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ENVIRONMENTAL IMPLICATIONS OF DIFFERENT SUGAR TECHNOLOGIES WITH SPECIAL REFERENCE TO INDIA[1/]

by

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INTRODUCTION

An analysis of the environmental implications of different sugar technologies, when the term environment is broadly defined to cover economic, physical and social aspects, transcends mere monetary cost evaluation. The analysis is necessarily interdisciplinary. Apart from the availability of natural conditions such as favourable climate, fertile soil, drainage facilities, and technological possibilities by way of improved crushers, effective clarificants and convenient mechanical devices for performing different operations, other factors such as social motivation, proximity to rural conglomerations, and risks and uncertainties of such employment opportunities demand attention. As the sugar industry grows in size, these factors gradually gain importance and technology choice becomes difficult. During the last 75 years in which India emerged as a major sugar producing country, it passed through many vicissitudes and the journey is not yet over. Her experience shows the various complexities of the problem on whose solution an effective path for the future course of the industry's development could be evolved. With this aim in view, the first chapter of this paper gives a brief introduction to the status of sugar industry in India; the second chapter deals with technological constraints existing outside the factory gate as well as inside it; and the third chapter is concerned with socio-economic aspects of the subject. Basic data relevant to the study are given in appendices.

I. STATUS OF THE INDUSTRY IN INDIA

The sugar industry is the second largest commodity producing industry in India, next only to the cotton industry. Among the leading sugar producing countries of the world, India with an annual production of 4.5 to 5 million tonnes occupies the fourth place, the other three being Brazil (6.5 million tonnes), the United States (5.9 million tonnes) and Cuba (5.5 million tonnes). In 1975-76, 142.7 million tonnes of sugarcane were grown on 2.79 million hectares of land which enabled the country to produce 12.87 million tonnes of sweetening agents, of which 4.26 million tonnes were white crystal sugar and 8.61 millions tonnes gur (jaggery) and khandsari (raw sugar). 25 million cane growers and their families depended on cane cultivation, over 260,000 were directly employed in sugar mills and many more were dependent on the industry indirectly for their livelihood. Employment in gur and khandsari units is difficult to estimate. The units receiving assistance from Khadi and Village Industries Commission and producing Rs.354.61 million worth of gur and khandsari themselves provided part-time employment to 110,746 persons in 1974-75. The sugar industry is one of the largest pay masters; Rs.7000 million are paid annually as cane prices; the aggregate salaries, wages and other benefits amounted to Rs.1,050 million per year. Annual production of sugar is of the order of Rs.10,500 million. The sugar industry by way of excise duty etc. contributed more than Rs.2750 million every year to the State and Central Exchequer. During 1975-76, India exported 1.20 million tonnes of sugar earning Rs.4750 million in foreign exchange. Sugar industry has contributed in many ways to the agro-industrial development of the country.

Sugar manufacture is characteristically a rural enterprise; sugar manufacture must be carried out within 45-50 kms of sugarcane cultivation. Etymologically, the word "khandsari", which has now received international currency, is derived from 'khandsala' which primarily refer to a place rather than to a process or an output. It has been in use since ancient times, but the vacuum pan sugar technology introduced since 1903 in India has changed the sugar map in the country. The first factory set up at Mairwa, a small village in North Bihar even today maintains its rural features but in 1975-76, there were 260 white crystal sugar factories, of which 141 were joint stock units, 104 cooperative units and 15 units established in public sector. In addition to these units, 98 factories are under erection of which 81 would be in cooperative sector, 16 in public sector and one is a joint stock unit. All these are rural based. But more than 7,000 khandsari units are reported to be operating in different parts of the country at different levels of technologies and their details are not yet available. It is estimated that in 1975-76, these units processed more than double the sugarcane crushed by vacuum-pan factories.

Statewise distribution of sugar factories is given in Appendix I. More than 92.24 per cent of sugarcane produced in India came from nine states, namely, Uttar Pradesh (40.79%), Maharashtra (13.43%), Haryana (4.81%), Tamil Nadu (10.36%), Andhra Pradesh (6.60%), Bihar (3.43%), Karnataka (6.98%), Punjab (4.33%) and Madhya Pradesh (1.49%). 91 per cent of sugar factories were located in these 9 states which produced 95 per cent of sugar and 91 per cent of khandsari. Uttar Pradesh and Maharashtra situated in the tropical region taken together accounted for 54.22 per cent of sugarcane production and 65.03 per cent of vacuum pan sugar but only 47.96 per cent of khandsari and gur. Tamil Nadu located in the sub-tropical region produced 10.36 per cent

of sugarcane, manufactured 4.15 per ent of vacuum pan sugar but 14.51 per cent of total khandsari production.

The first large-scale sugar factory in India was established in 1903, but effective progress occurred only after 1932 when the industry received tariff protection. Expectation of earning cash from the crop during a period of general economic depression induced many farmers to switch over to sugarcane cultivation. In 1931-32, only 32 sugar factories existed in India which produced less than 0.16 million tonnes of sugar; Uttar Pradesh and Bihar manufactured three-fourths of the total. Soon after protection, the number of factories began to increase, and production of sugar swelled. In 1932-33, the number of factories rose to 56 which in the following year doubled; 111 factories operated in 1933-34; and production of sugar amounted to 0.29 million tonnes in 1932-33, and 0.46 million tonnes in 1933-34. But, as it would be seen from the following table, it became apparent that there was basic instability in sugar industry with regard to productivity of cane cultivation as well as the duration of the crushing season, which was ultimately reflected in disturbed rate of annual production.

