MINISTRY OF FOOD PROCESSING INDUSTRIES
GOVERNMENT OF INDIA

PMFME
सूक्ष्म उद्यमों का संबल

NIFTEM
THANJAVUR

PM Formalisation of
Micro Food Processing Enterprises Scheme

Processing of Jaggery Powder

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CHAPTER 1
INTRODUCTION

1.1 Status of Sugarcane in India

Sugarcane (Saccharum officinarum) family Gramineae (Poaceae) is widely grown crop in India. It provides employment to over a million people directly or indirectly besides contributing significantly to the national exchequer. Sugarcane growing countries of the world lay between the latitude 36.7° north and 31.0° south of the equator extends from tropical to subtropical zones. Sugar cane originated in New Guinea where it has been known for thousands of years. Sugar cane plants spread along human migration routes to Asia and the Indian subcontinent. Here it cross-bred with some wild sugar cane relatives to produce the commercial sugar cane we know today.

1.1.1 Cultivation Scenario

Cultivation of sugarcane in India dates back to the Vedic period. The earliest mention of sugarcane cultivation is found in Indian writings of the period 1400 to 1000 B.C. It is now widely accepted that India is the original home of Saccharum species. Saccharum barberi and Polynesian group of island especially New Guinea is the centre of origin of S. officinarum. It belongs to family Gramineae (Poaceae), class monocotyledons and order Glumaceae sub family Panicoidae, tribe Andripogoneae and sub tribe Saccharininea. The cultivated canes belong to two main groups: thin, hardy north Indian types S. barberi and S. sinense and thick, juicy canes Saccharum officinarum. Out of these, S. officinarum is highly prized.

Among the sugar yielding crops like sugarcane, sugarbeet, palms and sorghum, sugarcane is the most important. 90% of the production comes from Bihar, Haryana, Punjab, Uttar Pradesh, Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu; Uttar Pradesh being the maximum producer .Indian sugarcane acreage during 2020-21 sugar season (SS) is estimated at 52.25 lakh hectares, registering 8 percent growth, as compared to 48.41 lakh hectares recorded during the 2019-20 sugar season.

1.1.2. Sugar cane varieties suitable for jaggery production

Co 8371 (Bhima)	Co 7219 (Sanjivani)
CoM 7125 (Sampada)	CoM 88121 (Krishna)
Co 8014 (Mahalakshmi)	CoC 671
Co 99006	CoA 92081
CoJn 86-141	CoJn 86-600

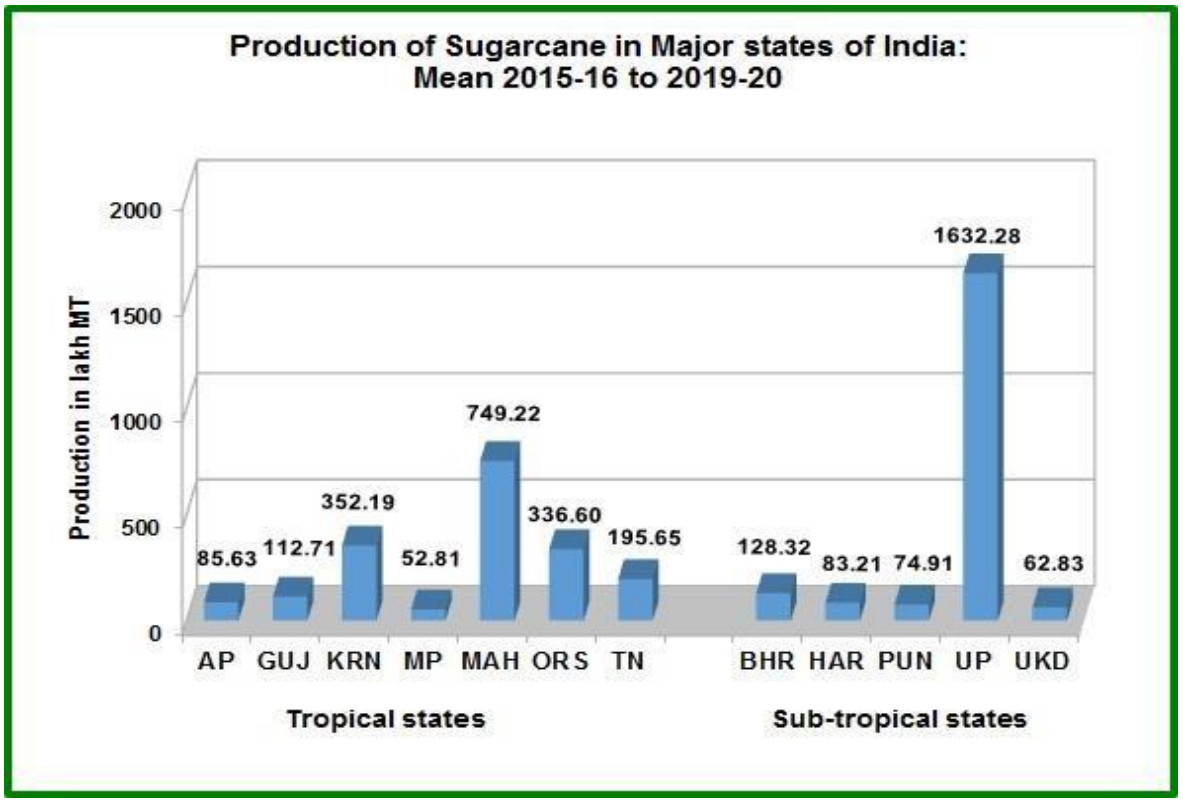
1.1.3. Production and yield of sugar cane in major states in India

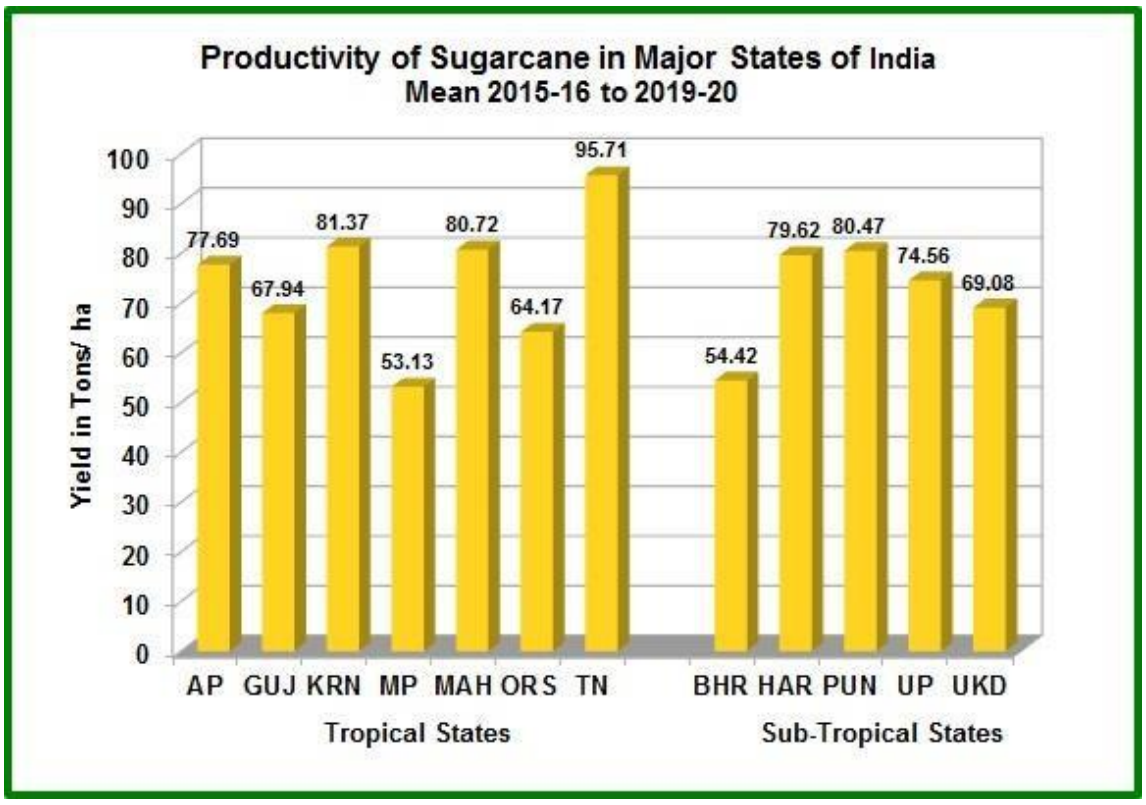
A= Area in '000 ha; P= Production in '000 Tonnes; Y = Yield in Tonnes/ha

