Balancing Sugar and Energy Production in Developing Countries: Sustainable Technologies and Marketing Strategies

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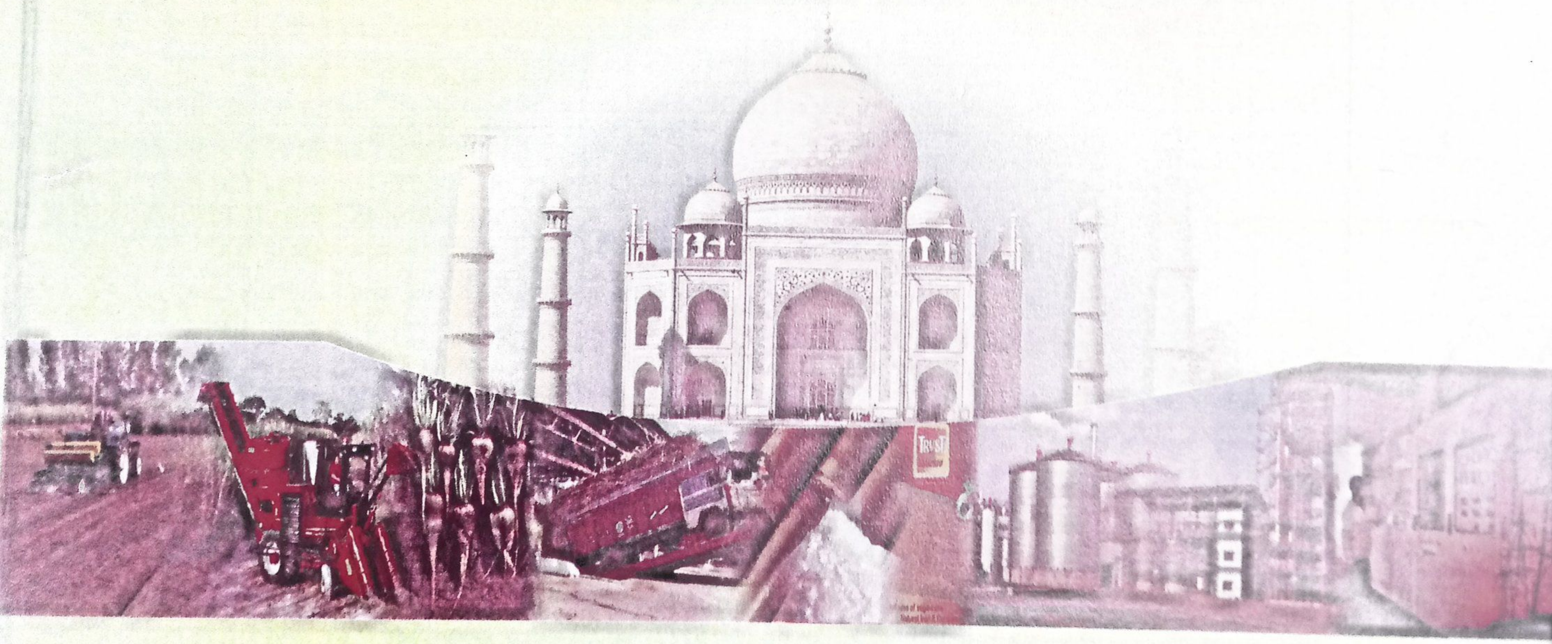

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EMERGING TECHNOLOGICAL DEVELOPMENTS SUITABLE FOR VIABLE COTTAGE SUGAR PRODUCTION IN DEVELOPING COUNTRIES