Table I

Year	Area under cane cultivation (000 hectares)	yield of cane per hectare (tonnes)	production of sugarcane (000 tonnes)	Average Duration (days)	Total sugar produced (000 tonnes)
1932-33	1,386	37.5	51,950	138	295
1933-34	1,385	38.5	53,297	103	461
1934-35	1,458	37.9	55,218	104	578
1935-36	1,681	37.0	62,185	126	934
1936-37	1,870	36.6	68,401	138	1,128
1937-38	1,636	34.6	55,533	113	946
1938-39	1,328	32.9	43,792	93	661
1939-40	1,265	31.8	40,145	129	1,242

Source: Indian Sugar Mills Association, New Delhi

The need for providing institutional support soon became manifest. The setting up of the Indian Institute of Sugar Technology at Kanpur, and the Indian Central Sugarcane Committee fulfilled urgent requirements of the industry. The former carried out research on scientific and technological aspects of sugar manufacture, while the latter financed and guided sugarcane works. Establishment of a network of sugar cane research stations throughout the country encouraged cultivation of improved varieties of cane; the sugarcane Committee was assisted in its work by the funds raised in the shape of cane cess, excise duty etc. The Development Council for the Sugar Industry set up in 1956 under the Industries (Development and Regulation) Act, 1951 recommended targets of production, coordinated production programme, worked for improvement of quality and reduction in production costs. To protect the interest of sugarcane cultivators, the Government stipulated statutory minimum cane prices to be paid by the sugar mills; the Government also sanctioned reservation of areas of sugarcane cultivation for sugar mills in different areas in order to ensure regularity of cane supply to them. While formulating the industrial development programmes for the country, provisions were made to make available sugar machinery either by imports or indigenous manufacture. Two consortia consisting of three manufacturers each were also formed in 1953 for this purpose. The consortia were able to accept orders for the fabrication of 4 sugar plants each of a daily crushing capacity of 1,000 tonnes of sugarcane for delivery during 1961-62, and 8 such plants during 1961-62. The consortia developed capacity to fabricate from 1961-62 onwards 12 complete plants per year and equipment for replacement and expansion equivalent to 9 plants. In 1973-74, sugar machinery worth Rs.223 million were manufactured indigenously; in 1978-79 Rs.400 million worth of such

machinery have been planned. The country is self-sufficient in regard to the machinery requirements for the industry.

Apart from governmental efforts to institutionalize the support lent to sugar development through the Development Council for sugar industry, and the Directorate of Sugar, non-governmental agencies have also originated. The Indian Sugar Mills Association, the National Federation of Cooperative Sugar Factories and a large number regional producers' associations have presently been working for it. Cane-growers' association have also been established at different levels. The formation of sugar cooperatives - there are 104 cooperative units out of total 260 sugar mills - has been important for coordinating and securing various support programmes initiated. The special characteristics of sugar industry which link farmers, plant pathologists, financial institutions, transport agencies and cane processing units have induced the varied interested parties to come together to secure the best results. Presently, the sugar industry has organized a powerful vocal interest in the country. Wherever efficient cooperatives have been organised, there the growth and extension of the industry have been marked.

Well organized institutional support has been absent in regard to khandsari and jaggery units. An All-India Improved Khandsari Sugar Manufacturers' Association exists in Moradabad, U.P., but it has not been very effective in rendering much assistance. A research group has been established under National Sugar Institute, Kanpur to look after the needs of khandsari industry. The Khadi and Village Industries Commission, Bombay has been entrusted by the Ministry of Industrial Development to attend to the needs of gur and khandsari manufacturers. Among others, the improvement in technology, supply of machinery, popularisation of improved methods of production with a view to raising the levels of productivity and earnings of

the workers, and institutionalization of various activities, formed the main features of the developmental activities of the Khadi and Village Industries Commission in this regard. The Commission, in 1974-75, disbursed Rs.2.04 million by way of financial assistance - Rs.0.24 million as grants and Rs.1.80 million as loans - to khandsari units; the distribution of improved crushers rose from 291 in 1973-74 to 649 in 1974-75, the supply of power driven and bullock driven crushers increased from 9 and 282 respectively in 1973-74 to 29 and 620 in 1974-75.

The average size of the factory increased from 481 tonnes of cane per day in 1932-33 to 778 tonnes in 1939-40, then remained almost stationery till 1947-48 when it amounted to 815 tpd; in 1974-75 it rose to 1534 tpd. In early 1950s, the size of sugar mills varied from 50tpd to over 2,000 tpd of cane crushing capacity though a minimum capacity of 800 tpd was considered economic. Half the factories operating at that time were uneconomical. The number of sugar mills did not increase much during the first plan period (1951-56) but the working efficiency of these mills improved and the scales of their operation widened from 220 tpd to 3,200 tpd and less than 31 factories worked below the uneconomic level of 800 tpd. Presently, the average per day crushing capacity of sugar mills is estimated to be 1250 tpd (while that of jaggery units is 20 tpd, and khandsari units using hydraulic pressure it is 40-50 tpd). Appendix III gives details of various indicators of the development of sugar industry in India.

II. PRODUCTION CONSTRAINTS

A. Problems of Sugarcane Cultivation

Three main forms of sweetening agents, namely gur (jaggery), khandsari (brown sugar) and white crystal sugar are derived from sugarcane. Sugar entered world consumption as a major carbohydrate energy producing food only in the 19th century, while gur and khandsari have a much older tradition. Technically, gur is merely concentrated sugar juice; in appearance, it is a lumpy brown substance containing, apart from sucrose, other nutritive materials as well. In many parts of India, it is a staple element of human and livestock diet; gur price being almost half that of sugar, it is a poorman's energy food. Three-fourths of it are used for purposes other than as a sweetener.

Khandsari is a powdery, yellowish product; cane juice is never fully expelled from it. The crystals are very fine and its taste is distinctly different from that of white crystal sugar. It is an intermediate product between gur and white crystal sugar produced under vacuum pan system.

The basic industrial input for sugar industry is sugarcane whose cultivation presents special problems. Sugarcane stalks being 3 - 6 metres high, and 2 - 7 cms in diameter require rich, and moist alluvium to sustain them and sunny skies to provide right maturity to juice. Uniform high temperature, strong sunlight and frequent shower during the growing season are necessary. Impoverishment of soil following each harvest has to be counteracted by liberal application of adequate doses of right kind of fertilisers. The cultivation of sugarcane is restricted by the geological condition of land, and climatic conditions of the region. Sugarcane cultivation is primarily carried in tropical climes. Irrigation facilities are desirable and fertilisation essential to sustain productivity; the plot of land should

be sufficiently big to produce an adequate quantity of cane to make it marketable to the sugar-making units. The dependence of cultivators on sugar producers is acute. In order to make sugarcane cultivation purposeful, the cultivation should be on large plots of land and the farmers should have adequate financial support and dependable demand for the crop. The formation of cane growers' association arises from these compulsions.