STATE		2016-17	2017-18	2018-19	2019-20*
ANDHRA PRADESH	A	103	99	102	126
	P	7830	7948	8091	9593
	Y	76.0	80.28	79.33	76.14
GUJARAT	A	169	182	167	153
	P	11950	12052	12036	9198
	Y	70.7	66.22	71.97	60.00
KARNATAKA	A	397	350	506	451
	P	27378	28263	42006	40612
	Y	69.0	80.75	83.0	90.0
MADHYA PRADESH	A	92	98	118	118
	P	4730	5430	6956	5733
	Y	51.4	55.41	58.95	48.59
MAHARASTRA	A	633	902	1163	979
	P	52262	83134	92443	73090
	Y	82.6	92.17	79.50	74.65
ORISSA	A	5	4	6	2
	P	344	240	381	141
	Y	68.8	64.95	63.06	59.92
TAMILNADU	A	218	180	165	206
	P	18988	16536	16208	20600
	Y	87.1	92.02	98.24	100.00

* Provisional;

1.1.4. Production and productivity of sugar cane in major states of India





1.2. Sugarcane products market

India is the largest consumer and the second largest producer of sugar in the world. Sugar industry is the second largest organized sector industry in the country. Since ancient times, sugar has been produced in the local units in India using traditional Khandsari process. Modern sugar making was introduced in India probably by Dutch. The first Sugar Mill was started in India in Bihar in 1903, followed by another unit in 1904 in Uttar Pradesh. By mid of the 20th century, Sugar industry expanded and before India's independence there were 138 sugar mills in India.

Jaggery (also called as *Gur*in India, *Desi*in Pakistan, *Panela*in Mexico and South America, Jaggery in Burma & African countries, *Hakuru*in Sri Lanka, and *Naam Taan Oi*in Thailand) and *khandsari*are traditional Indian sweeteners, which are produced in addition to sugar from sugarcane. These traditional sweeteners are the natural mixture of sugar and molasses. If pure clarified sugarcane juice is boiled, what is left (usually possessing 65-85% sucrose) as solid is jaggery. *Khandsari* sugar is a finely granulated, crystallised sugar that contains 94-98 % sucrose.

1.2.1. Indian Market Outlook

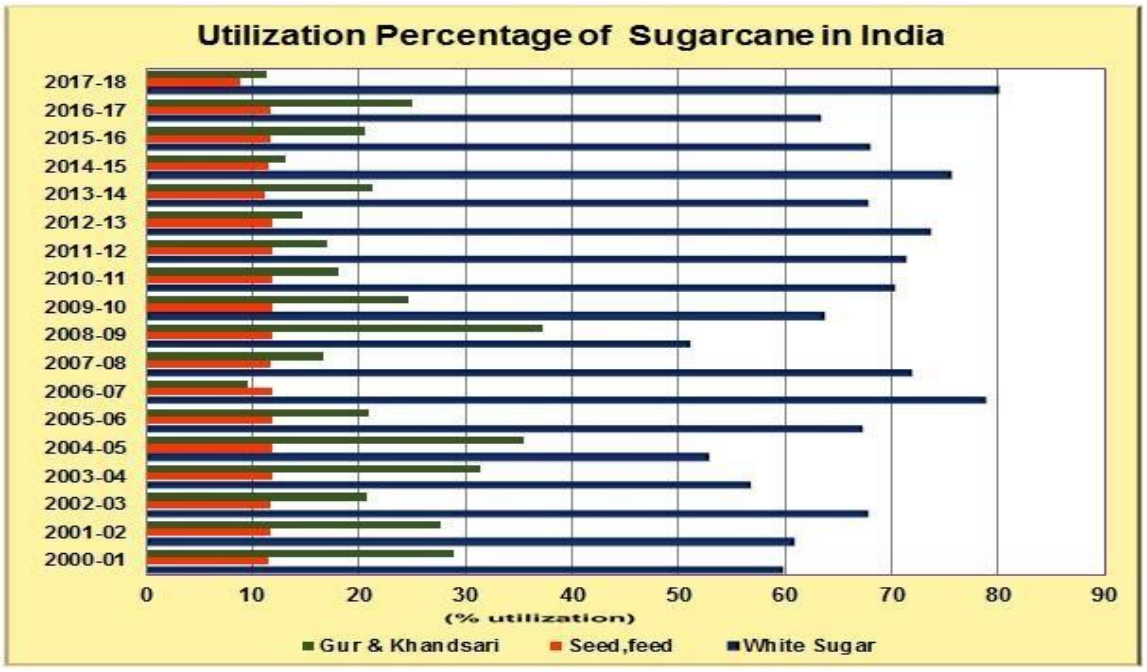
In the early 1930's, nearly 2/3rdof sugarcane production was utilized for production of alternate sweeteners, jaggery and *khandsari*. With the introduction of sugar mills and their multiple growth, better standard of living and higher per capita income, the sweetener demand had shifted to white sugar, which contains purely sucrose (99.7%). Therefore, jaggery and *khandsari* production got setback to some extent.

Jaggery manufacturing is done on a small scale by groups of farmers; the process has been creating employment opportunities to the millions of people in rural areas. From time immemorial, sugarcane crop has been known as a cash crop by Indian cultivators and so also the preparation of jaggery. It is estimated that two thirds of the sweetening requirement in rural areas is met by jaggery.

Thus, there are strong indications that the jaggery and khandsari cottage industry would continue to play an important role in processing sugarcane at rural level and in creating employment opportunities to the millions of people in rural areas. Jaggery industry is probably the most wide spread cottage industry in India. India produces more than 70% of the total jaggery of the world. Being an eco friendly sweetener with additional nutritional value, jaggery holds good export potential. To sustain the market and export potential of jaggery, it is imperative that the jaggery quality need to be sustained.