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Abstract

Unlike the large scale (vacuum pan) industries, the economic viability and growth or expansion of sugar production by cottage industries in most developing countries is not favourable. Among other technological factors and problems such as inefficient juice extraction and low crystallization rate of syrup were identified as major contributing factors for the inefficient overall performance of cottage sugar factories in many developing countries. As such, two new innovations: cane cutter/juice expeller to cut sugarcane and extract juice efficiently, and combined air and water cool crystallizer, to increase the crystallization rate, were developed to replace the older technologies for cottage sugar production. In the present study, the cottage level sugar production plant, developed at the National Cereals Research Institute, Badeggi, Nigeria, was used to conduct the research work. The former set of machineries using rollers to extract sugarcane juice was used to process approximately 1,000 kg of sugarcane. The new innovative technology was used for extracting juice from the same quantity of sugarcane(1000kg). Also about 1,000 litres of massecuit were crystallized separately in the air cool and combined water/air cool crystallizers and the data obtained were analyzed. Results indicated that the juice extraction efficiency of the new technology (cane cutter/juice expeller) was 98.5% compared to 56% in older methods. This represented an increased juice extraction of about 76% per kg cane. Consequently, sugar recovery also improved abruptly from 5.5% to 8.5%. All these indices resulted to the viability of cottage sugar production as clearly indicated in the economic analysis. In addition, the bagasse temperature immediately after extracting the juice was recorded as high as 65°C, thus it was used as source of heat energy for open pan boilers directly without additional energy and cost requirement for drying.

Key words: Cottage sugar; small scale sugar industry; juice extraction; crystallization; brown sugar

INTRODUCTION

A cottage scale brown sugar processing plant having capacity to crush 10 tons of sugarcane per day was established in 1988 by the National Cereals Research institute, Badeggi for the Jigawa State Government. It has an overall sugar recovery of 0.6 tons per day. The plant was established with a view to assisting the nation in augmenting the nation's huge short fall in sugar production of about 99% (Amosu et al. 2000). It was also meant to enhance the capability of local sugar cane growing communities to process their canes into brown sugar, thereby, increasing their income, provide rural employment and contribute to rural development. It was also expected to be economically sustainable and viable. However, the viability of the plant was in doubt. It has been reported that the sustainability of these types of Small scale sugar factories in developing countries like India was made possible by protective government fiscal policies on both vacuum pan (VP) and Open pan system (OPS) (Baron 1975) and Guerin et al. 1977). The intervention of the government into the sugar industry politics was to save the OPS (Small sugar Factories) from economic frustration due to it's low initial sugar recovery rate of 7.0 to 7.3% compared to 9.5-11.0% in VP (Large Scale) mills. This support encouraged the existence of the small scale industries until the advent of new technologies like the improved Shell furnace (Forsyth 1977, 1990; Alpine 1980).

The introduction of shell furnace to evaporate cane juice in the OPS increased sugar recovery from about 7.0 to 8.0 thereby reducing the sugar recovery differential between the VP and OPS from about 4.0 to 2.1 (Garg and Mc. Cheney 1980). However, tribe and Alpine (1982) asserted that the unit cost of sugar production were less for larger (VP) mills than small (OPS) mills. This effort has actually encouraged the establishment of over 313 VP mills with 27 under construction, 6,000-8,000 medium plants and about 100,000 jaggary (local) sugar plants as at 1982 (Kaplinsky 1984). Although government protection policies of OPS was commendable, Bell (1982) cautioned that protection alone is not a sufficient condition for the OPS to have rapid economic viability.

In Africa, Kenya is the only country where the sugar industry has thrived well. The eight large scale (VP) and three small scale (OPS) plants established in that country between 1980 and 1981 have been economically viable and able to satisfy the domestic consumption requirement (Blankhart 1983). In Nigeria, two major sugar factories, Nigeria Sugar Company Ltd. (NISUCO), and Savana Suagar Company at Bacita and Numan, respectively, have been operating at huge losses and

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now they have even stopped the production. Perhaps, the only hope for self sufficiency in domestic sugar production is to encourage the establishment of efficient indigenous cottage plants that can easily be managed and requires less running cost.

As a result, research efforts were geared towards developing efficient cane processing technologies that can yield high sugar recovery. Consequently, the cane cutter/juice expeller system and combined air and water cool crystallizer were developed in the National Cereals Research Institute, Badeggi, Nigeria, to efficiently extract sugar cane juice and crystallize syrup.

Factors responsible for improved performance of the new cottage sugar production plant

Introduction of sugarcane cutter and juice expeller system

The method of extracting sugar cane juice from the canes in the small scale processing system has been the application of vertical pressure on the canes which is applied through a set of horizontal serrated rollers. This set of rollers is comprised of a single upper and two lower rollers. These rollers ensure the tearing and pressing of the canes when rotating at 60rpm as about 4 to 6 stalks of canes are passed through them.

