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APPROPRIATE TECHNOLOGY FOR PRODUCTION OF SUGAR AND OTHER SWEETENING AGENTS

Background Paper

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APPROPRIATE TECHNOLOGY FOR PRODUCTION OF SUGAR AND OTHER SWEETENING AGENTS

by

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ABSTRACT

Different technologies for the production of various sweetening agents such as gur, khandsari sugar, plantation white sugar, raw-sugar, refined sugar etc. have been described in detail. The quality of the products has been specified. The cane, financial and technical skill requirements for various technologies have been outlined. The parameters required for adoption of one technology or the other have been indicated. It is pointed out that the vacuum pan technology producing plantation white sugar is the cheapest and is ideally suited for developing countries.

SUMMARY OF CONCLUSIONS/RECOMMENDATIONS

(a) Cane forms the cheapest raw material for the production of sweetening agents in developing countries.

(b) Gur, solidified cane juice, can be produced by individual farm-owners for their domestic consumption. The poor keeping quality of gur and storage difficulties set a limitation for its commercial production on large-scale.

(c) Khandsari sugar, which is white crystalline in nature, can be manufactured in mini factories with capacities ranging from 50-300 tonnes cane crushing capacity per day and adopting modern sulphitation open pan technology. This technology is inferior in the sense that the recovery of sugar is very very low, of the order of 6 to 7.0 % and involves wastage of national energy wealth of sugar and should not be encouraged excepting under limited conditions. The same should be considered only in areas where other superior technologies could not be adopted due to lack of finance or technical skill.

(d) Plantation vacuum pan white sugar technology is the cheapest and the most efficient. The quality of the product is superior to the open/khandsari sugar and is roughly equivalent to the refined sugar. This technology is most suited for developing and developed countries. The size and the capacity of the factory

however, depends upon the availability of raw material. Factories with capacities ranging from 100 - 10,000 tonnes can be designed and set up with ease. The cost of production is inversely proportional to the capacity of the factory.

(e) The raw-sugar manufacture is the simplest technology and is a prologue to the manufacture of refined sugar. The high colour content of raw sugar leads to low market acceptability for direct consumption.

(f) Refined sugar manufacture is the costliest technology.

1. Introduction

1.1 Sugar is the cheapest energy food to improve the health of a common man and growing children. In general, in the economically well developed countries where general standard of health of the population is good, the per capita consumption of sugar is also high. The per capita consumption of sugar in different countries is given below :

Table - 1

Per Capita Consumption of Crystal Sugar

Sl. No.	Country	Kilograms - Raw value				
		1971	1972	1973	1974	19 /5
1.	Poland	39.6	44.6	46.4	46.0	47.0
2.	Spain	28.8	29.2	29.5	29.2	30.8
3.	USSR	42.2	43.4	44.8	44.6	44.5
4.	Yugoslavia	28.4	29.3	29.6	29.8	30.5
5.	Canada	48.6	47.0	55.0	43.8	45.6
6.	USA	50.1	50.1	49.8	48.0	42.0
7.	Cuba	71.2	53.8	52.0	57.4	54.0
8.	Mexico	38.4	40.1	43.2	40.3	42.5
9.	Brazil	39.0	41.8	42.1	42.5	45.3
10.	China	4.3	4.5	4.8	4.8	5.1
11.	India	8.1	7.0	6.7	6.5	6.2
12.	Philippines	17.5	19.2	19.8	23.0	20.4
13.	Ghana	10.7	9.9	9.1	5.5	6.6
14.	Tanzania	9.2	9.8	9.8	9.1	8.5

1.2 It has been observed that the per capita consumption of sugar in the developed countries is more than 40 kg. whereas the same in under-developed or developing countries is less than 10 kg. In India, in addition to (vacuum pan sugar) two more sweetening agents viz. gur and khandsari are produced and consumed. The total consumption of the sweetening agents during the last five years is given below :

Table - 2

Per Capita Consumption of Sweetening Agents in India

Sugar Year (Oct. to Sep)	Population as on 1st March (Millions)	Per Capita Consumption (Kg.)		
		Sugar	Gur & Khandsari	Total
1972-73	570	6.2	12.3	18.5
1973-74	581	6.1	13.8	19.9
1974-75	593	5.8	13.6	19.4
1975-76	605	6.1	14.2	20.3
1976-77	617	6.1	14.3	20.4

1.3 The per capita consumption of sugar, gur and khandsari in India has increased slightly; in 1972-73 it was 18.5 Kg. and the same increased to 20.4 Kg. in 1976-77. There is, however, need to increase the consumption of sugar particularly in developing countries; promotion of production of sugar in these countries would go a long way for increasing the per capita consumption. For this purpose, it is of marked significance to provide appropriate technology to those countries such that sugar is produced in adequate measure and at a low cost. This paper discusses the various technologies and also indicates the parameters demanding the choice of one technology or the other.

2. Raw Material and Resources

2.1 Beet root and sugarcane are the two important raw materials for manufacture of sugar. In sub-tropical countries where temperatures are low, beet is grown abundantly and profitably; and the same forms raw material for sugar in countries like USSR, Canada, France, Federal Republic of Germany, Italy, Turkey, Poland, Spain, etc. (See Table 3).

Table - 3

Production of Sugar Beet in Some Important Countries of the World

Sl. No.	Country	Million tonnes				
		1972	1973	1974	1975	1976
1.	China	6.0	6.1	7.8	8.2	8.4
2.	France	18.7	21.9	21.9	22.8	21.0
3.	German Democratic Republic	6.2	6.7	7.0	6.4	5.0
4.	German Fed.Rep.	14.7	16.6	17.0	18.2	18.0
5.	Italy	10.7	9.4	7.7	12.5	12.1
6.	Poland	14.3	13.7	13.0	15.3	14.2
7.	U.K.	6.4	7.4	4.6	4.9	6.3
8.	U.S.A.	25.9	22.2	20.1	27.0	26.7
9.	U.S.S.R.	75.7	87.0	77.9	66.3	98.6
	World Total	240.2	253.3	242.9	256.6	294.7

2.2 In tropical countries where temperate climate is obtainable, sugarcane is grown and is employed for manufacture of sugar and other sweetening agents. India, Brazil, Cuba, Australia, Mauritius, Mexico, Philippines, etc. are noted for sugar cane cultivation and for cane sugar.