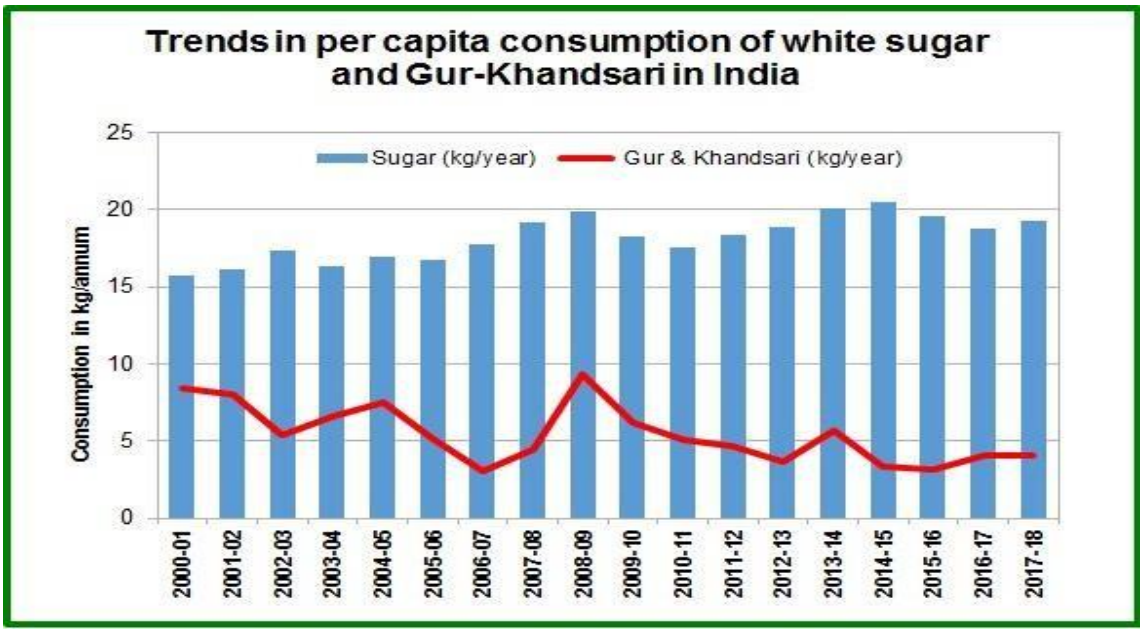
1.2.2. Utilization of Sugarcane

In India, almost 80%of the sugarcane produced is processed into white sugar, around 12% into jiggery and khandsari, and approximately 8% is used as seed cane. The per cent utilization of sugarcane for production of jaggery and khandsari has considerably declined from 37.20 in the year 2008-09 to about 12% in 2017-18. This implies the need of research in jaggery sector to produce a quality jaggery and thus to change the scenario.



Source: ICAR-SBI

1.2.3. Trend in per capita consumption of white sugar, gur and khandsari in India



1.3. Nutritive value of Jaggery

Jaggery is a very nutritious and healthy food and used as a main sweetener for rural and urban people. It contains about 80-85% sucrose and 5-15% reducing sugars. Jaggery provides necessary nutrients like-proteins, fats, vitamins (B-complex and folic acid), minerals (calcium, iron, phosphorus, magnesium, potassium and traces of zinc, copper etc., which are not present in sugar).

Compared to khandsari, jaggery is a wholesome diet. It contains 0.6%-1.0% minerals; important among them are iron (11mg), calcium (0.4%), magnesium and phosphorous (0.045%). Jaggery also contains reducing sugars including glucose and fructose (10-15%), protein (0.25%), and fat (0.05%). Daily use of jaggery may increase human life span. Incidence of less diabetes is reported in jaggery consuming areas compared to sugar consuming areas.

1.4. Medicinal properties of jaggery

a) Jaggery purifies blood

One of the most popular advantages of jaggery is that it possesses the ability to purify blood. If consumed regularly, jaggery goes a long way in cleansing blood and in leaving the body healthy. It also helps in preventing different blood disorders and diseases by boosting the count of hemoglobin. Jaggery also boosts immunity and thus helps in the prevention of different blood related problems.

b) Iron content

Jaggery is quite rich in its content of folate and iron and therefore it helps in the prevention of anemia. Jaggery powder also offers instant energy preventing weakness and fatigue of the human body. When eaten in combination with foods that are rich in vitamin C, jaggery helps in the absorption of iron within the body.

c) Mineral content

Jaggery is packed with minerals and antioxidants like selenium and zinc and these help in preventing free-radical damage. These minerals and antioxidants also help in boosting the body’s resistance to different infections.

d) Cosmetic benefits

Jaggery proves to be highly beneficial when used for a beauty treatment. It comes loaded with several natural properties ensuring the health of the skin for a very long span of time.It is rich in its content of different minerals and vitamins and thus offers proper nourishment to the skin.

e) Jaggery benefits digestion

Jaggery stimulates the secretion of digestive enzymes and therefore speeds up the procedure of digestion. Proper digestion helps in regulating bowel movement and in preventing issues like constipation, intestinal worms and flatulence. It is quite effective in maintaining the proper functioning of the digestive system. Properly functioning digestive system means proper prevention of digestive issues and improvement indigestion at the same time.

f) Jaggery increases metabolism

The high mineral content of jaggery and high levels of potassium helps in the management of weight. This is done by reducing the retention of extra water in the human body. The potassium content of jaggery maintains electrolyte balance, improves metabolism and builds muscles help in weight loss.

g) Jaggery treats water retention

Minor health issues like water retention, migraine, bloating and cough and cold that are experienced by individuals on a regular basis can easily be dealt with the help of jaggery. The only thing that needs to be done is mixing jaggery with warm water or adding it in tea for reaping instant benefits.

h) Jaggery balances hormone levels

Women who experience mood swings prior to having their periods can greatly benefit from having jaggery. Mood swings are the cause of fluctuating hormone levels in the body. Jaggery helps in the release of happy hormones called endorphins. These relax the body making women feel better.

i) Good for Brain

Jaggery also helps in preventing major issues faced with the nervous system of the body. It contains several natural properties which are of good help in keeping the nervous system functioning properly. This in turn helps individuals in staying healthy and normal.

j) Treats Respiratory Problems

Having jaggery on a regular basis can help in prevention of different respiratory issues like bronchitis and asthma. Experts are of the view that taking jaggery in the form of a natural sweetener in perfect combination with sesame seeds can be highly beneficial for the respiratory system in human beings. Jaggery contains properties that help in regulating the temperature of the body and this is something that is highly beneficial for the patients of asthma. It is also worth noting that jaggery contains anti-allergy properties as well

k) Useful in Joint Pain

For those suffering from joint pains and aches, jaggery can offer the much required relief. If experts are to be believed, jaggery when taken along with ginger can work wonders in alleviating joint pain. Having a glass of milk along with jaggery on a regular basis can also help in strengthening the bones and in preventing bone and joint problems like arthritis.

1.5. Jaggery vs Sugar

Jaggery exhibits supremacy over sugar in many ways, as:

1. It is an important source of energy (383 kCal energy per100 g of jaggery).
2. Jaggery is an essential ingredient in various baked products such as-chocolates, biscuits, breads, cakes, pastries, rolls, gajak, chikki etc.
3. It is utilized for production of several ayurvedic medicines and syrups for treating throat and lungs infections, relaxation of muscles, nerves, blood vessels, maintaining blood pressure, increase hemoglobin, prevents anemia.
4. The molasses present in jaggery acts as laxative and improves the digestion.
5. It used as post-partum medicine to women and domestic female animals traditionally.
6. Although, sucrose recovery in jaggery production is 3-5% lower in comparison to sugar industry but it is compensated by recovery of reducing sugars, proteins, fats and minerals, which are lost during sugar production in sugar mills.