The resulting upward and downward vertical reactive pressure on the cane ensure the squeezing out of the juice from the canes. This system of juice extraction had average extraction efficiency 55- 60% which indicates that about 40-45% of the juice is lost in the bagasse. This had resulted to low sugar recovery of 5- 6% as against 10 to 12% obtained with vacuum pan technology as shown in table 1. Further more this had given rise to the non economic viability of the technology.

In other to improve the overall sugar recover of the technology, further research activities in the National Cereals Research Institute, Badeggi resulted to the successful development of a cane cutter juice expeller to extract sugar cane juice efficiently (Fig. 1). The system is comprised mainly of two units: the cane cutter and juice expeller.

The cane cutter cuts sugar canes into fragmented sizes of 2 to 8cm with the aid of a horizontal rotating knife assembly and metering sieve placed at 1cm below the knives. The cut canes were conveyed out of the cane cutter and delivered to the cane juice expeller at a horizontal distance of 100cm. The cane juice expeller which is comprised of a worm rotating inside the cage barrel ensures the crushing and squeezing of the cane fragments in two sections to release the juice which passes through the clearances provided in the cage (Fig. 2). Result of performance assessment of the system as presented in table 1 showed average Juice extraction efficiency of 98%. Due to the higher juice extraction efficiency, higher sugar recovery per ton of cane was observed. This indicates that additional juice and sugar recoveries of 76%, each per kg of cane, was realized. The increase in the percentage juice extracted and the sugar recovery were due to the fact that the initial cutting of the canes exposed more surface area of the canes to be subjected to varying degrees of lateral, horizontal and vertical pressure.

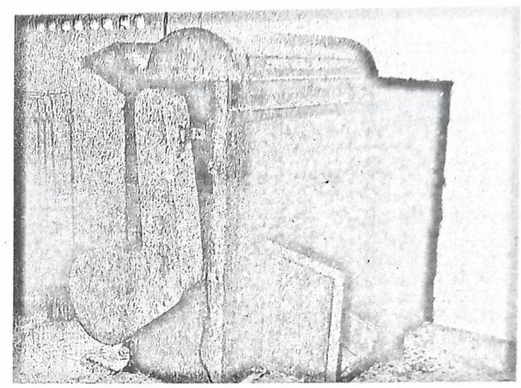

Fig.1. Cane cutter

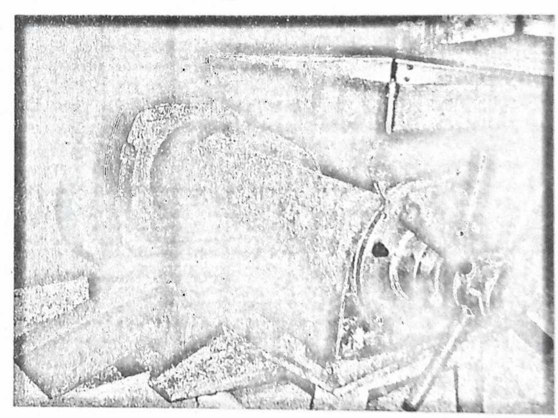

Fig. 2. Cane juice expeller

Table 1. Performance of roller model juice extractor and expeller model juice extractor

Nos.	Process Parameters	Roller Model	Expeller Model
1	Average weight of sugar cane BD 95-30(kg)	1000.5	1000.5
2	Brix of juice (%)	19.5	19.5
3	Volume of Extracted juice	459.5	750.8
4	Weight of wet baggasse (kg)	542.5	249.0
5	Weight of dried baggase (kg)	240.5	239.1
6	Weight of moisture in baggasse(kg)	302.0	9.9
7	Weight of sugar left in baggasse (kg)	58.9	1.9
8	Juice extraction time (minutes)	120	184
9	Machine input capacity (kglhr)	450	324
10	Juice extraction efficiency %	56	98.5
11	Percentage juice extraction from total weight of cane	45	75.0
12	Sugar recovery per ton cane	5.5	8.5
13	Average temperature of baggase immediately after juice extraction °c	28	65