The land on which sugarcane is cultivated could successfully grow rice, wheat, cotton, maize and millets. Farmers cultivating sugarcane have many alternatives amongst which they have to make their decision. Some of the factors influencing them are purely economic, whilst others are technological. As the farmers are primarily concerned with economic returns their decisions are greatly affected by the procurement prices of rice and wheat, anticipated market prices of other alternative crops that could be grown on the same plot of land, as well as by the statutory minimum cane price that they are likely to obtain. Cane cultivation is capital as well as labour intensive, as such the average cultivators with small holdings and limited resources are not enthusiastic about it. Transportation of cane from the field to the factory needs special arrangements. This is specially so when the adjoining fields are sown with different crops. Furthermore, the cultivators of sugarcane are tied to this kind of cultivation for several years once they decided to cultivate this crop. Agriculturists engaged in cultivating crops like rice, wheat, maize and such other crops could shift from one crop to another easily after every crop-season, but in sugarcane this possibility is almost denied.

The special cultivation method known as "Ratoon Cropping" which is a specialty of sugarcane cultivation, primarily consists of not harvesting

the sugarcane stalks completely, but cutting them from a height of half-metre or so, so that from the "eye" of the cane left in the field fresh sprouts could grow in due season. This crop matures early thus providing early cane to sugar mills for crushing and enabling them to extend the duration of their crushing operation. The yield from Ratooon Cropping is lower than the normal yield, but there is a saving on the earlier stages of cultivation operations, such as, preparation of land, sowing etc. In some countries, as many as 5 to 6 crops are harvested from Ratoons, but in India, only one or two crops are grown. How to increase the yield from the Ratoons and the number of harvests from them is a problem on which the research institutions are presently working.

Exclusive dependence of sugarcane cultivators on millowners for the purchase of their sugarcane has introduced much uncertainty among them. In order to discourage the cane cultivators from diverting the land to other competing crops, cane cultivation must be made remunerative. High yielding varieties of wheat have considerably diminished the attractiveness of sugarcane cultivation. Shrinkage in acreage under sugarcane can be checked by evolving farming technology which could counteract the attractions exerted by other crops. The researches done at the Sugar Research Institute, Kanpur and at other research installations have been significant in raising the status of cane cultivation. A technique of growing sugarcane along with wheat or pulses known as "companion cropping" has been developed. This kind of intercropping arises from the fact that the sugarcane cultivation has a period of about three-four months during which period the land is exposed almost fully to sunshine and the cane sprouts have not covered the total area. Sugarcane takes six to eight weeks to germinate and a further period of four to six weeks of tillering after which begins the early period of

growth when the vigorous growth begins and sheds the ground completely. During this intervening period of 3 - 4 months peas, mustard, onion, potatoes, gram, legumes, vegetables, groundnuts and even sugar beets could be tried. Improved varieties of wheat and pulses have also been tried in some cases. Field experiments have shown that intercropping have even improved the quality of juice, though there has been marginal deleterious effect on the cane yield. Data from intercropping of sugarcane and maize rather than cultivating sugarcane alone showed that the net profit of the farmer increased by 35 percent(1).[1/] Intercropping or "companion cropping" could be advantageous to the cultivators but such interplanting retards the growth of sugarcane of the early maturing variety which reduces the length of the crushing season.

Sugarcane cultivation is a labour-intensive operation. From a survey made in Surat District of Gujarat, it was concluded that a total 202 man-days were needed for sugarcane cultivation against 199 mandays for banana growing, 99 mandays for paddy cultivation and 38 days for wheat. Among the various agricultural operations, harvesting and threshing were the most labour-consuming operations; they needed 105 mandays while ploughing, planting, weeding, irrigation, fertilization and other activities required only 97 mandays for cultivating sugarcane on one acre of land(2). The limitations due to labour availability is much greater outside the factory premises than inside it. One estimate (2) showed that the employment created on farms was over five times the additional employment generated within the factory from a given increase in the production capacity of the plant. This impinges on the social repercussions of setting up of large-scale sugar mills.

1/ Numbers in parentheses refer to the corresponding numbers on the reference list at the end of the paper.

Extensive sugar cultivation leading to organised labour employment in a capital intensive agriculture operation leads to a rise in their wage-rates; the cost of sugarcane cultivation rises to a higher level; farmers growing substitute crops on alternative plots of land also face increased costs for their cultivation; and mechanisation of agricultural operation becomes inevitable. The increasing scale of sugar manufacture is generally accompanied by some kind of inflationary spiral and discontentment among the rural population. Sugarcane cultivation demands the entire rural community to be engaged in the same kind of rural activity.

Dependence of sugar manufacture on an agricultural crop which cannot be stored for a long period for subsequent processing creates many disturbing situations: it creates instability in the crushing season and fluctuations in the level of sugar production; excessive strain on local transportation and locational constraint on sugar factories are imposed; and the emergence of different sugar technologies with conflicting interests also occurs. Generally speaking, all these years India faced a cyclic variation of two years of rising trend in cane production followed by two years of decline. This is reflected in the changing levels of sugarcane production over a number of years. In order to prolong the cane-crushing season, the availability of sugarcane at the factory-gate should be staggerred but this involves judicious combination of early, mid-late and late varieties of cane for planting.