CHAPTER 2

Processing of Jaggery Powder

2.1. Processing of jaggery

Sugarcane juice is an opaque liquid and varies in colour from gray dark green to light yellow depending upon the colour of cane. In addition to various nutritional constituents, it also contain mud, wax and several other soluble and in soluble impurities. To maintain proper quality in jaggery, all these soluble and in soluble undesirable fractions should be removed. However, the manufacturing process depends on the ultimate form to be produced. Also, the minute detail of the process varies widely from state to state, in the state from one district to another, and in some cases within a district.

2.1.1 Forms of Jaggery

Jaggery is available in the market mainly in three forms namely solid jaggery, liquid jaggery and granular jaggery. Of the total production of jaggery in India, approximately 80% of the jaggery is prepared in solid form and the remaining 20% is prepared in liquid as well as granular form. Liquid jaggery is a part of diet in most parts of Maharashtra & West Bengal and is gaining commercial importance. Liquid jaggery is widely utilized as sweetening agent in foods and drinks in Maharashtra, Gujarat, Kerala, Andhra Pradesh, West Bengal and Tamil Nadu. The granular jaggery is also popular particularly among rural masses.

Composition of different forms of jaggery

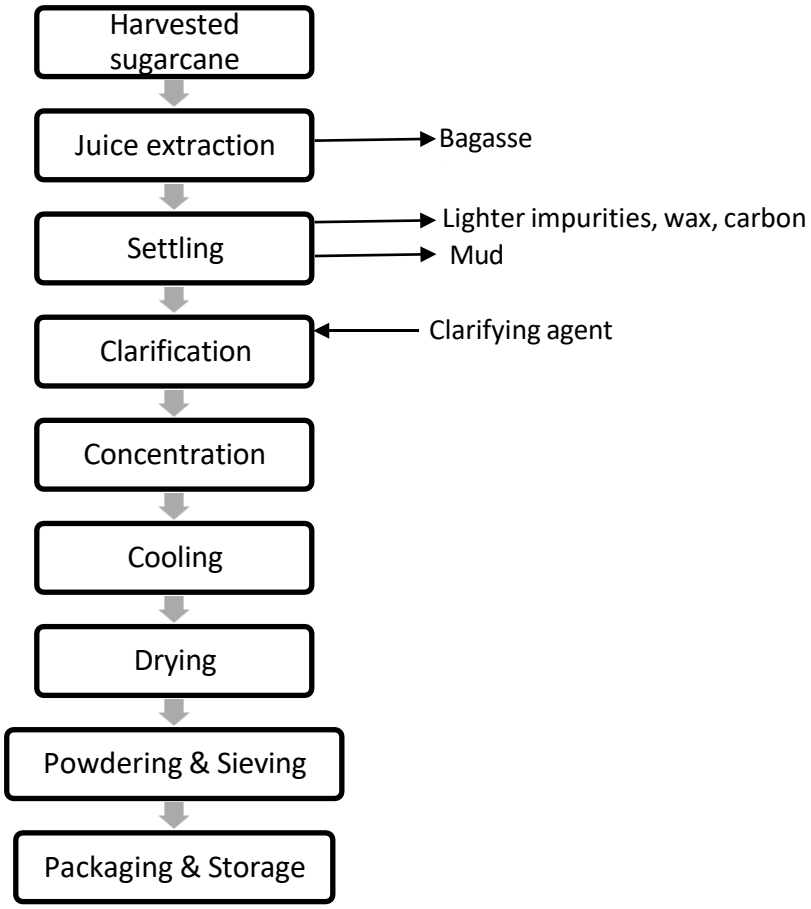
Composition per 100g	Types of jaggery		
	Solid (lumped)	Liquid	Granular
Water (g)	3-10	30-35	1-2
Sucrose (g)	65-85	40-60	80-90
Reducing sugars (g)	9-15	15-25	5-9
Protein (g)	0.4	0.5	0.4
Fat (g)	0.1	0.1	0.1
Total minerals	0.6-1.0	0.75	0.6-1.0
Calcium (mg)	8.0	300	9.0
Phosphorous (mg)	4.0	3.0	4.0
Iron (mg)	11.4	8.5-11	12
Energy (Kcal)	383	300	383

2.1.2 Granular or Powder Jaggery

It has been inferred from research that granular/ powder jaggery with low moisture content (up to 1-2 % d.b.) increased storage life up to two years; the free flowing nature offers this advantage. Research attempts are being made to develop better technology for jaggery granules. Increasing pH of cane juice with lime, up to 6.0-6.2 and striking point temperature of 120°C was found to yield quality granular jaggery with high sucrose content of 88.6 per cent, low moisture of 1.65 per cent with good colour, friability and crystalline texture. Jaggery in the form of granules (sieved to about 3 mm), sun dried and moisture content reduced to less than 2 per cent and packed in polyethylene polyester bags or polyethylene bottles, can be stored for longer time (more than two years), even during monsoon period with little changes in quality.

2.2. Traditional production process

The unit operations involved in jaggery manufacturing process from sugarcane is presented in the flowchart. It involve juice extraction, juice clarification, juice concentration by boiling, cooling of concentrated juice followed by drying, powdering, packaging and storage.



2.2.1 Juice Extraction

The first step in jaggery manufacture is the **e**xtraction of juice by crushing sugarcane. Three roller cane crushers (vertical/horizontal) are used to extract juice. Vertical three roller crusher has the juice recovery efficiency of 50- 55%, whereas, the same for horizontal crusher is 55-60%. Therefore, the horizontal three-roller crusher is preferable. In sugar factories, the same technique of crushing is used but with multiple crushing and application of hot water during crushing, which increases the efficiency to the extent of 77-80%. This method is not practiced by the jaggery farmers due to more energy requirement for producing hot water and evaporation of this water during boiling process. One tonne of sugarcane crushed yields 650 kg of juice and 350 kg of bagasse (50% m.c., wb). The bagasse was sun dried to bring down the moisture from 50% to 20% (wb) and after drying, 245-250 kg was obtained from 350 kg bagasse which is used as furnace fuel for concentration of the juice.

2.2.2 Juice clarification

The extracted juice is collected in a masonry settling tank and rested for few minutes for separation of light and heavy particles. The clear juice is drawn from a middle port of settling tank and transferred to an iron open boiling pan made to fill only 1/3rd of its capacity. In general, jaggery quality, storability and its acceptability depend on the clarity of the juice used in preparation. The juice collected from settling tank is clarified during the boiling stage. It is mostly done by using lime (calcium hydroxide). Calcium in the lime acts as a complexing agent and forms scum, which needs to be removed frequently during boiling. Lime addition simultaneously increases the acidic pH of juice, i.e. 5.2 – 5.4 (which depends on harvesting status, variety of cane and soil condition) to around 6.0 to 6.4.