2.3 Both beet and sugarcane require water and sunshine in abundance. Therefore wherever water and sun are available, the sugar industry flourished.

2.4 Since most of the developing countries are situated in the tropical belt, where sugarcane is grown abundantly and profitably (See table 4), the cane sugar technology is most appropriate.

Table - 4

Production of Sugarcane in Some Important Countries of the World

Sl. No.	Country	Million tonnes				
		1972	1973	1974	1975	1976
1.	Africa	51.1	50.7	50.7	50.8	56.6
2.	Australia	18.9	19.3	20.4	22.0	23.4
3.	Brazil	95.1	94.4	96.4	91.4	104.0
4.	Cuba	45.5	55.0	53.2	56.0	51.0
5.	India	113.6	124.9	140.8	144.3	142.7
6.	Mauritius	6.3	6.2	6.0	4.3	6.6
7.	Mexico	36.3	36.5	33.5	35.6	33.8
8.	USA	25.7	23.4	22.5	25.9	26.1
9.	South Africa	16.8	15.5	16.6	16.8	19.2
10.	Philippines	18.1	22.6	23.2	24.6	25.5
	World Total	597.3	626.6	654.8	666.4	694.1

2.5 In the year 1975 beet sugar production (32 million tonnes) is about 40% of the total world sugar production (81.6 million tonnes) and cane sugar constitutes about 60% (49.6 million tonnes).

3. Indian Sugar Industry and Technologies

3.1 It may be noted that India produces the largest quantity of sugar cane in the world. In 1977-78 season the total production of cane is about 160 million tonnes. It occupies the first place in the world as far as production of sugarcane and the sweetening agents are concerned. About 35% of the total cane production is employed for production of plantation white sugar; approximately 10% is utilised as seed material and the rest (about 55%) of the production goes for manufacture of gur and khandsari. There are 8000 small khandsari sugar units having daily crushing capacity ranging from 5 to 300 tonnes of cane.

3.2 About 5 to 6 million tonnes of plantation white sugar is produced annually in India in about 290 factories situated in different parts of the country. The capacities of the factories range from 1250 to 6000 tonnes of cane crushing

per day, the average capacity is about 1800 tonnes. India occupies the third place in the world for crystal sugar production.

3.3 Technical Efficiency in the Sugar Industry

3.3.1 The Chemical control in the plantation white sugar factories is among the best in the world. Modern and new units as well as expanded capacity units have achieved high efficiency results and tend to maintain far above the following minimum norms of technical efficiency.

(a)	Reduced mill extraction	93
(b)	" boiling house extraction	90
(c)	" Overall extraction	84
(d)	Total sugar losses percent cane	2.3 to 2.7
(e)	Fuel consumption in terms of bagasse	26-28%
(f)	Capacity utilisation/gross day	87.5
(g)	" " per 24 hrs. operation	95.0

3.4 Sugar Machinery Manufacture in India

3.4.1 At present, there are number of sugar machinery manufacturers in India who supply complete sugar plants. The entire sugar machinery required for the establishment of new units and for expansion programmes is being manufactured indigenously.

3.4.2 The following firms are registered and reputed firms for manufacturing sugar factory equipment :

1. Buckau Wolf New India Engineering Works Ltd.
   Poona - 411018
2. Binny's Engineering Works Ltd.
   Madras - 600061
3. Engineering Projects (India) Ltd.
   Kasturba Gandhi Marg
   New Delhi - 110001
4. Indian Sugar & General Engineering Corporation
   Yamunanagar (Ambala)
5. The K.C.P. Ltd.
   Madras - 600019
6. Kay Iron Works
   Yamunanagar (Ambala)

7. National Heavy Engineering Co-operative
   Poona
8. Prem Heavy Engineering Works Ltd.
   Meerut (U.P.)
9. Texmaco Ltd.
   Calcutta - 700056
10. Triveni Engineering Works Ltd.
    Allahabad (U.P.)
11. Walchandnagar Industries Ltd.
    Walchandnagar (Poona)

3.4.3 India is not only self sufficient in respect of sugar machinery but has surplus capacity. In the recent past large amount of sugar machinery has been exported. Four factories have been set up in other countries like Malaysia, Tanzania, Uganda, etc.

3.5 Exports

3.5.1 Until 1957, during the years of shortfall in production, India had to import sizeable quantities of sugar for meeting the internal requirements. Since 1957, however, India entered the export market and import of sugar has been completely stopped. India has established itself to be surplus sugar country and is one of the significant exporting countries.

3.5.2 Sugar exports have ranged from the minimum of 16000 tonnes in 1959 to the maximum of 0.97 million tonnes in 1975 (See table - 5).

Table - 5

Export of Sugar from 1971 to 1976

Year	Export of sugar (Million tonnes)
1971	0.332
1972	0.099
1973	0.249
1974	0.443
1975	0.966
1976	0.843

3.5.3 India has future plans to export more than one million tonnes every year from its surplus sugar.

3.6 Research and Development Need in Sugar Industry

3.6.1 India is well equipped for research and development needs of sugarcane and sugar industry. There are three research institutions at Coimbatore, Lucknow and Kanpur financed and administered by the Central Government. Besides these, there are other institutions viz., Deccan Sugar Institute Poona and Planning Research and Action Institute, Lucknow who also do the work of advisory and co-ordination to the sugar industry. The former mainly render advice to cooperative vacuum pan sugar factories. The latter does the extension work regarding researches done in collaboration with National Sugar Institute for the Khandsari Sugar Industry.

3.6.2 The Sugarcane Breeding Institute at Coimbatore develops different varieties of cane suitable for different parts of the country. This Institute has done commendable work in this field and the Coimbatore (Co) varieties of cane are world famous and are being employed in many countries.