Experiments carried out at some factories in South India have shown the possibility of prolonging the crushing season to about ten months; such cultivation capability however depends on the agro-climatic conditions of different regions which cannot be universalised. The National Sugar

Institute Kanpur has evolved a scheme under which the entire plot of land is not harvested at the one time; under its Pre-Harvest Maturity Scheme, the method of preparation of harvesting schedule is altered and only the cane at peak maturity is harvested. As a result of this device, the growers benefit by higher yield, the millers by higher recovery to the extent of 0.5 to 1.3 per cent of cane and there is staggerred supply of sugarcane. In a tropical region, it is possible to maintain regularity of cane supply from mid-October to mid-April, but under this method of cultivation inter-cropping becomes very important: three-times the area harvested in any year is needed to maintain a regular pattern of production. Further description is given in Appendix VI. The advantage of stretching the cane supply over such a longer period under this system is however counteracted by the proportionately large area of land needed under cultivation for the purpose.

Strain on transportation arises from the fact that the loading of canes is done on carts and trucks in agricultural fields. Railways have also been mobilised for this purpose but mainly by factories which are very big with their own reserved areas of cultivation through which they themselves have laid the railway track. Such tracks are very limited. Even where the Indian Railways serve, transportation from field to the rail head and again from railway station to the factory has to be arranged for. All these arrangements require to be completed in such a way that the cane is available for crushing within 48 hours of harvesting otherwise its quality greatly deteriorates. Carriage of cane is largely done either by bullock carts or by trucks. At the factory gate the cane has to be weighed, arrangements made for payments and facilities provided for waiting vehicles, Overcrowding is natural at these gates which besides causing delays and increasing the drying of the cane, necessitates that the sugar mills have large open areas around them

so that the movement of carts and trucks could be regulated. Scientific lay-out and rationalization of operations have to be extended even outside the factory gate.

B. Production Differences Inside the Factory Gate

Gur (jaggery) whose sucrose content is between 56 and 59 per cent and which contains 8 per cent to 20 per cent of inverted sugar when compared with crystal sugar containing 99 per cent to 100 per cent of glucose, makes gur preparation appear an inferior industry though at present it processes more than half the sugarcane produced in the country. It is based on the open pan boiling process. Juice is extracted by passing the cane through two or more vertical rollers of wood, stone, or steel geared to a long-lever and sweep-turned by hand or animal. Electrical power is also used for this purpose. The juice is subsequently boiled in an open pan upto a certain amount of thickness which when cooled and solidified produces gur.

The traditional process of gur making does not extract more than 55 per cent juice from the cane; heavy inversion loss occurs even during boiling. The quality of the product is not standardized. The introduction of power crushers has significantly improved the productivity of gur making units: a traditional bullock-driven crusher engaging 2 persons and 2 bullocks crushed 7.5 quintals of sugarcane a day, whilst improved crushers with the same number of men and animals crushed 10 quintals. Introduction of power for rotating the crushers greatly increased the crushing capacity of 'kolhus' or the crushers but this radically altered the environmental structure of such production units as well.

Improvements made in the gur-making process yielded 80-85 per cent of juice extraction and raised recovery ratio to 15-16 per cent against 10-11 per cent in the conventional open-pan boiling. Even the inversion loss is considerably reduced as a result of which gur gave higher recovery ratio than refining. Adoption of such improvements has however remained at the laboratory stage because the survival of gur industry much depended on the simplicity of the processes. By incorporating sophistications, the simplicity criterion of the industry is lost, which renders it less popular.

The khandsari industry in India utilized about 7-8 per cent of sugar-cane produced in the country; using hydraulic rollers, the units could crush upto 50 tonnes of cane a day; it needed Rs.0.6 million as fixed capital investment and Rs.0.1 million as working capital; the average sugar recovery ratio was 7 per cent though with improvements it could go 9.7 per cent; the inversion loss in khandsari process may be as high as 30 per cent against only 10 per cent in vacuum pan system; and the average operating cost has been estimated at Rs.210 per tonne. The khandsari manufacture is primarily based on open-pan system (OPS) though a firm in Mysore has set up a plant with a cane crushing capacity of 200 tonnes a day using the vacuum pan process. Such innovations have not so far found much acceptance. The following stages in the production process of khandsari are common: (a) milling of cane for extraction of juice, (b) clarification of cane juice, (c) preparation of rab or the massecuites, (d) crystallization, (e) centrifuging and (f) drying.

During the last two decades, khandsari technology has much improved. The earlier method of operating the Kolhus or the crushers with 3 vertical

rollers and driven by bullocks is now superceded by use of large-size horizontal 3 roller power crushers or 5 or 6 crushers with higher crushing capacity per day. Improved crushers based on screw press device for extracting juice and fitted with cane cutting machine are now becoming popular. The cutting machine is provided with a mechanical cane carrier and a revolving pair of knives placed at right angles to the direction of cane supply which cuts the cane in small bits of a few centimetres in length and the cut bits are mechanically elevated to the juice extractor. Introduction of power has much increased the operational efficiency of the industry. In some larger units, apart from increased roller efficiency caused by the introduction of hydraulic cane crushers, the recovery ratio is increased by the "imbibition' process. Under this system, bagasse is sprinkled with hot water or liquid chemicals so that the left over juice is more thoroughly extracted.

Popularity of khandsari depended upon adoption of improved clarification methods. Sugarcane juice obtained after the milling operation when strained yields 0.2 per cent to one per cent of suspended matter, is dark brown in colour, full of air bubbles and acidic in reaction with pH 4.5 to 5.4. The suspended impurities consisted of field soil, bits of cane fibre and small amount of cane-wax. Clarification of juice is needed in order to obtain good sugar crystals when the juice is crystallized and acceptable colourisation of the sweetening agent achieved. Four-fold aims of clarification are (i) neutralizing the acidity of cane juice, (ii) eliminating suspended impurities, (iii) increasing the sucrose content of the juice, and (iv) decolourisation in order to produce good-sized crystals. Limitations of the khandsari process in regard to its clarification process have significantly

reduced its competitive strength vis-a-vis large-scale sugar mills worked on vacuum pan technology.