Addition of lime also improves the consistency of jaggery by increased crystallization of sucrose, but at the same time it darkens the colour if added in excess. During preparation of jaggery from over matured canes where sucrose content decreases due to inversion, addition of lime improves the jaggery consistency. The quantity of lime to be added depends upon the quality of lime. One kg of lime (with purity of 80-90%) is mixed with 4 litres of water and the supernatant lime water is filtered with a thick cloth. About 60-70 ml of the resulting solution, i.e. milk of lime is added to every 100 kg of cane juice. After the addition of lime to adjust the pH, the juice should be boiled in a pan for about 2 hours removing scum as and when it forms.

Among the other chemical clarifying agents, hydros is preferred next. However, hydros being a bleaching agent, has a decolourisation effect. Addition of super- phosphate, phosphoric

acid, chemiflocks and alum are also reported. Use of these chemical clarifying agents is specific depending on the juice as they may function as bleaching agent, electrolyte or pH adjusting agent. Vegetable clarifying agents like mucilages of bindi, chikani, ateshevari, etc. were used in early period. Nowadays, use of natural clarifying agents is encouraged due to the problems like exceeding the permitted level for chemical clarifying agents and their impact on taste and storability of the product.

A) Vegetable clarifying agents used in jaggery manufacture

Common name	**Plant part used**	**Methodology**	**Quantity per quintal juice**	**Remark**
Deloa	Stem and root of green plant	Pound and extract in water. Use mucilaginous extract	40-50 g	
Bhindi	Stem and root of green plant	Pound and extract in water. Use mucilaginous extract	45-50 g	More effective in removing colouring matter
Phalsa	Green bark of the tree	Pound and extract in water. Use mucilaginous extract	50-55 g	
Semul	Green bark of the tree	Pound and extract in water. Use mucilaginous extract	55-60 g	
sukhlai	Dry bark of the plant	Soak in water. Pound plant and rub in water. Use the extract	45-60 g	
Castor	Seed	Grind decorticatedseed with water. Usemilky liquid afterstraining	70-75 g	Good results with juice of immature waterlogged and infested canes
Groundnut	Seed	Grind decorticated seed with water. Use milky liquid after straining	70-75 g	Good results with juice of immature waterlogged and infested canes
Soybean	Seed	Flour	30-40 g	-do-

B. Chemical clarifying agents used in jaggery processing

Chemical	Action	Immediate effect on product	Effect on storability
Hydros(sodium hydrogen sulphite)	Colour bleaching	Brightens colour temporarily	Hastens darkening and process spoilage within a month
Lime(Calcium oxide)	Removes juice acidity. Helps in clarification	Liming to pH 6.3-6.6 results in good quality. Useful in solidification of gur from waterlogged lodged cane. Excess liming results in hard gur of dark colour	Hard gur; stores better
Sodium carbonate	Reduces acidity	Helps in settling and improving gur quality from inferior canes.	Hard gur; stores better
Sodium bicarbonate	Colour bleaching	Brightens colour temporarily	Hastens process spoilage
Sajji(50% sodium carbonate, 6.4% sodium sulphate, 4.5% sodium chloride)	Partial neutralization of juice acidity, colour bleaching	Brightens colour temporarily, reduces the taste	Adverse effect on storage
Super phosphate	Increases natural acidity, improves colour	Reduces crystallization	Reduces shelf life
Alum	Improves clarification. Needs neutralization with lime / soda	Brightens colour temporarily	Reduces shelf life

2.2.3 Juice concentration

In traditional method gur or jaggery was done with the help of a skilled person who has sufficient knowledge and experience. Boiling of sugarcane juice is the 2nd important step in jaggery making process. The main objective of boiling is to concentrate the juice to make solid or granular jaggery or thick liquid jaggery, to increase the shelflife of juice. During this process, several physical and chemical changes occur, which are closely monitored by a skilled worker. The boiling of juice is continued in a regulated manner for more than 2.5-3 h till the concentrated syrup attains the striking point.

The temperature at which thickened cane juice slurry becomes jaggery is known “Striking Point”. The endpoint or striking point is usually decided manually by dropping a small quantity of hot syrup into cold water taken in a container and it can be shaped with fingers. Temperature plays a major role in the molding of the syrup into different forms of jaggery. The striking point varies from product to product, for solid jaggery making it is at 118ºC, liquid jaggery making is 106-107ºC and for granular jaggery making it is 120-122ºC.

To prevent excess frothing during boiling, small quantity of ground nut/ mustard oil is sprinkled. It also facilitates easy flowing of hot syrup during transfer from one container to another in the following process.

The thermal efficiency of the furnace is as low as 14.75% since the juice is boiled for longer periods at very high temperature. Vacuum pans, or steam jacketed kettles are an alternative to open pans to make the process energy efficient. Dried bagasse is utilized as fuel, additionally other fuels like wood, agricultural residues and even old tyres are used.Overheating may lead to dark color product with bitter taste.

2.2.4 Cooling and jaggery powder making

After reaching the striking point, the pan containing hot mass is removed from the furnace and kept on a platform for 10-15 min. During that time, hot mass is thoroughly stirred with flat wooden stirrer for uniform cooling of hot mass by natural air. Then, it is left for 5-10 min without any further stirring to facilitate crystal formation. The moisture content of this semi cooled mass is around 9- 10% (d.b.). The semi cooled mass containing seed crystals is then transferred from pan to aluminium tray and the mass is converted into granules by applying severe shearing action using wooden or stainless steel scrappers, sometimes even wooden hammers. The shearing action exposes more surfaces for atmospheric cooling.

At this stage, to prepare 35-40 kg granules from 350-400 kg cane, 3 or 4 labourers are required for 15-20 min to make the mass into granules. Otherwise the mass gets solidified into different size of agglomerates or pieces.

2.2.5 Drying, powdering and sieving

Jaggery granules after preparation are dried to 1-2% (d.b.) moisture content. The initial moisture content of granules is 10-12% (db) which is brought to 1% to 2% by sun, tray/ polyhouse drying.

The dried granules are sieved through 3 mm sieve as less than 3 mm are found to be better for quality granular jaggery.

The jaggery powder thus produced is usually packed in 400 gauge polythene sheet or polyethylene terephthalate (PET) bottles. Jaggery should be stored at 40-60% Relative humidity for good keeping quality.

2.2.6 Technical drawbacks of traditional method

1. The naturally occurring enzymes and other compounds in sugarcane juice react with each other and several other components of the juice due to uncontrolled heating forming dark colored complex compounds.
2. Secondly, due to excessive heating, sugars in the juice caramelize and form dark colored compounds.
3. Finally, excessive use of lime and leaching of iron from pans also result in dark color.
4. To improve the color of Jaggery, Sodium Hydrosulphite, a harmful chemical, is normally used.
5. Hydros, bleaches colored compounds and changes the color of Jaggery to golden yellow. It ultimately releases Sulphur dioxide in Jaggery which is harmful to health.
6. The entire process of Jaggery production is conducted manually by traditionally skilled persons without having any scientific knowledge