3.6.3 The Indian Institute of Sugarcane Research at Lucknow develops the cultural practices required for different varieties of cane under different climatic conditions of the country. State Governments are also maintaining large number of cane research stations; their main object is to provide the guidance to the cultivators of the area and to provide healthy cane seed for commercial cultivation. Some of the State research stations/centres such as those at Anakapalle in Andhra Pradesh, Padegaon in Maharashtra, Shahjahanpur in Uttar Pradesh, Jullundur in Punjab, Pusa in Bihar, etc. have done remarkable amount of work for the development of cane varieties and cultural practices suitable to the areas.

3.6.4 The National Sugar Institute at Kanpur deals with all the technological and engineering aspects for the establishment of new sugar factories, rehabilitation, modernisation and expansion of the existing units and factory

operations for production of centrifugal sugar and other sweetening agents. The Kanpur Institute also attends to the research and development activities relating to gur, khandsari sugar, raw sugar and refined sugar. This Institute has been playing an important role in the development of the sugar industry during the past 50 years.

3.6.5 The National Sugar Institute at Kanpur undertakes all the R & D activities for the development of gur and khandsari industries too. Improved crushers were developed for improving the juice extraction. Methods of clarification of cane juice for producing good quality gur were also developed. For Khandsari sugar industry, hydraulic type crushing units were designed; liming and sulphitation process for juice clarification was developed, furnaces with better fuel efficiency were designed and different boiling techniques for producing better quality sugar were advocated. The R & D efforts of NSI have led the khandsari factories to produce good quality white crystal sugar in appreciable quantities. The NSI maintains adequate staff for guiding and advising the three technologies viz., plantation white sugar, khandsari sugar and gur manufacture.

3.6.6 Planning Research & Action Institute, Lucknow in collaboration with the Institute has done commendable work of execution and popularisation of the result of the researches. The khandsari industry has been really benefitted by the efforts of PRAI, Lucknow, in taking the advantages of researches carried out from time to time in NSI or elsewhere.

3.6.7 One of the important functions of the Institute at Kanpur is to train personnel to man the sugar industry including khandsari industry. Annually about 50 technologists and 20 engineers are trained. It also imparts training to many candidates from the neighbouring countries. The following gives the list of candidates trained from different countries:

1. Afghanistan	4
2. Burma	5
3. Egypt	31
4. Iran	2

5.	Ghana	13
6.	Kenya	5
7.	Malaysia	3
8.	Nepal	12
9.	Philippines	1
10.	South Vietnam	2
11.	Sri Lanka	16
12.	Sudan	28
13.	Tanzania	8
14.	Uganda	20
	Total	150

Upto 1977, 2524 candidates have been trained at the Institute who are holding different positions in the Industry.

3.7 Technical Guidance to Foreign Countries

3.7.1 The technical experts from India have in the recent past been deputed to many countries to help their developing sugar industry, sugarcane cultivation, for working out project reports for expansion, rehabilitation and modernisation of sugar factories, for setting up of new units and to improve the working of existing sugar factories, etc. Indian experts have also been assigned the entire job of development of the area, establishment of new units and they are operating them successfully in foreign countries, namely Malaysia, Tanzania etc. Technical know-how and detailed projects have also been given by Indian experts to foreign countries particularly African countries on khandsari sugar also.

3.8 From the above it may be noted that as far as sugar is concerned, India is a well developed country; and has expert knowledge on different technologies of utilisation of sugarcane for producing different sweetening agents.

4. Different Sweetening Agents from Sugarcane and Technologies of Their Production

4.1 In India, the following sweetening agents are produced from sugarcane :

(i) Gur or Jaggery

(ii) Khandsari sugar

(iii) Plantation white sugar
  (a) Standard Vacuum pan sugar plant
  (b) Mini Vacuum pan sugar plant
(iv) Raw sugar
(v) Refined sugar
(vi) Cube sugar

4.2 Similar sweetening agents can be produced in other countries employing appropriate technology depending upon the circumstances obtainable in that country.

5. Production of Gur

5.1 Gur is solidified clarified cane juice, where there is no production of molasses. It is hard, crystalline and having colour varying from golden yellow to brownish yellow and contains all the nutrients and sweetening substances, as present in cane. The approximate composition of Gur is as under :

1. Sucrose	65-85 %
2. Invert sugar	10-15 %
3. Ash	2-5 %
4. Moisture	3-6%
5. Proteins	0.25 %
6. Insoluble matter	Below 5%

5.2 Juice is extracted from sugarcane by two or three roller vertical or horizontal crushers, which are either bullock driven or power driven. Crushers with 3-5 tonnes daily cane crushing capacity are normally bullock driven or at some places camel driven. But crushers with higher capacity are energised by electric or diesel engine. The juice is strained through coarse cotton cloth and heated in shallow iron pans where it is clarified by vegetable mucilages such as Deola (Hibiscus Ficulenus), Bhindi (Hibiscus esculentus), Sukhlai (Cadia Calycina) etc. In some cases small quantities of lime water, crude sodium carbonate, sodium hydrosulphite (Hydros), soda ash, superphosphate etc. are used with a view to have better clarification of juice and impart greater luster and brilliancy to the Gur, but the effect of such

chemicals has never been lasting. The scum is scooped out and juice is concentrated to the striking temp. (116°C). Some emulson of castor seed is also sprinkled just before obtaining striking point to subside the foam and bubbles. Thereafter it is transferred to a cooling pan where mass is vigorously stirred by means of wooden Khurpi and then semi solid mass is sliced off and made into lumps or moulded in different shapes viz., rectangular or square blocks, round balls, or bucket shapes of desired sizes. The recovery of gur percent cane varies from 8-12 %, depending upon the solid contents in juice which depends on the quality of cane and the period of crushing season.

5.3 The capital investment varies between Rs. 5,000 for small bullock driven kolhus (excluding bullocks, land, etc.) to Rs. 1,00,000 for bigger power driven crushers of 30 tonnes cane crushing per day. The number of persons employed (including 1 or 2 supervisors) vary between 6 to 22 depending upon the quantity of cane being crushed. The conversion charges are about Rs. 22-30 per quintal of gur produced.