Such non-essential ingredients like water, suspended impurities, colloids and other organic and inorganic substances have to be removed from the juice before it is processed further. While doing so, it is noted that the juice obtained after crushing is acidic in reaction and hence susceptible to deterioration. Clarification and boiling of the juice needs to be done quickly. The suspended impurities are removed by straining. Vegetable clarificants such as deola (hibiscus ficuluous), bhendi (hibiscus esculentus), groundnut (arachis hypogaea), castor seed (ricinus communis) and other like items are used at the preliminary clarification stage; at a later stage, chemicals like sodium hydrosulphite (for improving colour), lime (which clarifies the liquid and helps in maintaining proper acid-alkali level), and sulphitation are used. After the completion of the liming process, sulphur dioxide gas is passed through the juice in the sulphitation tank. The action of sulphur dioxide on juice is in regard to neutralizing the acid-alkali balance, bleaching the liquid and reducing its viscosity. Sulphitation is a process which requires careful control both in the duration of the process and the maintenance of pH. After the cleaned juice from the setting tank is removed, the mud left out at the bottom is taken care of by bag filters for separating the juice. For this purpose there are two bags, the inner made of medium quality filter cloth while the outer one is of jute. The bag filters are preferably arranged in filter boxes to avoid fall in temperature and consequent reduction in filter rate. Normally, a bag filter takes three-quarters of an hour to filter out 75 to 80 per cent of the total available juice in mud. Vegetable clarificants do

not have much chemical action on juice; the vegetable albumen cogulate on heating, entangle the suspended and coloidal impurities and bring them to the surface like scums of different colours which are strained off till white froth appears. The chemical clarificants have deeper reactions. Vegetable clarificants succeed in removing aoout 10-15 per cent of non-sugar elements from the juice, lime carbonation gvve 50-55 per cent result, while defecation by adding lime followed by further refining through carbon filteration, is 60 per cent efficient.

After clarification, juice is heated for crystallization. Well designed furnaces ensuring fuel economy and control over temperature are necessary. For thickening process so that right consistency of syrup, rab or massecuite is produced, different kinds of multi-pan furnaces have been evolved. Single pan furnaces are used for the manufacture of gur but multipan furnaces are adopted for the manufacture of rab where large quantities of cane are handled. As the pans under khandsari are heated under open atmosphere (in contrast with controlled heating under the vacuum pan system), the khandsari is generally known as open pan system sugar. In such a system, temperature control depends on lay-out, design and dimensions of pans, as well as on the expertise of the boilers. For khandsari production, juice is boiled at 108°C-110°C at which there is substantial loss of sugar. To minimize this kind of loss, the boiling period is shortened. Direct heating obtained from dry bagasse or such other materials is employed which makes its control difficult. Such fuel sources necessitate large open space around the units for their sun-drying. The sucrose loss under OPS is estimated at 15 per cent against only 2 per cent in the vacuum pan method.

The exact temperature at which boiling is stopped and the syrup "struck" has significant effect on crystallization which is caused by sudden cooling of the supersaturated liquid. When the hot massecuite comes out of the pan at more than 100°C temperature, there are no crystals in it. Crystallization begins by sudden cooling of the supersaturated liquid. Only when the hot syrup begins to be aerated does the cooling process induce crystallization. When the fine grains are formed, they serve as nuclei for the development of crystals.

Crystallization takes place in two stages. First, formation of the grains of crystals, and second, the development of crystal grains already formed. The fall in temperature enables granulation to take place and the cooling mass becomes the magma of fine crystals mixed with the mother liquid. The process of aeration sets the crystallization in motion, but seeding helps in increasing the size of crystals. Sudden drop in temperature and aeration are important factors for crystallization; in OPS these are unregulated processes depending on atmospheric conditions and crude mechanical devices for aeration.

There are generally two methods of crystal formation - crystallization at rest, and crystallization in motion. The first consists of cooling the magma without disturbing it in the container as it cools. This is generally done in small-scale units where the massecuite is filled in an earthen vessel where it remains stored for two or three weeks and left to cool. The rate of cooling here is irregular and uncontrolled. About a week is required just to reduce the temperature from 80°C to 40°C. Temperature at the top and sides of the pot is lower than in the centre. Lumpiness in the massecuite

results from this kind of uneven temperature. These lumps are broken later. They also create difficulties during centrifuging. Rapid cooling at the surface of the container caused formation of false grains; irregular and uneven rate of cooling cause graining at different times in different portions of the magma in the same pot. Such unevenness inhibits the development of grains to bigger sizes and the crystals are also of varied sizes.

Crystallization-in-motion adopted in khandsari units eliminates some of the difficulties mentioned above. In this process, the aerated massecuite is stored in crystallizers fitted with slow revolving stirring gear which tries to introduce uniformity in the cooling process. Uniform and bigger sizes of crystals are therefore acheived in this process. In 2-3 days, the magma is cold, crystallized and ready for centrifuging.

Centrifuging: Sugar crystals from the massecuite are separated by a centrifuge operated either by a pedal or by power. The machinery is essentially a mechanical contraption for separating solid crystals from liquid massecuite. On the efficiency of this machinery and the speed with which it is operated, depends the uniformity of crystal sizes and the quantum of crystals centrifuged from the mother liquid. Viscosity of the magma does impair its operational efficiency. At this stage, chemicals are sometimes added to reduce viscosity and improve the colouring of crystals. As a result of this operation, molasses are strained from crystal sugar and the crystals are scraped from the cage of the centrifuge. Lumps of sugar often formed due to defective massecuite preparation or presence of false grains have to be broken. Khandsari needs drying before it is bagged and marketed. These are crude operations, often needing much ground space. In large-scale units,

these operations are mechanically performed.

The various phases of production show that the production constraints arising from conditions prevailing outside the factory gate are of the same nature for all technologies. They are connected with the vagaries of agricultural operations. Within the factory gate, clarification and boiling present the major differences. As heat needed for boiling the syrup is not controlled so effectively under OPS, there occur some variations in quality of the output, khandsari under this process. The acidity of the juice which rapidly destroys its sucrose content, and the brief span between harvesting and crushing available to achieve the highest juice recovery ratio are major problems for which scientific solution has been lacking. Storage of cane, and of cane juice without causing much damage to them are yet unsolved on whose solution a radical change in sugar technology possible.