Immediate utilization of bagasse in open pan boilers in new system

The bagasse obtained from the cane cutter juice expeller was very dry recording a moisture content of less than 4% and temperature of over 65°C (depending on the degree of pressure exerted on the sugar cane fragments through the pressure adjustment device). This was a remarkable achievement that is associated with the new technology compared to the former method of juice extraction using rollers in which moisture content of bagasse was 55% and exit temperature of bagasse of about 28°c. Since the bagasse obtained with the latest technology of juice extraction had very low moisture content with high temperature it was immediately utilized a source of heat energy for boiling the sugar cane juice in the open evaporation system, while the bagasse produced by the old method (roller model) of juice extraction was usually dried in the sun for two to three days due to its high moisture content before utilizing them as source of heat energy for evaporating the cane juice in the open pan system. Thus additional labour was required for drying and parking of the bagasse. As a result running expenses in operating the latest technology was less than that of the roller type.

Introduction of a combined air and water cool sugar crystallizer

The development of combined air and water cool crystallizer in the National Cereals Research Institute, Badeggi to crystallizer sugar syrup resulted to increase in sugar recovery from about 751 Kg. to 890 kg as shown in Table 2. The initial crystallizer (Fig. 3) that was developed used only air as the cooling medium in the Open Pan Boiler (OPS). It was observed that crystallization period took longer duration of 85-90hours especially during the dry (hot) season in Nigeria. The long crystallization period does not encourage the formation of big crystal because of retention of heat in the syrup for a long duration which impedes crystallization rate. Since utilization of canes for processing into sugar extends into the dry season in Nigeria and most developing countries on the same geographical belt, it became very essential to develop a system that would accelerate the crystallization rate and further enhance the formation of bigger crystal. Thus the combined air and water cool crystallizer was developed (Fig. 3) to utilize water as additional cooling medium to air through a heat exchanging system. Water from an overhead storage tank enters the crystallizer through a central pipe and distributed to a jacket and the rotating heat exchanging pipes to cool the crystallizer. The result of the comparative study of the air cool and combined air and water cool crystallizer given in table 2 indicated average sugar crystal growth increase of 18% (as the quantity of the crystal increased from 750.6kg to 889.0kg) for that of the combined air and water cool crystallizer over that of the air cool system. In addition, the average crystal sizes of 1.0 for the combined air and water cool model were bigger compared with the average sizes of 0.5mm for the air cool model. The significant increase in crystal growth and size contributed to higher sugar recovery sugar recovery due to the fact that more crystal were retained in the centrifugal basket during centrifugation (separation process) as less quantity of sugar crystal escape through the inner centrifuge sieve.

Table 2. Performance of Air cool and combined Air and Water cool crystallizers

Nos.	Process Parameters	Air Cool Model	Water and Air cool
1	Quantity of masssercuitt (Litre and kg)	1000 litres (1,200kg)	1000 litres (1,200 kg)
2	Mass of sugar crystal (kg)	750.6 kg	889.0 kg
3	Quantity of molasses (litres and kg)	373 litres (447.6 kg)	259.2 litres (309.5 kg)
4	Crystallization of time (hrs)	52 hrs	48
5	Average crystal size (mm)	0.05	0.09