6. Production of Khandsari Sugar

6.1 The Khandsari sugar is a finely granulated crystallised sugar manufactured by the open pan system on a cottage industry scale and in the manufacture of which neither vacuum evaporator nor vacuum pan is employed. The same is being manufactured either by the use of vegetable mucilagenous extracts as clarificant or adopting improved modern sulphitation process, practically analogous to vacuum pan sugar factories, for juice clarification. The approximate composition of khandsari sugar, produced by adopting modern sulphitation process is as under:

1. Pol %	99.4-99.9
2. Reducing sugar %	0.10-0.40
3. CaO (mg/100 gm)	45-80
4. SO_2 (ppm)	5-25
5. Colour (400-550 mμ)	0.04 - 0.15
6. Viscosity cp.	20-30
7. Conductivity mhos/cm^2 x 10^6	50-200

8. Turbidity %	40-70
9. Filtrability (F_k)	50-400
10. Shape of crystal	Flattened
11. Moisture %	0.15-0.50

6.2 This sugar compares favourably well with that of crystal sugar produced by vacuum pan sugar factories and at times it becomes difficult to make a distinction visually between the two types of sugar. However, khandsari sugar can be distinguished from vacuum pan sugar by carefully observing the crystals, as the former contains more of fine crystals and the crystals are soft which can be crushed between the thumb and fore-finger. Besides, analysis also shows difference in filterability, conductivity, turbidity and CaO content.

6.3 As regards extraction of juice from sugarcane, mostly power crushers containing 3 or 6 rollers, without hydraulic or hydraulically loaded, are employed which are driven by diesel engine or electric motor. In order to improve further the juice extraction, experiments are being conducted at Kanpur Institute under a scheme financed by All India Khadi & Village Industries Commission on the use of expeller, for extracting juice from cane. The capacity of khandsari units ranges from 5 to 300 tonnes of cane per day. The juice extraction varies between 60-70 % depending upon size, hydraulic loads, power etc. The low capacity units (less than 20 tonnes) employ vegetable mucilages for clarification of cane juice whereas bigger and modern khandsari units employ sulphitation process for clarification.

6.4 The units which clarify juice by employing vegetable mucilagenous extracts, add this extract in heated juice before it starts boiling and the scum rising to the surface is removed on and often by a perforated laddle leaving the juice clear and transparent. On the other hand, the modern khandsari units, adopting single sulphitation process, for clarification, add 1.2 % by volume milk of lime of 15°Be and treat it with SO_2 simultaneously so as to ultimately obtain a pH of 7.0. This results in heavy coagulation of impurities and the juice is heated to 100°C (called cracking point). This

treated mass is settled in settlers and clear juice is decanted. The muddy juice remaining at the bottom of settling tanks is either filtered through bag filters (now out of date) or through filter-presses provided with filter cloth.

6.5 The clear decanted juice and filtered juice available by either of the processes is concentrated in the standard Bel to form Rab (massecuite) whose striking temperature is 108°C. The mass is kept under motion in crystallisers and crystals are separated therefrom by centrifuging. The separated crystals are dried and bagged. The molasses obtained after separation of crystal is often boiled to another rab, cooled and centrifuged to obtain 2nd crop of sugar crystals. These are also dried and bagged. The molasses resulting therefrom is again boiled into 3rd rab, which is cooled and allowed to crystallise for 4-6 weeks and the third sugar thus produced is brown in colour and is generally reprocessed in the next season. In older system, using mucilages clarificants, the total recovery is generally 6 %. In modern khandsari units adopting sulphitation process for clarification, it is possible to obtain a recovery of 7.5% on cane (about 5 % as I sugar, 1.7 % as II sugar and 0.8 % as III sugar). The production of molasses is of the order of 4.5 %.

6.6 The capital investment for khandsari units varies according to the capacity of the plant. The same is of the order of about Rs. 2 million for a 100 tonnes factory and Rs. 3.6 million for a 300 tonnes factory. Khandsari factories have very high employment potential. The project cost and employment potential per tonne of sugar produced per day is Rs. 0.28 million and 26.4 persons respectively in a 100 tonne khandsari unit. The conversion charges per quintal of khandsari sugar is about Rs. 102. Thus, the cost of production of sugar in open pan khandsari units is of the order of Rs. 316/- per quintal.

7. Production of Plantation White Sugar

7.1 The plantation white sugar is defined as sugar in crystal form, manufactured by vacuum pan factories directly from sugarcane and which has a minimum sucrose content of 99.5 % and moisture content less than 0.08 %. The plantation white sugar in India is being produced by adopting either double carbonation and double sulphitation process of clarification or only double sulphitation process. The approximate composition of plantation white sugar is as under :

1.	Polarisation % (min)	99.50
2.	Moisture % (max.)	0.08
3.	Reducing sugar % (max.)	0.10
4.	Sp. conductivity mhos/cm^2x10^6(max.)	100.00
5.	Insoluble matter % (max.)	0.01
6.	SO_2mg/kg(max.)	70.0
7.	Arsenic mg/kg (max.)	1
8.	Copper mg/kg (max)	2
9.	Lead mg/kg (max)	2

7.2 The juice is extracted from cane by a milling tandem comprising of 12-18 rollers, fully hydraulically loaded and driven by steam engines/turbines or electric motors. The undiluted juice extraction is of the order of 78-80 % on cane. The juice so obtained is clarified by either adopting standard De Haans double carbonation & double sulphitation process of clarification or only standard double sulphitation process. In case of double sulphitation process, the juice is subjected to liming and sulphitation upto pH 7.0. The treated juice is allowed to settle in continuous settlers and the clear juice is decanted out. Muddy juice (settled material) is filtered either in vacuum filters or plate and frame type filters with cloth. In case of double carbonation process, the juice is subjected to liming and carbonation - two times and filtered also two times and then sulphited finally to pH 7.0. The clarified juice is concentrated in multiple effect evaporators and finally massecuites are made in vacuum pans. Normally 3 or 4 massecuite system of boiling is adopted and mostly I and II grade sugars are

marketed after proper drying and cooling. The recovery of sugar % cane varies from 8 to 13 depending on the quality of cane, processing, period and efficiency of units.