III SOCIO-ECONOMIC ENVIRONMENT

The social environment of rural India provided many special characteristics for the successful introduction of different sugar technologies in the country. The jaggery production based on bullock driven crushers gave on an average employment to 2 men and 2 bullocks which could be productively employed for about 6 months in a year if the farmer had 3 hectares of land under sugarcane cultivation. The economic changes taking place during the last few decades have distorted the ancient socio-economic balance while the modern structure has not yet stabilized the society. The role of

different sugar technologies in making the rural economy viable, and in initiating a self-generating growth is significant.

Traditional rural society, almost all over the world has deep-rooted conservatism resenting any radical incursion from the industrialized metropolis. But, any change initiated at the village level with help, cooperation and involvement of the local population is readily adopted. Such changes to be effective should be related to agriculture, cater to one of their basic needs, and increase their employment potential. Evolution of different sugar technologies is based on these characteristics which make them effective in initiating programmes of economic change.

The basic input for sugar manufacture is sugarcane. The cultivation of sugarcane is radically different from other crops; its extension is restricted by geo-climatic characteristics of the region; the period of cultivation is unusually long and the land tied to this crop very much restricts the manoeuvrability of the farmer; the crop is very disease-prone and the quality of the cane quickly deteriorates after harvesting; capital needed for this kind of agricultural cultivation is high, and alternative uses of sugarcane almost absent. To succeed under these conditions, the agriculturists should be scientifically oriented, capable of taking assistance from research institutions and (State) financial institutions, and having easy access to sugarcane crushing establishments. As a result of this linkage, adoption of sugar production as an economic activity would require a readiness among the farmers to adopt new methods of cultivation, faciltiies for mechanization, and willingness to form cooperatives.

Whatever the scales of operation, sugar production needs, besides sugarcane, limestone, sulphur, coal, coke and other kinds of fuel; sugar production yields bagasse, molasses and press mud, besides the sweetening

agents in the form of white crystal sugar, khandsari and gur, Gur or jaggery is largely consumed by the rural people themselves, but for other items like khandsari and sugar organized markets are essential. The manufacturing units, under technological constraints, have to be set up in the rural environment. Power is now an essential component of sugar technology; the rural areas must be electrified, or self-contained power-generating sets will have to be installed. Good road/rail link between the cultivating field and the manufacturing unit is important. The availability of water is necessary for irrigating cane fields as well as for washing the cane before crushing and for other production requirements. The production period being uncertain and seasonal, depends on temporary flow of labour force which could be drafted when needed, after which they could revert to their former occupation. As the villages are not so constituted as to such finely adjusted production-mix to release such a seasonal labour force, sugar production assumes underemployment in order to be economical. Existence of small cottage industries would be helpful in removing the anomaly arising from this situation.

Generally speaking, sugar production needs ten-times its weight of sugarcane, and about one-tenth its weight limestone. A similar amount of coal is also needed. Bagasse is used as a fuel; it has the possibility of alternative uses. It may be a raw material for making paper, pulp, newsprint and insulation boards; it can also be used after chemical treatment for the production of plastic moulding powder, cattle feed, bio-gas, mauure etc. Molasses constitute about 4 per cent of sugarcane and is at present used by the distilleries in the production of industrial alcohol,

potable spirit etc., but it can be used also as manure, cattle feed, tobacco curing agent and for the manufacture of polythene, plastic etc. The main difficulty standing in the way of better utilization of molasses seems to be the absence of adequate storage, distribution and transport facilities from the factories to the consuming centres. Presence of this item around the factories often produces a stinking smell which makes living in the neighbourhood almost impossible. Yield of press mud is about 3 per cent of the cane in sulphitation factories and nearly 7 per cent in the carbonation factories. The latter does not have any commercial use but its storage is space consuming; generally it is used to fill up pits; mud resulting from sulphitation process of juice clarification could be used as manure, as such it is given to the farmers, either at a nominal price or free, but in either case, transportation has to be done. The establishment of sugar production units as an impetus to rural industrialization needs coordinated development of rural industries based on utilization of sugar by-products and close integration between the interests of farmers and the factory management.

Relative importance of different sugar technologies - the scale of its operation and the method of its production - is connected with the cane cultivating area, product preference of the people, anticipated market prices of different agricultural crops and the price differential between alternative sweetening agents. Sugar mills presently operating under a system of various restrictions relating to price and distribution. On the total production of sugar from vacuum pan method there is a levy of 65 per cent which the Government obtains from the mills at a levy price for its own distribution system; the remaining 35 per cent is sold by the mills anywhere.

The levy sugar is paid prices which differ for different states but at all these places the prices are fixed which enable the consumers to receive their sugar quota of ration at a cheaper price; the price of free sale sugar is also fixed by the Government though at a much higher rate. While the levy price of sugar in Haryana was Rs170.58 per quintal, the free sugar was selling at Rs.335.00. The mills have to pay ad-valorem excise duty which has presently been 41.5 per cent for free sugar and 15 per cent for levy sugar. To encourage the mills to continue production even after the main sugar season is over, special rebates are offered.

The sugar mills have to pay a stipulated sugarcane price over and above which there is a mark up for better quality cane. The statutory minimum price of sugarcane per quintal in 1976-77 has been Rs.8.50 for a basic recovery level of 8.5 per cent over which premium for every increase of 0.1 per cent above basic recovery level has been fixed as Rs.0.10. The actual price paid by the sugar mills has generally been higher than these prices. In 1975-76, when the range of statutory minimum prices for sugarcane was Rs.8.50 to 12.80, the mills actually paid the farmers cane prices upto Rs.18.00. As far as the khandsari manufacturers are concerned, they do not suffer from these restrictions. There are no price restrictions on them; they could purchase cane at any price, sell khandsari at any price and anywhere. Excise duty on their production could be either 17.5 per cent ad-valorem, or according to the compounded levy scheme under which scheme, the khandsari units have to pay the levy on the basis of the type of machinery used and the capacity of the unit, but they could claim rebates on grounds of under-utilization. The effective rate of excise duty under this system

is estimated between 6-9 per cent ad-valorem. Such differential treatment enables the khandsari unit to obtain sugarcane cheaper even when the mills are paying higher rates because the vacuum pan units cannot pay less than the statutory minimum prices even when there is the glut in the supply; the incidence of tax is less on khandsari units and freedom to sell at any price increased their competitive power. Some effort has already been made to link the cultivators with sugar mills of the region, nonetheless the effective solution of the problem has not yet emerged. Whether the coexistence of different sugar technologies could be fostered in any community by administrative price controls and regulatory mechanism without destroying their viability is a mute point. The superiority of OPS sugar production seems to lie in its close integration with the socio-economic organization of the society where it is carried out, in its adaptability to existing conditions rather than in its comparative cheapness of production, labour intensity of the project or the quality of the output.