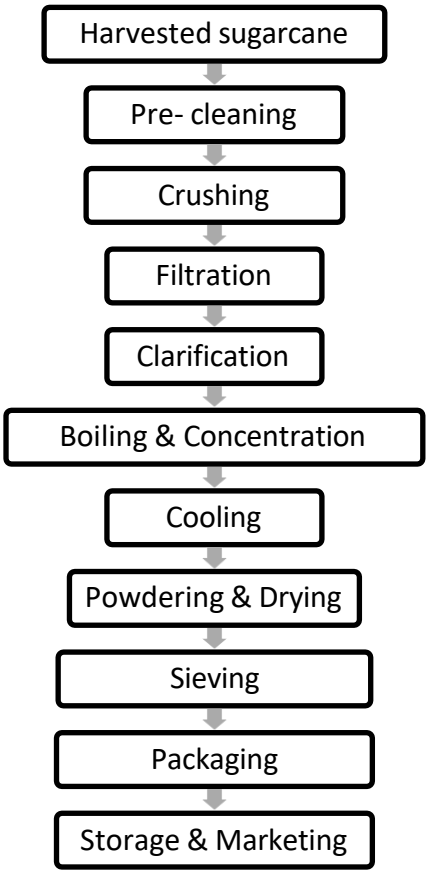
2.2.7 Disadvantages of Producing Jaggery by Traditional Method

1. Even though Jaggery is a popular product, the traditional Jaggery making process has remained a point of pain for producers, consumers and the community at large for several reasons.
2. Completely manual process gives an unhygienic and inconsistent quality Jaggery.
3. The process being manual, has capacity limitations.
4. Many times skilled manual labour is not available thereby risking product quality
5. Due to the uncontrolled nature of manufacturing, Jaggery may contain harmful chemicals such as SO2 and Polyacrylamides.
6. Inefficient and improper combustion in open pan boiling process produces high particulate laden combustion gases which pollute the surrounding atmosphere.
7. The traditional process uses waste materials for fuel which produce harmful gases and adversely affect the environment.
8. Jaggery with high moisture content has low shelf life of three months.

2.3. Modern scientific method of Jaggery Production

The jaggery producers should adopt the modern scientific technology for making quality jaggery at low cost of production. In this method, jaggery is produced in very clean, tidy and hygienic conditions. The utensils and equipments used in jaggery production keeps clean and sterilized. The cemented floor of jaggery unit remains free from insects, ants, flies, bacteria, fungi etc. The utilization of harmful and costly chemicals are avoided and herbal clarifying agents are used for clarification of cane juice.

This process of jaggery production involves various steps such as: harvesting, pre-cleaning and crushing of canes, filtration, clarification, heating, boiling and concentration of cane juice, cooling of concentrated cane juice (i.e. slurry), powder making, packaging, storage and marketing of jaggery.



2.3.1 Harvesting of Canes

The completely ripened canes (possessing more than 16% sucrose in cane juice) are harvested. The dry leaves are removed from the canes and the green top leaves are used as fodder for the domestic animals. The canes should be harvested properly (i.e. from the ground level), because jaggery production per unit area will be reduced if very long stubbles are left in the field and more soil particles shall be mixed in cane juice, if harvesting is done below ground level.

2.3.2 Pre-cleaning of Canes

To improve quality of jaggery, the canes should be cleaned thoroughly under high-pressure water guns to eliminate soil and dust particles, waxes, insects and other impurities present on sugarcane stalk. Some power drawn abrasive peeler of saw tooth type peeling unit have been developed for this purpose, which consists of four peeling blades (possessing 15 cm long 22-25 tapered teeth) attached at uniform spacing inside a square frame of 15cm. It can peel canes having diameters up to 3.5cm with peeling depth of 0.2 cm. The peeling unit has efficiency of 85% with capacity of 100 kg canes per hour.

2.3.3 Crushing of Canes

After pre-cleaning canes are crushed with the help of sugarcane crushers to extract cane juice. The cane juice is collected in clean stainless steel or plastic containers. The various types of crushers are available in the market. These crushers can be categorized on the basis of various aspects, such as: At present power, operated crushers are mostly used due to higher crushing power. A power operated horizontal crusher has relatively better extraction percentage as well as capacity.

- Based on Number of Rollers:

On the basis of rollers present in the crushers, there may be two roller, three roller and four roller crushers. The three roller horizontal crusher exhibited best performance of about more than 65%.

- Based on Orientation of Rollers:

On the basis of roller orientation, the crushers are of two types viz. vertical and horizontal. The horizontal crushers were observed to be 2-4 % more efficient in juice extraction than the vertical crushers.

2.3.4 Filtration of Cane Juice

After extraction, the cane juice is filtered. The juice filtration is carried out through a five-layered filter. The juice travels through the underground pipes and directly reached to the stainless steel juice-settling tank. It is settled for approximately 20 minutes. By this process, all course impurities like-bagasse particles, leaves, dust particles etc. are removed from the cane juice.

2.3.5 Clarification of Cane juice

The clarification of cane juice is necessary for making light coloured, crystalline, hard, less hygroscopic and hygienic jaggery. Earlier clarification was mostly furnished by heating method. Alum used for sedimentation of impurities, exhibited greater improvement in colour, while utilization of phosphoric acid exhibited the best golden yellow colour of quality jaggery. Sodium hydrosulphate makes the colour of jaggery very attractive, but from the health point of view, the utilization of detrimental chemicals degrades the quality of jiggery. Hence their use should be avoided. Natural clarifying agents should be used for clarification. of cane juice. The mucilaginous extract from vegetative clarifying agents viz. Doela (wild okra), okra, falsa or semal (40-60 grams of stem and roots of green plant per quintal of cane juice) or 70-75 grams of caster or groundnut or 30-40 grams of soybean seeds per quintal of

cane juice are supplemented prior to heating the cane juice for its clarification. The pH of the juice should be maintained at 6.0-6.2.

2.3.6 Boiling and Concentration of Cane juice

The juice is transferred from settling tank to boiling pans (i.e. vessels) situated over pit furnaces. The sugarcane juice is now heated up to 80° C by firing under the boiling pan. All impurities float up during boiling, which are removed by scumming. After that, it set to boiling. While boiling, the sugarcane juice gets concentrated and after evaporating almost all the water, pasty crystalline yellow substance known as slurry, is left in the boiling pan, which becomes solid after cooling. The cane juice is concentrated until the striking temperature reached. Scientifically, the striking point for solid jaggery is 120-122°C depending upon the varieties, paddling and allowed to cooling.

Alternatively, the clarified juice can be concentrated by heating in steam driven energy efficient multistage evaporators. Due to controlled boiling of sugarcane juice in stainless steel evaporators, formation of dark coloured compounds is minimised. The juice is further concentrated to its final consistency in a secondary concentrator to produce jaggery. The water evaporated during juice boiling, is recovered by condensation in various stages of the multiple effect evaporator, pre-heater and air-cooled condenser.

The bagasse is combusted in an efficient steam boiler which fulfils energy requirements of the Jaggery plant. The remaining surplus bagasse is sold as a valuable by-product.

2.3.7 Cooling of Concentrated Cane Juice

Once the striking point reached the concentrated cane juice, (i.e. slurry) is poured into cooling pan made up of wood or iron. The slurry is cooled here for some time and then puddle with the help of ladle. At the moment, when the shining of slurry disappears, it is ready for graining.

2.3.8 Powdering & drying

The mass is converted into granules by applying severe shearing action using wooden or stainless steel scrappers, sometimes even wooden hammers. The shearing action exposes more surfaces for atmospheric cooling; faster cooling rate causes increase in moisture evaporation. The granules or powdered jaggery is also made in granular jaggery making machine or in powder making machine.