7.3 At present a vacuum pan sugar factory of 1250 tonnes of cane per day capacity (TCD) expandable to 2000 TCD is considered to be economically viable and all new sugar factories are being set up of this capacity according to the standard specifications for the plant and machinery worked out by National Sugar Institute, Kanpur (NSI). At present the cost of the project for setting up of a new factory of 1250 TCD is about Rs. 60 millions. The project cost and employment potential per tonne of plantation white sugar produced per day is Rs. 0.48 millions and 6.8 persons respectively. The conversion charges per quintal of plantation white sugar is about Rs. 65. Thus, the cost of production of plantation white sugar is of the order of Rs. 215 per quintal.

8. Production of Raw Sugar

8.1 Normally India does not produce or consume raw sugar. However, the same was produced in the country by existing sugar factories for the purposes of export during the years 1962 to 1973, according to the requirements of importing countries. The same normally had following composition :

1. Pol % (min)	97.5-98.5
2. Safety factor (max)	0.3
3. Reducing sugars % (max)	1.0
4. Ash % (sulphated)	0.8
5. Colour IC MSA units (max)	250

8.2 For the production of raw sugar, the plantation white sugar factories, especially the sulphitation factories adopted defecation process with minor modifications for juice clarification. The defecation process involves treatment of cane juice with lime only (neither CO_2 nor SO_2 is required to be used along with lime) for clarification purposes. The defecation process results in inadequate clarification of juice leading to the production of coloured or brown sugar. The rest of the steps during its manufacture are the same

except single curing for raw sugar. The raw sugar produced by this defecation process is of 97.5-98.5 purity and generally had a thin layer of molasses over the crystal. The recovery obtainable from raw sugar in the same vacuum pan factory, which normally produces plantation white sugar, is about 0.2 % more than plantation white sugar.

8.3 The capital investment for producing raw sugar is practically the same as that for plantation white sugar though there is some increase in recovery, saving in chemicals, fuel, capacity in boiling house etc. The same results in reduction in cost of conversion by about Rs. 3.70 per quintal of raw sugar.

9. Production of Refined Sugar

9.1 Refined sugar is produced in India in very limited quantities by two factories at Daurala (U.P.) and Tilaknagar (Maharashtra). The quantities produced by these factories form only a fraction of the total production of sugar produced by them in any year viz. 7-8 % in Daurala and 1.0-1.6 % in Tilaknagar.

9.2 The refined sugar produced in India mostly conforms to the following specifications :

1. Pol % sugar (min.)	99.8
2. Moisture % (max.)	0.05
3. Red. sugar % (max.)	0.03
4. Sp. conductivity (mhos/$cm^2 \times 10^6$) (max.)	15
5. Colour ICUMSA units (max)	50

9.3 As very small quantity of refined sugar is manufactured, so normally plantation white sugar of D or E grain size is melted in hot condensate at 60-70°C. The melt is treated at Tilaknagar with milk of lime and phosphoric acid and filtered in two filter presses in series to obtain water white liquor. However, at Daurala melt is treated with activated carbon and hyflo-supercel and filtered twice to obtain water white liquor. This clear water white liquor is boiled to form refined massecuite, which on purging gives refined sugar. The recovery of refined sugar is 40 to 50 % on melt. The extra cost of conversion of plantation white

sugar is reported to be Rs. 60/- per quintal. This process can only be adopted for producing small quantities of refined sugar in conjunction with units producing plantation white sugar; as more than 50% of the refinery molasses, obtained after separating 40-50% refined sugar, has to be returned to the plantation white sugar or raw sugar process.

9.4 Although the procedures, described above and being adopted by two factories in India for producing refined sugar, are technically simple and need minimum capital investment, yet it is not possible to adopt them for producing large quantities of refined sugar. Moreover, recovery of sugar from refinery molasses poses a serious problem. The cost of production would naturally be high if refined sugar is produced in small quantities in a unit adjunct to the plantation white sugar factories.

9.5 In case, refined sugar has to be produced on large scale it would be necessary to produce raw sugar by the process described earlier. The raw sugar so made have to be melted and treated with phosphoric acid and neutralised by milk of lime. The treated liquor used to be heated to 95°C and aerated and sent to the continuous floatation clarifier where scums float and clear liquor drained off. The clear liquor is again heated with activated carbon and filtered. This is the most modern process for clarification being adopted by refineries. The clear water white liquor is then boiled by adopting 3-massecuite system of boiling and curing schemes whereby 3 grades of refined sugar are obtained and final refined molasses is returned to the raw sugar house, for being used in high grade boiling. The refined sugar so obtained is dried in rotary drier, cooled, graded and suitably packed.

9.6 The capital investment required for a 1250 tonnes cane crushing sugar factory and capable of producing about 16000 tonnes refined sugar annually adopting above process is expected to be about Rs. 75 millions as compared to about Rs. 60 millions for plantation white sugar factory project. The production cost of refined sugar on big scale, as suggested in above para, is expected to be Rs. 291/- per quintal as against about Rs. 211/- for raw sugar.

10. Production of Cube Sugar

10.1 The refined sugar produced at present by Daurala (U.P.) and Tilaknagar (Maharashtra) is already in insignificant quantity. The same is mostly converted into sugar Cubes, which are being either consumed in most sophisticated hotels or for export. A part of the refined sugar is also used for production of syrups for pharmaceuticals or for beverages.

10.2 The cube sugar making is simply moulding of refined sugar, with water under pressure, into suitable size of cubes and thereafter drying them in hot air chambers, and subsequently packing them in suitable wrappers or cartons. The extra cost for producing cube sugar has been estimated to be about Rs.100/- per quintal of sugar cubes over refined sugar.

11. Cost Output and Employment Ratios of Different Technologies :

11.1 In what follows are discussed the cost output ratios and the employment potential for different technologies. In this discussion, the capital, manpower etc. required for production of 1 tonne of sweetening agent from sugar cane is worked out, instead of computing the parameters for 1 tonne of cane crushed. This appeared necessary because of the variations in recovery in different technologies.