Appendix I

Sugarcane hectareage, recovery ratio, sugar factories in Operation and the duration of crushing season

States	Hectareage (000)		Recovery Ratio		No. of Sugar Mills in Operation		Duration of Crushing Season	
	1974-75	1975-76	1974-75	1975-76	1974-75	1975-76	1974-75	1975-76
1. Uttar Pradesh	1,492	1,450	9.40	9.50	74	77	152	116
2. Maharash-tra	185	217	11.17	11.25	52	55	160	156
3. Haryana	161	159	8.97	9.28	3	3	199	180
4. Tamil Nadu	160	155	8.43	9.20	17	16	169	88
5. Andhra Pradesh	195	136	10.07	9.90	21	21	127	102
6. Bihar	141	134	8.63	9.05	28	27	80	67
7. Karnataka	124	131	10.89	10.68	17	19	140	123
8. Punjab	123	115	9.02	8.59	6	6	154	157
9. Madhya Pradesh	81	69	8.82	9.44	6	6	142	105
ALL INDIA	2,894	2,790	9,90	10.20	247	253	140	120

Source: The Indian Sugar Mills Association, New Delhi.

Appendix II

Production of Sugarcane, sugar, and gur and Khandsari

Unit: thousand tonnes

States	Sugarcane		Sugar		Gur - Khandsari	
	1974-75	1975-76	1974-75	1975-76	1975-75	1975-76
1. Uttar Pradesh	61,479	58,214	1,431	1,166	3,783	3,796
2. Maharashtra	17,178	19,168	1,515	1,606	215	334
3. Haryana	5,910	6,870	114	107	390	486
4. Tamil Nadu	14,593	14,786	384	177	950	1,250
5. Andhra Pradesh	11,496	9,421	397	326	754	611
6. Bihar	5,568	4,907	212	177	233	226
7. Karnataka	8,629	9,965	336	361	472	566
8. Punjab	6,150	6,180	77	83	452	444
9. Madhya Pradesh	2,000	2,131	57	48	110	136
ALL INDIA	144,289	142,704	4,794	4,262	8,063	8,611

Sources: (1) The Indian Sugar Mills Association, New Delhi

(2) Directorate of Economics and Statistics, Ministry of Agriculture and Irrigation, New Delhi.

Appendix III

Sugarcane production, yield per hectare, total cane crushed, recovery ratio, average duration of crushing

Year	Sugarcane Production ('ooo Tonnes)	Average capacity of sugar Mills (tpd)	Total cane crushed ('ooo Tonnes)	Recovery of sugar (% cane)	Average duration (days)
(1)	(2)	(3)	(4)	(5)	(6)
1932-33	51,950	481	3,404	8.66	138
1939-40	40,145	778	13,342	9.31	129
1947-48	58,170	815	11,014	9.91	110
1950-51	69,220	873	11,147	10.03	101
1953-54	53,848	956	10,092	10.08	86
1956-57	83,848	1,048	21,187	9.73	150
1959-60	91,394	1,167	24,811	9.91	138
1962-63	91,913	1,151	20,755	10.24	108
1965-66	123,990	1,253	36,404	9.68	159
1968-69	124,676	1,320	37,455	9.50	150
1971-72	133,569	1,437	30,973	10.03	107
1974-75	144,289	1,534	48,435	9.90	140

Source: The Indian Sugar Mills Association, New Delhi.

Appendix IV

Ex-Works Cost of Sugar Manufacture

Zones	Based on Zonal average of 5 yrs duration & recovery					
	Season (Days)	Recovery (%)	Cost of cane at notified minimum prices	Conversion charges	Return	Ex-works Cost (4+5+6)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1. Punjab	99	8.27	101.26	61.45	12.60	175.31
2. Haryana	151	8.70	101.90	44.23	"	158.73
3. Rajasthan	74	8.88	95.19	75.45	"	183.24
4. West U.P.	144	9.23	102.14	39.08	"	153.82
5. Central UP.	149	9.06	102.24	38.75	"	153.59
6. East U.P.	115	9.28	101.66	46.12	"	160.38
7. North Bihar	97	9.22	101.71	53.52	"	167.83
8. South Bihar	72	8.59	102.51	77.77	"	192.88
9. Gujarat	141	9.92	105.14	39.31	"	157.05
10. Madhya Pradesh	81	9.20	97.91	69.10	"	179.61
11. Maharashtra	171	11.16	101.79	34.01	"	148.40
12. Karnataka	146	10.34	104.74	41.40	"	158.74
13. Andhra Pradesh	122	9.55	99.42	36.46	"	148.48
14. Tamil Nadu & Pondicherry	189	8.48	107.67	37.06	"	157.33
15. Orissa, Assam & West Bengal	87	9.01	94.07	54.89	"	161.56

Appendix IV cont'd

Zones	Based on Zonal average of 5 yrs duration & recovery Season (days)	Recovery (%)	Cost of cane at notified minimum prices	Conversion charges	Return	Ex-works Cost (4+5+6)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
16. Kerala	70	8.60	96.05	71.24	12.60	179.89

Source: Report on the Cost Structure of and Fair Price, Payable to the Sugar Industry, Tariff Commission, Bombay, 1973.

