane juice extractor is about 480 kg/hr per day and that of the cane cutter/ juice expeller is about 500 kg/hr.

v. Suitability of baggasse to be utilized as heat energy source: The baggasse extracted from the cane cutter/juice expeller was found to be more suitable to be utilized as source of heat energy for the open pan boilers because the temperature of the baggasse was observed to be above 65⁰C immediately after juice extraction from the expeller. Unlike the new technology, the baggasse obtained from the roller juice extractor recorded temperatures of 28⁰C, hence had to be dried in the sun for about 1-2 days depending on the sun intensity before utilizing them to fire the open pan boiling system. Thus, additional energy and labour is expended in drying the baggasse before they we utilizable as source of heat energy.

Conclusion

The comparative study of the two technology: roller (old) and cane cutter/juice expeller (new) technologies

indicates that the cane cutter/juice expeller model for extracting juice from sugarcane in cottage sugar plant is more preferable to the roller model because of the numerous advantages it has. Apart from the high juice extraction efficiency of over 98%, the instantaneous utilization of the baggasse to fire the open pan boiling system because of its high degree dryness, thereby saving additional energy and labour cost for drying the baggasse is a very encouraging result. Therefore, small scale sugar manufacturers in developing countries who cannot afford the sophisticated and very costly vacuum pan system of sugar production can adopt the new technology since its economic viability has been ascertained by the discovery of the new innovation (cane cutter/juice expeller).

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