12. Plantation White Sugar Manufacture

12.1 Plantation white sugar can be manufactured in big factories or in mini factories. For the former, a 1250 TCD factory is taken as standard as that capacity has been considered to be economically viable. For a mini factory 100 TCD is considered economically viable.

12.2 Standard Vacuum Pan Sugar Technology (Maxi Technology)

12.2.1 The cost of the project for setting up of a new vacuum pan sugar factory of 1250 TCD is about Rs. 60 millions.

12.2.2 A 1250 TCD factory produces about 125 tonnes of sugar per day, on the assumption that the recovery is 10 percent. Assuming that cane price paid is Rs. 150/- per tonne (including purchase tax, transportation charges etc.)

the cost of production of sugar in a 1250 TCD factory is Rs. 215/- per quintal, the break up being -

a) Cost of cane per quintal of sugar Rs. 150/-
b) Conversion charges per quintal of sugar Rs. 65/-

12.2.3 On the average, 850 persons (both permanent and seasonal) are employed in a 1250 TCD factory. Attempts are being made for reducing the number through standardisation, modernisation and automation. The success in this direction has been very minimal till today. Most of the employees in sugar factories are paid wages according to the recommendations of the Sugar Industry Wage-Board.

12.2.4 The employment potential and capital investment required for a standard vacuum pan factory are as follows :

i) Project cost per tonne of sugar produced/day Rs.0.48 millions
ii) Employment potential per tonne of sugar produced/day 6.8 persons
iii) Capital investment per unit employment Rs.71,000

12.3 Mini Vacuum Plant Technology (Mini Technology)

12.3.1 The National Sugar Institute, Kanpur had a mini vacuum pan factory of 34 TCD when the Institute was located in the down-town and occupied the premises of the H.B.T.I., Nawabganj, Kanpur. The 34 tonne factory was reported to have been set up in 1930's by purchasing an old plant from Indonesia. It was meant for imparting practical training for the sugar technology and sugar engineering students. The plant and machinery deteriorated with time. When the Government of India took a decision to shift the Institute to its own new building at Kalyanpur, Kanpur it was decided to discard the old 34 tonne plant and to instal a 100 tonne mini vacuum pan sugar factory. The 100 tonne mini factory had its trial season last year. All the details of the specifications of the plant and machinery are available. The machinery was fabricated by reputed indigenous sugar machinery manufacturers. The technological operations in

the mini vacuum pan factory are exactly the same as in a standard 1250 TCD or more capacity vacuum pan factories. The operational efficiencies such as milling extraction, boiling house extraction, etc. are also the same. The unknown losses are however, more because the losses due to inversion, spillage, etc., which constitute the unknown losses would become indicated as more on per tonne cane crushed basis.

12.3.2 The project cost of a mini factory of 100 tonnes capacity is estimated to be Rs. 8 million on the basis of prices of the machinery prevailing at present.

12.3.3 For reasons explained earlier, the recovery per cent cane in a mini vacuum pan factory is slightly lower than in a standard factory and would be about 9.5 per cent. The 100 tonne mini factory produces about 9.5 tonnes of sugar per day. The cost of production of sugar in a mini factory is about Rs. 258/- per quintal of sugar, the break-up being -

a) Cost of cane per quintal of sugar	Rs. 158/-
b) Conversion charges per quintal of sugar	Rs. 100/-

12.3.4 In computing these figures, it is assumed that wages to the workers are on the same basis as in a standard capacity factory. About 350 persons will be required for a 100 tonnes plant.

12.3.5 The project cost and the employment potential in a mini vacuum pan factory are given below :

i) Project cost per tonne of sugar produced per day	Rs. 0.84 millions
ii) Employment potential per tonne of sugar produced per day	36.8 persons
iii) Capital investment per unit employment	Rs. 23,000

13. Khandsari Sugar Plant Technology

13.1 In areas where adequate amount of cane was not available to sustain a standard 1250 TCD factory, Khandsari units were being set up. State Governments had been issuing licences for the same. It is reported that more than 8000 Khandsari units are operating in the country, and produce annually 0.6 to 1.2 million tonnes of Khandsari sugar.

13.2 The capacity of Khandsari units ranges from 5 tonnes to 300 tonnes of cane per day. The low capacity (less than 20 tonnes) employ vegetable mucilages such as deola, bhindi, etc. for clarification of cane juice. 'Bigger' and modern Khandsari units employ sulphitation process for clarification, the process being roughly similar to the one adopted in a standard or mini vacuum pan factories.

13.3 The project cost for a Khandsari factory of 100 TCD is about Rs. 2 million.

13.4 The average recovery in Khandsari is about 7.0 percent. A 100 tonne factory produces about 7 tonnes of sugar. The Khandsari factories produce different grades of sugar, commonly known as first grade (5.0%), second grade (1.2%) and third grade (0.8%). The third grade sugar which is brown in colour is not generally sold in the market and is reprocessed in subsequent seasons. First and second grade sugars are sold in the market which is about 6.2 % only.

13.5 The cost of production of sugar in a Khandsari unit is about Rs. 316/- per quintal, details being -

a) Cost of cane per quintal of sugar	Rs. 214
b) Conversion charges per quintal of sugar	Rs. 102

Here it is assumed that the price paid for the sugarcane is the same, being Rs. 15/- per quintal as in the standard and mini sugar factories. A 100 tonne khandsari factory employs 185 persons. Wages paid to the employees are, however, not governed by any Wage Board.

13.6 Inspite of the high cost of sugar production about Rs. 316 per quintal (as compared with Rs. 215/- per quintal in a standard vacuum pan factory), the Khandsari factories operate successfully because of the following :

(i) Low excise duty : Khandsari units pay excise duty at the rate of 17.5 % on actual sale price or on the compounded basis taking into account the size and number of centrifugal machines employed.

(ii) Entire sugar sold in free market : While the vacuum pan factories are governed by sugar Policy of 65 % levy, and 35% free, Khandsari units sell their entire produce in the free market.