The jaggery powder is dried from around 9-10% moisture content up to about 1-2% for good keeping quality, by way of sun, tray or solar drying. Tray or solar drying will help to maintain keeping quality intact.

2.3.9 Sieving &Packaging

Less than 3 mm sized crystals were found to be better for quality granular jaggery. The particle size significantly affects chemical properties of jaggery.

Jaggery can be packed in attractive packaging material that should protect jaggery from insects, dust particles, moisture and direct contact with hands, while handling and distribution. The composition, weight, name of manufacturing agency, date of manufacturing, date of packaging and health related aspects of jaggery etc. may be printed on the packet for enhancing its marketing.

2.3.10 Storage and Marketing of Jaggery

The maximum returns can be obtained by selling jaggery in off-season. Thus, jaggery should be stored in cool and dry places to avoid direct contact to moisture, because microorganisms exhibited maximum growth at 10% moisture content and 30°C temperature. The moisture content of freshly prepared jaggery ranged from 4-11%, while the optimum moisture for storage should be 7-8%. The optimum relative humidity for storing jiggery is around 41-60%. At very low temperature (1.5-3°C), jaggery can also be stored at very high relative humidity (92-95%).

The jaggery packets can be stored and marketed easily. Jaggery marketing can be enhanced by highlighting health related benefits of jaggery consumption over sugar.

2.4 Modified furnace by IISR, Lucknow

For heat economy, efficient modified bottom pans have been developed and 3 or 4 boiling pans are arranged in a series (line) and flue gases pass under the entire boiling pans one after the other and then escape through chimney. Indian Institute of Sugarcane Research, Lucknow has developed thermally efficient two-pan and three-pan furnaces. The processing time in these furnaces is comparatively less than the conventional furnaces. These furnaces have 2 or 3 pans for pre-heating of cane juice so that the processing time is reduced.

The modified pans have also been developed for two pan furnaces, which efficiently saves bagasse used for evaporating per kilogram of water from the cane juice and producing per

kilogram of jaggery as well as reducing time in jaggery production. A Waste Heat Recovery System (WHRS) has also been incorporated in IISR designed two pan furnace for recovery of waste heat for bagasse/jaggery drying and/ or space heating. The material mainly used as fuel in furnaces for heating the cane juice may be dried bagasse, dry leaves of sugarcane, straw etc.

IISR 2-pan furnace

IISR improved 3-pan furnace

Modified pans for jaggery furnace

2.5 Advantages of Modern Technology

1. No manual processing or handling other than feeding sugarcane to the crusher
2. Very high shelf life of 18-24months of the powdered Jaggery produced
3. Sulfur-free, chemical-free and hygienic processing
4. Consistent product quality
5. Resource conserving product, therefore better project viability
6. Compact plant constructed with food grade stainless steel contact surfaces
7. Continuous production process
8. Fetches higher price to farmers and producers

2.6 Organic jaggery

In manufacturing of organic jaggery, the process starts from cultivation of sugar cane. In sugar cane cultivation, the only natural organic fertilizer used is cow dung. The difference between organic and commercial jaggery making is mainly in clarification process. In organic jaggery making process, only organic clarifying agents and little bit of lime (to decrease the acidity of juice) can be used. So organic jaggery will be dark coloured when compared with commercial jaggery.

2.6.1 Challenges in producing Organic Jaggery

Farmers have not yet converted to organic sugarcane cultivation, which makes it impossible to produce organic jaggery and label it so. Even if the processing is organic, the final food product cannot be labelled as so, unless the raw material is organic too. This is a major limitation for Indian Jaggery, and products made thereof, to reach global organic food markets. Apparently, the main reason for not growing organic sugarcane is reduced crop output per acre. To mobilize cultivation of organic sugar cane, government will have to incentivise its farming by providing higher pricing for the crop.

2.7 Jaggery Production: Constraints and remedies

In India, jaggery industry faces many problems. Some of the serious constraints are:

i. **Juice Extraction Efficiency:**

The efficiency of cane juice extraction of the cane crushers is less than 60 %, which reduce the jaggery production per unit area. Hence, there is a great need to develop gearbox type efficient 3-4 horizontal roller scientifically improved crushers, to improve the juice extraction efficiency more than 70 %.

ii. Non-availability of High Jaggery Producing Varieties/ Hybrids:

Although, more than 600 varieties have been developed so far in sugarcane, but there is very limited availability of high jaggery producing varieties and hybrids of sugarcane. To improve jaggery and khandsari industry there is an urgent need to develop such varieties and hybrids, which can produce high jaggery and khandsari.

iii. Uncertainty in Market Prices:

There is very uncertainty in market rates of jaggery and khandsari, since if the production is high the prices goes down and vice-versa, results into narrow margin of profit to the jaggery producers, therefore they don't want to take a risk and sale out jaggery immediately at whatever may be the market price.

iv. Decreasing Consumer Awareness:

In order to increase per capita consumption of jaggery, special attention and campaign for consumer awareness towards consumption of jaggery at national level needs to be initiated. There is a scope to increase jaggery consumption by introducing and making various value added products. Jaggery can be used in manufacturing bakery products, chocolates, confectionary, beverages etc. The use of sugar can be replaced or minimized by jaggery wherever possible.

v. Poor Storability:

Jaggery is very critical to store. The non-sucrose constituents viz. salts, proteins, glucose, fructose and reducing sugars present in jaggery can absorb moisture from the atmosphere. This hygroscopic nature coupled with non-availability of proper storage structures are major reasons of poor storing ability of jaggery. About 10-25 %, losses may occur during storage of jaggery. To reduce economical losses of jaggery, high production technology and quality packaging along with appropriate storage technique and storage structures should be made available to the jaggery producers.

vi. Scarcity of Labour:

In jaggery industry, large number of labourers is required for various unit operations of jaggery processing. The unavailability of labour and higher wages is the severe problem. To overcome acute labour problems and for hygienically jaggery production, there is an urgent demand for automatization of jaggery processing.

CHAPTER 3

Packaging of Jaggery Powder

The major problem associated with jaggery storage is the presence of invert sugars and mineral salts which, being hygroscopic absorb moisture particularly during monsoon season when ambient humidity is high, and lead to spoilage.It has been estimated that more than 10% of jaggery produced in the country worth Rs. 40 crore is lost every year due to deterioration.

The traditional packaging methods for storage in vogue e.g. inside a blanket of bhusa or wheat straw, cloth lined with polyethylene sheet, aluminum foil, plastic containers, earthen pots and jute bag , give far from satisfactory results. Further, at retail level, the jaggery is sold in open and under unhygienic condition. Hence, there is need to evolve suitable packaging technique to enhance shelf life and maintain quality of jaggery.

3.1 Packaging materials used for Jaggery

i. Glass packaging's inert nature eliminates the risk of potentially harmful chemicals found in some plastics that can leach into food, but this is outweighed by drawbacks of weight, expensive nature and fragility for handling.

ii. Usage of polythene avoids film moisture absorption and liquefaction of jaggery. Certain researchers reported that the heat sealed LDPE packets of 150 gauge was best suitable followed by glass jar and PET jar.

iii. To control the hygroscopic nature of the powder jaggery, it can be packed in moisture proof polyethylene-polyester laminates and PET.

iv. Three ply (PET+ Aluminium Foil +PE) packaging material helped more in checking of inversion rate. This three ply has advantages due to its higher strength with low water vapour transmission rate and low oxygen transmission rate.

v. Kraft Paper, PE coated / LDPE Laminates are also prevalently used nowadays because of its salient features like visual appeal, durability, light weight and customizable nature.

vi. Standup pouches with or without gussets and zip are the highly trending packaging seen for jaggery powder. These are heat sealable.

vii. Depending on the packaging material and style chosen, horizontal/ vertical form, fill, seal machine or band sealing or sachet pouch machines can be employed.