Appendix V

Losses During Khandsari Process

Data collected for two successive seasons by a U.P. research organization showed the following:

(Percentages)

Nature of Loss	I	II
Sugar lost in bagasse	17.98	24.1
Sugar lost in mud	1.72	1.6
Sugar lost in molasses	8.89	9.04
Other Losses	14.29	9.85
	42.29	44.59
Overall recovery	57.12	55.41
Recovery in terms of cane	7.97	6.92

Source: Report of Fourth Technical Seminar on the open Pan Sugar Manufacture, PRAI, Lucknow.

Appendix VI

Cropping Pattern

In the sub-tropical region cane is a crop of eight to twelve months' duration. Sowing is done in January-March and harvesting from middle of October to March. The time-cycle of area under this crop and also the duration from sowing to maturity almost coincides. There is no area which is not likely to be harvested within a given agricultural year. The area under cane is, therefore, the total area occupied by the cane crop; production is reckoned for the entire area, and the yield factor is a simple division of the total production in a given year by the total area under cane.

On the other hand, in the tropical region and typically in Maharashtra, the concept is more complex. The three broad classifications of the crop are "adsali", "pre-seasonal" and "seasonal" with seasons for sowing and harvesting as follows:

Type of Crop	Planting	Duration in Months	Harvesting
Adaali	15th July to 15th September	15-18	Mid-October to the end of December
Pre-seasonal	15th October to 15th November	15-17	1st January to end end of February
Seasonal	15th January to 15th March	13-14	February/March
Ratoon	15th January to 15th March	14-15	1st March to mid-April

There is an overlap of about six months when the previous year's crop is becoming mature and the current year's plantings are in the early stages of growth. With the requirement of inter-cropping before the next planting, three times the area harvested in any year is needed to maintain a regular pattern of production, in the case of adsali and somewhat less for other cane sowings. The apparent advantage of high yield in the tropical region is thus to a large extent neutralised by the proportionately greater land use when compared to similar factors for the sub-tropical region.

(Extracted from "Report on Cost Structure of the Sugar Industry and the Fair Price for Sugar," Tariff Commission, Bombay, pp. 15-16.

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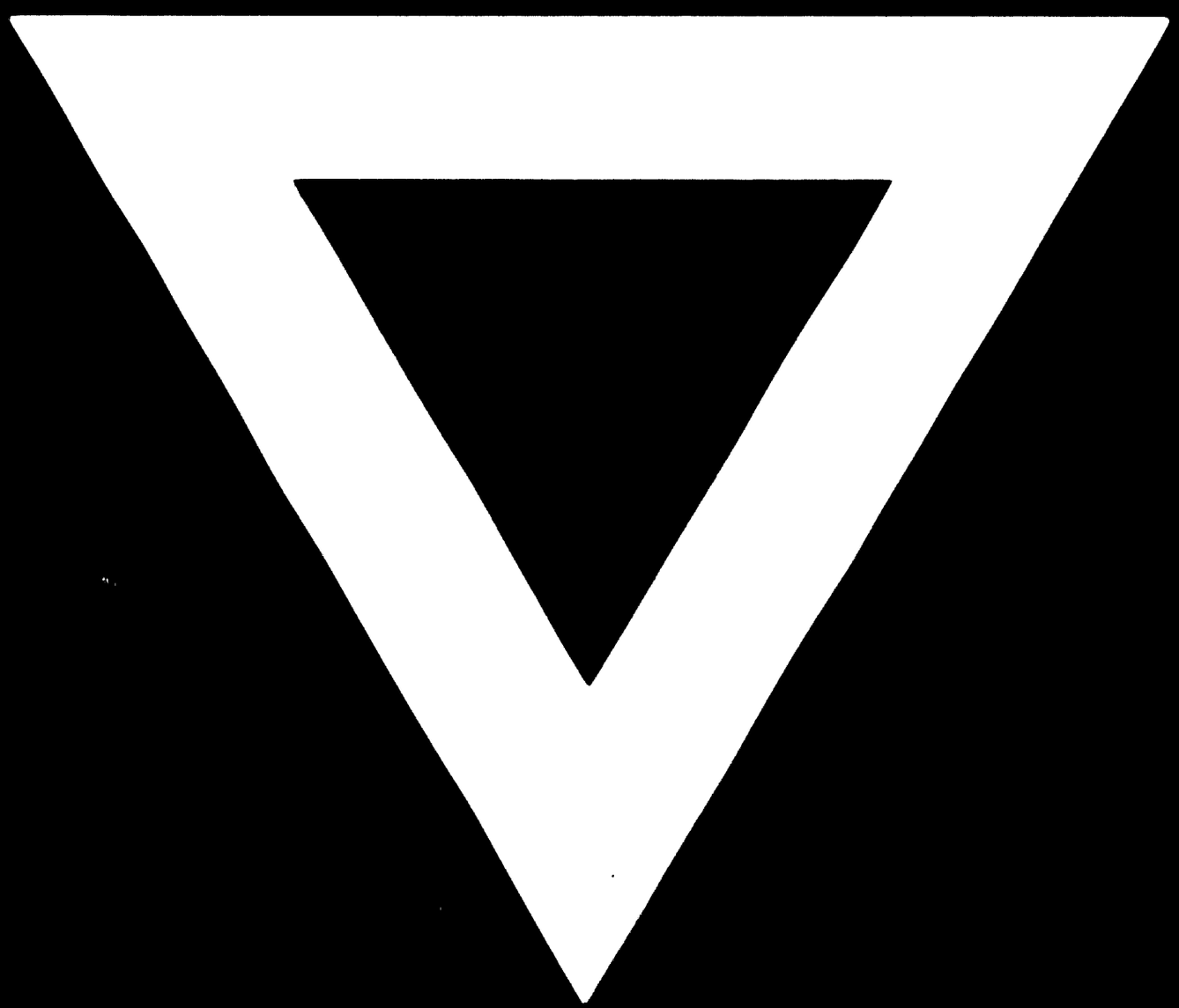

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