(iii) Higher realisations due to sale of molasses : Vacuum pan factories sell their molasses at a controlled rate of Rs. 60/- per tonne while Khandsari units sell their molasses at much higher prices.

13.7 The employment potential and capital investment required for a 100 tonne Khandsari unit, are as follows :

a) Project cost per tonne of sugar produced per day	Rs. 0.285 million
b) Employment potential per tonne of sugar produced/day	26.4 persons
c) Capital investment per unit employment	Rs. 11,000

14. Gur Technology

14.1 As mentioned earlier, the capital investment for Gur plant is according to its production capacity and the equipment employed. The capacity varies generally from 5 quintals to 30 quintals of Gur per day.

14.2 The employment potential, capital investment and cost of production are as follows :

Technology	Production of Gur per day (Tonnes)	Total project cost (Rs.)	Project cost per tonne of Gur (Rs.)
1	2	3	4
(a) Bullock driven kolhus/crusher	0.5	5000	10,000
(b) Diesel/motor driven vertical kolhus/ crushers	1.5	12000	8,000
(c) Power driven crushers	3.0	100000	33,334

Employment potential per tonne of Gur produced per day	Cost of production per qtl. of Gur (Rs.)	No. of persons employed	Capital investment per unit employment
5	6	7	8
(a) 12	130	6	833
(b) 6.7	132	10	1200
(c) 7.3	124	22	4545

14.4 The cost of production of Gur per quintal in above cases varies as follows :

	Cost of cane (Rs.)	Conversion charges (Rs.)	Total (Rs.)
(a) Bullock driven kolhus	101.50	28.50	130.00
(b) Diesel/motor driven vertical kolhus	101.50	30.50	132.00
(c) Power driven kolhus	101.50	22.50	124.00

15. A comparative statement of the cost output ratio of various technologies is given below :

Table - 6

Statement Showing the Comparative Figures for Different Technologies

Sl. No.	Particulars	Unit	Vacuum pan white sugar	Khandsari open pan sugar	Mini Plant (Vac. Pan)	GUR		
						Bullock driven	Diesel driven	Power driven
1	2	3	4	5	6	7	8	9
1.	Cane crushing capacity per day	(Tonnes)	1250	100	100	5.0	15	30
2.	Recovery % cane	-	10%	7%	9.5%	10%	10%	10%
3.	Production per day	(Tonnes)	125	7.0	9.5	0.5	1.5	3.0
4.	Total capital investment (Project cost)	(Rs. in millions)	60	2	8.0	0.005	0.012	0.100
5.	Cost of production per quintal	(Rs.)	215	316	258	130	132	124
	(i) Cost of cane	(Rs.)	150	214	158	101.50	101.50	101.50
	(ii) Conversion cost	(Rs.)	65	102	100	28.50	30.50	22.50
6.	Employment potential per tonne production per day	(Persons)	6.8	26.4	36.8	12	6.7	7.3
7.	Capital investment per unit employment	(Rs.)	71000	11000	23000	833	1200	4545
8.	Project cost per tonne of production per day	(Rs. in millions)	0.480	0.285	0.840	0.010	0.008	0.033
9.	Total No. of persons employed	(persons)	850	185	350	6	10	22

16. Choice of Appropriate Technology

16.1 In the foregoing paragraphs have been described various technologies for production of sweetening agents, such as; gur or jaggery, khandsari sugar, plantation white sugar, raw sugar and refined sugar. These sweetening agents can be produced by employing appropriate technology depending upon the requirement and circumstances obtainable in any country.

16.2 The technology to be chosen depends primarily on the availability of cane and the demand of the quality of the product in the country. The selection of a technology also depends upon the investment capability, Government policies in respect of excise duty and various taxes. A detailed study of the conditions existing in a country or in a place is a must before one technology or the other is chosen. In what follows are given broad outlines of the conditions governing the adoption of each of the above technologies.

16.3 Gur Technology : The technology of gur manufacture could only be adopted where the production of sugarcane is in small quantities. Large scale production is not feasible as the same involves manual operations. Further, gur has low keeping quality and is highly hygroscopic. It absorbs moisture and becomes soft. The sale value decreases considerably. The production on large scale has not been found feasible. The technology of manufacture of gur involves considerable amount of wastage of sugar present in cane. It should, therefore, be adopted on a limited scale, preferably by farmers for their own domestic consumption.

16.4 Khandsari Sugar Technology : This technology is adopted in India in areas where cane is available in limited quantities and where big size sugar factories could not be set up. Although white crystalline sugar (khandsari sugar) could be produced by adopting modern sulphitation open pan technology but this technology is very much inferior because of the following :

(1) low recovery (6-7%);

(2) inferior quality of sugar in respect of colour and grain size;

(3) involves mannual operations which set up limitation to the size of factories and hence high cost of production;

(4) Wastage of national energy wealth of sugar.

16.5 This technology (Khandsar sugar technology) is adopted under unavoidable circumstances in India, in place where big size factories cannot be set up due to shortage of either raw material or finance. Although the cost of production is high and the quality of sugar is inferior, the Khandsari units survive because of the Government of India's policy of giving excise rebate. The units have to exist and operate because of the force of circumstances. India produces 140 to 150 million tonnes of sugarcane. The total quantity of cane cannot be crushed or utilised in vacuum pan sugar factories now existing in the country which employ superior technology as pointed out earlier. The number of vacuum pan sugar factories is about 300 and their crushing capacity is hardly 60-65 million tonnes of cane. The rest of the cane produced in the country viz., 80-85 million tonnes has to be utilised. It is not possible to set up immediately or within a reasonable period of 10-20 years enough number of vacuum pan factories to consume another 65-70 million tonnes of cane as the same would take time. Till that time the inferior technologies such as Khandsari (and gur) have to exist and have to be supported by concessions, such as excise rebate etc. Semilar circumstances of large excesses of cane may not exist in other countries. Where cane is limited even then the inferior technology of Khandsari should not be adopted and mini vacuum pan technology be preferred. Where cane is a scarce commodity, technologies which give maximum extraction of sugar or recovery of sugar should be adopted, even if the capital requirements for the latter are comparatively more. As pointed out above, the Khandsari technology should be chosen carefully with full appreciation of all the facts relating to the same as indicated above viz., low quality product, high cost of production and above all, wastage of sugar content in cane. Under normal conditions, this technology should not be preferred.