CHAPTER 4

Export Market for Jaggery and Jaggery Based Products

India is world's second largest sugarcane grower with 354 million ton annual production and contributes to 70% of the world's total Jaggery production. About 88.5million TPA of sugarcane is processed to make 9.8million TPA of Jaggery through 40000 small units operating in the unorganized sector. Out of this about 40% is exported as interpreted from the report published by APEDA. Jaggery export market is of Rs 7500 million and domestic market of Rs 11000 million approximately. It is expected that this consumption can drastically increase by adopting modern processing technology with improved quality.

4.1 Export status of jaggery from India

The table shows details of top 10 Jaggery exporters from India.

Sr No.	Country	Qty, MT	Value, Rs. Lacs
1	SriLanka Dsr	51,210.12	12,812.82
2	Nigeria	15,150.59	11,729.73
3	Nepal	15,309.21	9,831.63
4	Malaysia	29,330.88	9,348.87
5	Tanzania Rep	27,513.08	8,172.20
6	U S A	8,200.90	7,958.36
7	UAE	10,558.17	6,603.86
8	Indonesia	15,988.10	5,307.30
9	Kenya	17,327.97	5,274.39
10	Uganda	17,124.12	4,496.18
	Total	**2,07,713.14**	**81,535.34**

4.2 Major constraints identified in jaggery exports suggested by APEDA

1. Lack of infrastructural facilities in jaggery production and insufficient price dissemination in jaggery marketing
2. Unorganized production - conventional methods followed under unhygienic conditions, without automation
3. There is no standard protocol being followed for making of Jaggery.

4. Since the demand for dark yellow Jaggery is high, producers use Sodium Hydrosulphite & other chemicals (non-food grade and harmful to the human health) to obtain the desired yellow colour.

5. Mostly units are using iron utensils for Jaggery making which are not permitted since iron is prone to gathering rust and making the product food unsafe.

6. There are no packaging standards for Jaggery

7. There is no Research & Development for product development and value-addition of Jaggery.

CHAPTER 5

Food Safety Regulations & Standards

5.1 Food Safety Regulations & Standards for cane jaggery or cane gur:

Cane Jaggery or Cane Gur means the product obtained by boiling or processing juice pressed out of sugarcane (*Saccharum officinarum*). It shall be free from substances unsafe to health and shall conform to the following analytical standards on the dry weight basis.

S. No	Characteristics	Permissible Limits
1.	Moisture, percent. by mass, Max	7.0
2.	Sucrose, percent. by mass, Min	70.0
3.	Total Sugars, Min	90.0
4.	Reducing sugars, percent. by mass, Max	20.0
5.	Sulfate ash, percent. by mass, Max	4.0
6.	Ash insoluble in dilute hydrochloric acid, percent. by mass, Max	0.5
7.	Extraneous matter and water insoluble matter, percent. by mass, Max	2.0

Sodium bicarbonate, if used for clarification purpose, shall be of food grade quality

2.8.8: Sodium Saccharin (Food Grade)

Sodium Saccharin is white crystals or white crystalline powder. It is odorless or has a faint odor. It is intensely sweet to taste, even in dilute solution. 1 g is soluble in 1.5 ml of water and in about 50 ml of alcohol. When tested in accordance with the method specified in Indian Standard, IS 5345, it shall conform to the following standards

S No.	Characteristics	Permissible Limit
1.	Purity as $C_7H_4NNaO_3S$, after drying at 120°C for 4 h, percent by mass, min	99.0
2.	Moisture, percent by mass, Max	15.0
3.	Acidity and alkalinity	To pass the test
4.	Benzoate and salicylate	To pass the test
5.	Readily carbonizable substances	To pass the test
6.	Toluene sulfonamides, ppm, Max	25.0

Calcium Saccharin (Food Grade) – (2.8.12)

Calcium Saccharin is white crystals or white crystalline powder. It shall be odorless or having a faint odor and an intensely sweet taste even in dilute solution. One gram is soluble in 1.5 ml of water. When tested in accordance with the method specified in Indian Standard, IS 5345, it shall conform to the following standards:

For Cane Jaggery or Cane Gur& Sodium Saccharin (food grade) and Calcium Saccharin (food grade), the following requirements must also be complied with.

S No	**Characteristics**	**Permissible Limit**
1.	Purity as $C_{14}H_8CaN_2O_6S_2$, on the dry basis, percent by mass, Min	99.0
2.	Moisture, percent by mass, Max	15.0
3.	Benzoate and salicylate	To pass the test
4.	Readily carbonizable substances	
5.	Toluene sulfonamides, ppm, Max	25.0

Machineries Manufacturers & Suppliers

S.No	Name of the company	Machinery
1	M/s. Kesavan Industries, 87, Dharapuram Road, Udumalpet – 642 126, Tamil Nadu. Phone: 04252 – 223939	Cane crusher
2	Moon Sun Group of Companies VidurkutiGanj Road, Bijnor - 246701, Uttar Pradesh, India Mobile :+91- 9412217161 Email : moonsun695@yahoo.com	Cane crusher
3	NSI Equipments Pvt Ltd 159, Saipuram, Opposite block Development Office, Delhi Road, Meerut – 250001, Uttar Pradesh	Cane Crusher
4	Shri. KhanderaoGhadge At/post- Kadamwadi, Tal – Karveer, Dist. Kolhapur	Churner, Juice Boiling Pan
5	Om Kailash Estate, Yadav Road, Rajkot, Upleta - 360490, Gujarat, India. Phone :+918037401692. Fax : +91--9978221107.	Juice Boiling Pan
6	**Annapurna Industries** Gola Road, LakhimpurKheri - 262701, Uttar Pradesh, India Call +91-8048424467	Juice Boiling Pan
7	**UP Small machinery corporation** Near Kashipur Road, Gandhi Colony, Rudrapur	Drying-cum Storage Jaggery Bin

8	**Infinity Engineering** 99, Somalapuram, Ambur, Ambur Taluk, Vellore-635802, Tamil Nadu, India	Jaggery crushing machine
9	**Tru Mark Enterprises** Shop no 14, grnd floor, Vighnharta Coop Housing Society, Mahadev Palav Marg, Currey Road, Mumbai-400012. India	Weigh filler and band sealer for standup pouch
10	**IPK Packaging (India) Private Limited** S.F.No. 9, Jagannath Industrial Estate, Chinnavedampatti Coimbatore - 641049, Tamil Nadu, India	Automatic pouch packing machine
11	**Best India** 14, 16/2, Mathura Road, OldFaridabadSector 20, Faridabad - 121002, Haryana, India	Automatic pouch packing machine
12	**Excel Plants & Equipment Private Limited,** Gate No. 611, Mouje Kuruli, M. I. D. C. Chakan, Pune - 410501, Maharashtra, India https://www.excelplants.com	Customized Industrial Jaggery Plant

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