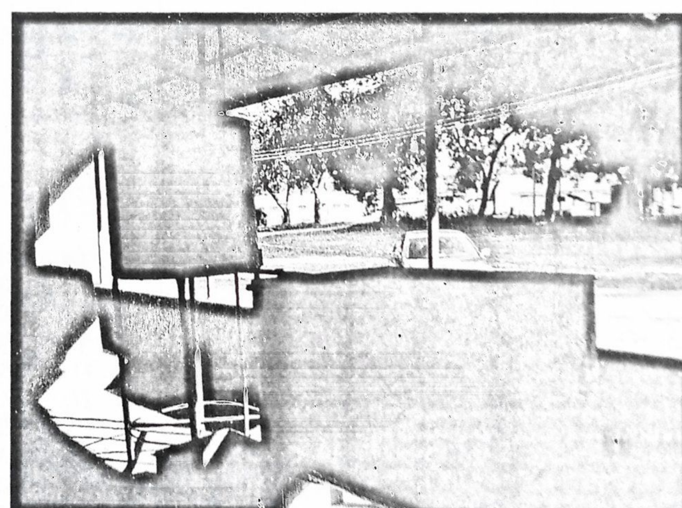

Plate 3. Combined water and Air cool crystallizer

Economic viability appraisal for the new and old technology

The new brown sugar technology was subjected to economic analysis (Total revenue generated per annum, simple rate of return (SRR), benefit cost Ratio (BCR), Net present Value (NPV) and Internal Rate of Return (IRR) to asses its financial advantage over the old technology. Table 3, showed a marginal value of Twelve million, four hundred and five thousand Naira (N12,405,000) Nigerian currency, as a result of the new technology

Table 3. Sources/revenue generated for one year full operation for both old and New technologies.

Nos.	Brown sugar Mini-Processing Firms Location	Revenue Source (s)	Tonnrd/ year	N/Tonne	Value per year (N)	Total Revenue/ year (N)	Marginal value added by new technology (N)
1	Old Technology	Brown sugar (crystal)	82.5	190,000	15,675,000	28,725,000	
		Liquid Sugar (Molasses)	130.5	100,000	13,050,000		
2	New Technology	Brown Sugar (crystal)	102	190,000	19,380,000	41,130.000	
		Liquid Sugar (molasses)	217.5	100,000	21,750,000		12,405,000

Source: 2010/2011, Survey data, on old and new Brown Sugar Mini-Processing Technologies in Nigeria

Table 4. Comparison of Simple Rate of Return between the old and the new technology

(a) S/No.	(b) Items	(c) Total investment cost (₦)	(d) Annual profit (₦)	(e) Net simple Rate of Return – R (d) / (c) x 100	(f) Marginal simple rate of return added by new technology
1	Old Technology	29,674,800	18,328,200	81%	
2	New Technology	32,767,800	30,475,200	93%	12%

Source: 2010/2011, Survey data, on old and new e Brown Sugar Mini Processing technologies in Nigeria.

Table 5. Computation of NPV IRR and BCR for Brown Sugar Mini-Cottage processing firm in Nigeria – old Technology

PROJECT YEAR	GROSS COST N	GROSS REVENUE N	NET REVENUE N	DF @ 25%	NPV OF NET REVENUE @ 25% N	NPV OF GROSS REVENUE @ 25% N	NPV OF GROSS COST @ 25% N	DF @ 50%	NPV OF NET REVENUE AT 50% N	IRR (25%)	IRR (50%)	BENEFIT COST RATIO (BCR) @ 25% N
0	21,420,00	0	21,420,000	0	0	0	0	0	0	95%	95%	3.479794
1	8,254,800	28,725,000	20,470,000	0.80	16376160	22980000	6603840	0.667	13653623			
2	8,254,800	28,725,000	20,470,000	0.64	13100928	18384000	5283072	0.444	9088769			
3	8,254,800	28,725,000	20,470,000	0.512	10480742.4	14707200	4226458	0.296	6059179			
4	8,254,800	28,725,000	20,470,000	0.409	8372311.8	11748525	3376213	0.198	4053100			
5	8,254,800	28,725,000	20,470,000	0.32768	6707675.14	9412608	2704933	0.132	2702066			
6	8,254,800	28,725,000	20,470,000	0.262144	5366140.11	7530086.4	2163946	0.088	1801378			
7	8,254,800	28,725,000	20,470,000	0.209715	4292907.99	6024063.4	1731155	0.059	1207742			
8	8,254,800	28,725,000	20,470,000	0.167772	3434326.39	4819250.7	1384924	0.039	798337.8			
9	8,254,800	28,725,000	20,470,000	0.134218	2747469.3	3855412.1	1107943	0.026	532225.2			
10	8,254,800	28,725,000	20,470,000	0.107374	2197967.25	3084318.2	886350.9	0.017	347993.4			
Total	103,968,000	287,250,000	183,282,000		73076628.4	102545464	29468835		40244413	95%	95%	3.479794

BCR = 3.47; NPV @ 25% = N 73076628.4 IRR is positive and greater than 50%

[Source: 2010/ 2011, Survey data, on old and new e Brown Sugar Mini-Processing Technologies in Nigeria]

Simple rate of return showed that in the first year of full operation, the new technology can generate 93% of the total Investment cost (Table 4), and this gives a marginal rate of return of over 12% over the old technology

From Tables 5 & 6, the Benefit Cost Ration (BCR), The Net Present Value @ 25% interest and the Internal Rate of Return (IRR) for the old and new technologies were 3,47, N73,073,628, 95% and 5.01, N117,564,760 and 134% respectively. It is clearly seen from the economic tools used that the new brown sugar mini-processing technology is superior to the old technology.