16.6 Plantation white vacuum pan sugar technology: The technology for manufacture of plantation white vacuum pan sugar is the cheapest and most efficient one. The quality of sugar is much superior to open pan khandsari and can very well be compared with the refined sugar. The sugar has appreciable market acceptability. It has good storage properties. The technology involves minimum manual operations. Capacity of any size can be had. Factories of 100-300 tonnes capacity can be set up. Large factories of 2000-10000 tonnes also can be set up. The technological operational ease is maximum. The low capacity factories can also be expanded to higher capacities with the progressive development of cane. In India, during 1930's and 1940's, many mini factories of 100-300 tonnes capacity operated. These in course of time expanded. Some even expanded to the capacity of 6000 tonnes of cane per day. A few factories are attempting to expand even upto 10,000 tonnes. The cost of production is the lowest amongst all technologies. Even in vacuum pan technology, the cost of production varies with size of the factory. Low capacity units have high cost of production; high capacity units have lower cost of production. Because of these, the vacuum pan technology is the most suitable. Even in developing countries the adoption of vacuum pan sugar technology should be encouraged, for, the quality of the product is good and has market acceptability and has the maximum efficiency in extraction or gives maximum recovery. It however, requires comparatively higher capital investment. If one has to extract more sugar and of better quality, capital input requirement will be naturally high. Nothing comes out of nothing in science or technology. The authors strongly advocate the adoption of vacuum pan technology for production of sugar in either developed, undeveloped or developing countries. The size of the factory to be chosen under this technology as pointed out earlier could range from 100 to 10000 tonnes or more depending upon the availability of

resources, viz., raw material and finance.

16.7 Raw Sugar Technology : This technology is the simplest but could only be adopted if there are plans to set up the refineries for production of refined sugar. The raw sugar is not acceptable for direct consumption due to high colour content and poor keeping quality. The storage difficulties also go against this technology.

16.8 Refined Sugar Manufacture: The technology for manufacture of refined sugar is the costliest and could only be adopted for purposes of sophistication.

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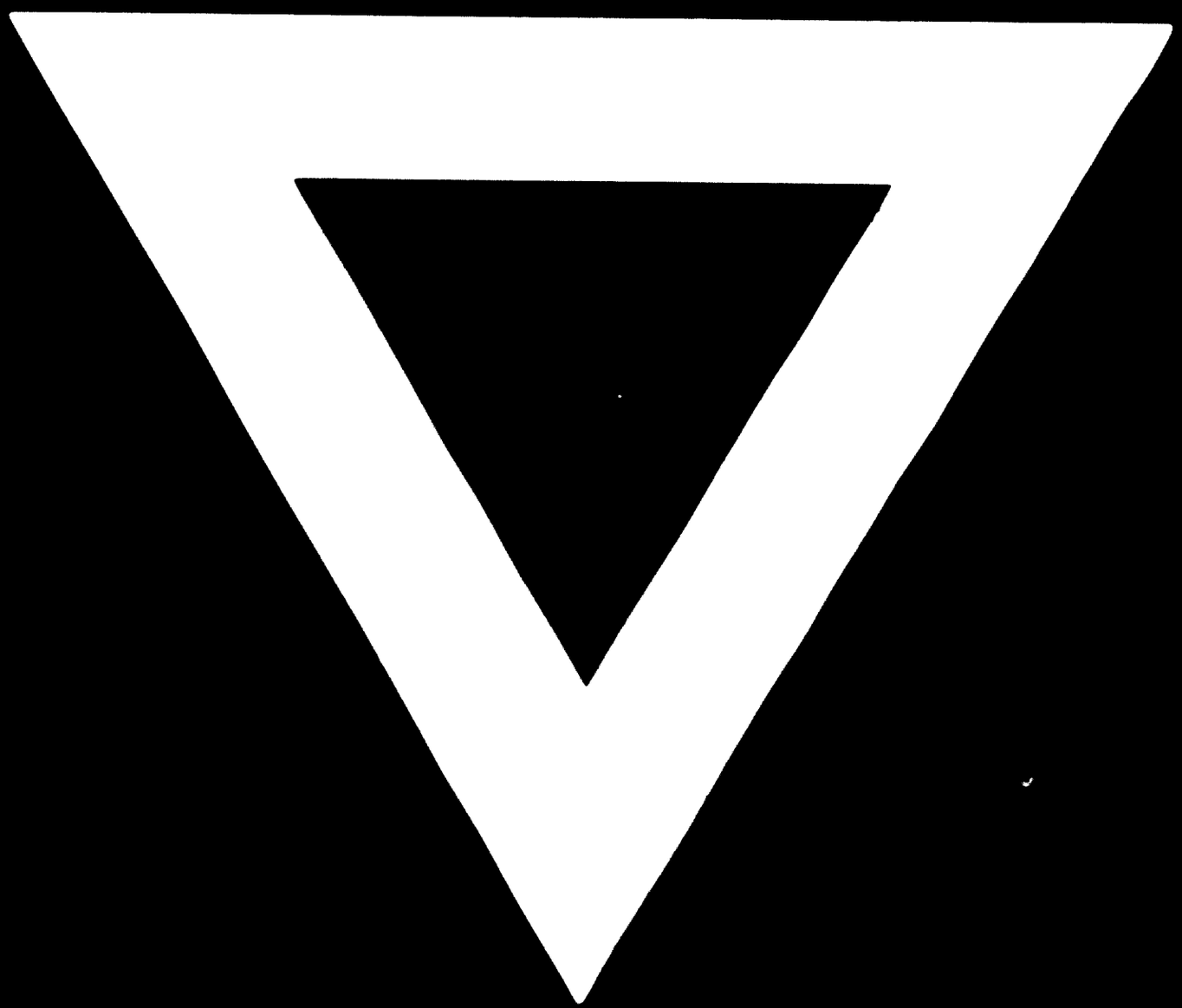

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