CONCLUSIONS

It was obvious that the introduction of the two new technologies, cane cutter/Juice expeller and water/Air cool crystallizer for extracting sugarcane juice and crystallizing concentrated sugar syrup respectively in the tremendously improved the sugar recovery rate of the cottage scale Brown sugar plant. This is because of the increase juice extraction of efficiency from about 56-98%. This means that about 75% of the juice which hitherto was lost to the bagasse was recovered. The high juice extraction efficiency of the new technology also

Table 6. Computation of NPV IRR and BCR for Brown Sugar Mini-Cottage processing firm in Nigeria – old Technology

PROJECT YEAR	GROSS COST N	GROSS REVENUE N	NET REVENUE N	DF @ 25%	NPV OF NET REVENUE @ 25% N	NPV OF GROSS REVENUE @ 25% N	NPV OF GROSS COST @ 25% N	DF @ 50%	NPV OF NET REVENUE AT 50% N	IRR (25%)	IRR (50%)	BENEFIT COST RATIO (BCR) @ 25% N
0	24,570,000	0	-24,570.000	0	0	0	0	0	0	134%	134%	5.0172
1	8,197,800	41,130,000	32,932,200	0.80	26345760	32904000	6558240	0.667	21965777			
2	8,197,800	41,130,000	32,932,200	0.64	21076608	26323200	5246592	0.444	14621897			
3	8,197,800	41,130,000	32,932,200	0.512	16861286.4	21058560	4197274	0.296	9747931			
4	8,197,800	41,130.000	32,932,200	0.409	13469269.8	16822170	3352900	0.198	6520576			
5	8,197,800	41,130,000	32,932,200	0.32768	10791223.3	13477478	2686255	0.132	4347050			
6	8,197,800	41,130,000	32,932,200	0.262144	8632978.64	10781983	2149004	0.088	2898034			
7	8,197,800	41,130,000	32,932,200	0.209715	6906376.32	8625578	1719202	0.059	1943000			
8	8,197,800	41,130,000	32,932,200	0.167772	5525101.06	6900462.4	1375361	0.039	1284356			
9	8,197,800	41,130,000	32,932,200	0.134218	4420094.02	5520386.3	1100292	0.026	856237.2			
10	8,197,800	41,130,000	32,932,200	0.107374	3536062.04	4416292.6	880230.6	0.017	559847.4			
Total	106,548,00	411,300,000	304,752,000		117564760	146830110	29265351		64744705	134%	134%	5.0172

BCR = 3.47; NPV @ 25% = N117,564,760; IRR is positive and greater than 50%; DF = Discount factor; NPV = Net Present Value; IRR = Internal Rate of Return and BCR = Benefit – Cost Ratio [Source: 2010/2011, Survey data, on old and new e Brown Sugar Mini-Processing Technologies in Nigeria].

resulted to the corresponding increase in the over-all sugar recovery from 5.3 to 8.5%. In addition, the suitability of the baggage produced by the new technology in firing the open Pan Boiling system instantaneously without additional energy requirement in drying the baggage reduced the labour requirement in the factory.

These factors contributed greatly to the viability of cottage sugar production especially in developing countries. These facts are corroborated by the viability appraisal on the economic indices of the cane cutter juice expeller and water/Air cool crystallizer technologies, where the rate of return on investment, benefit cost ratio (BCR), the net present value (NPV) on investment were very favourable for the new technology compared to the old one. Therefore, developing countries are encouraged to invest in such profitable technology for increased sugar production thereby contributing towards increasing the gross domestic products (GDP) of their nations.

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