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Sugarcane Production and Value-Added By Products

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Sugarcane (*Saccharum officinarum*), a vital cash crop from the Gramineae family, thrives in tropical and subtropical regions. Cultivated in around 200 countries, Brazil leads the world in production, contributing roughly 25% of the global output. The global annual yield stands at 1794 million tonnes, covering 25.4 million hectares. Sugarcane accounts for about 70% of global sugar production, with India being the second-largest producer and the top sugar consumer. With around 10% sucrose content, sugarcane contributes nearly 80% of global sugar production. Over the past six decades, India's sugarcane industry has grown significantly, with the cultivation area and production steadily increasing. India ranks second in cultivation area (5.11 million hectares) and production (303.83 million tonnes), following Brazil.

As a long-duration and nutrient-demanding crop, sugarcane requires high levels of macro- and micronutrients. Over 45 million Indian farmers and 65% of the rural population depend on this agro-based industry. However, high production costs and energy struggles necessitate the use of by-products as fertilizers to reduce expenses. The sugar industry, second only to textiles in India's agricultural sector, plays a crucial role in daily life.

Historically, between the sixth and fourth centuries BC, Persians and Greeks discovered "reeds that produce honey without bees" and spread sugarcane cultivation. Key products from the sugar and ethanol sector include sugar for the food market, anhydrous ethanol as a gasoline additive, and hydrous ethanol for flex-fuel vehicles, with some non-energy uses. Maharashtra stands out as a leading sugar-producing region in India.

Processing of Sugarcane

Sugarcane-processing industries generate various by-products that pose challenges related to storage and disposal. These by-products are produced during different stages of processing, such as milling, purification, and fermentation, for the extraction of sugarcane juice, sugar, and alcohol. Their potential use in agricultural ecosystems is being explored due to their organic nature, which influences soil properties through diverse nutrient pools and chemical and physical characteristics.

Upon arrival at the production facility, sugarcane undergoes washing before being processed through a series of four to seven milling units for broth extraction, where sugars are separated from fiber (bagasse). Bagasse is directed to the energy plant for fuel. To enhance sugar extraction, the chopped cane is washed with hot water multiple times. The final step involves passing the cane through a drying roller to produce bagasse for boiler use.

The extracted sugarcane juice can be processed into sugar or ethanol. For sugar production, the broth undergoes various treatments involving chemical reactions (through added substances) and physical processes (like sifting, heating, and flashing). These treatments aim to enhance sucrose recovery, remove impurities, and improve product quality by eliminating non-sugars, colloids, turbidity, and color. The broth is then heated to sterilize it, complete reactions with the alkalizing agent, coagulate insoluble impurities, and remove gases.

The treated broth is transferred to a decanter or clarifier, where flocculated impurities, known as sludge, are separated. The clarified broth flows from the top, free of most impurities. The sludge, combined with bagasse, is filtered to recover any residual sucrose, while the remaining filter cake serves as fertilizer in sugarcane fields.

Sugarcane-processing industries generate various by-products that present challenges in storage and disposal. The potential for their use in agricultural ecosystems is being considered, with by-products released during different stages of processing, including milling, purification, and fermentation, for the production of sugarcane juice, sugar, and alcohol. These organic by-products contain diverse nutrient pools and possess chemical and physical properties that can affect soil quality.

Upon arrival at the production facility, sugarcane is washed and directed to the broth preparation and extraction system, which includes four to seven milling units. The extraction process separates sugar from the fiber (bagasse), which is sent to the energy plant. To improve yield, the shredded cane undergoes multiple hot water washes to extract more sugar. A drying roller then processes the bagasse for use in boilers. The extracted juice can be used to produce either sugar or ethanol.

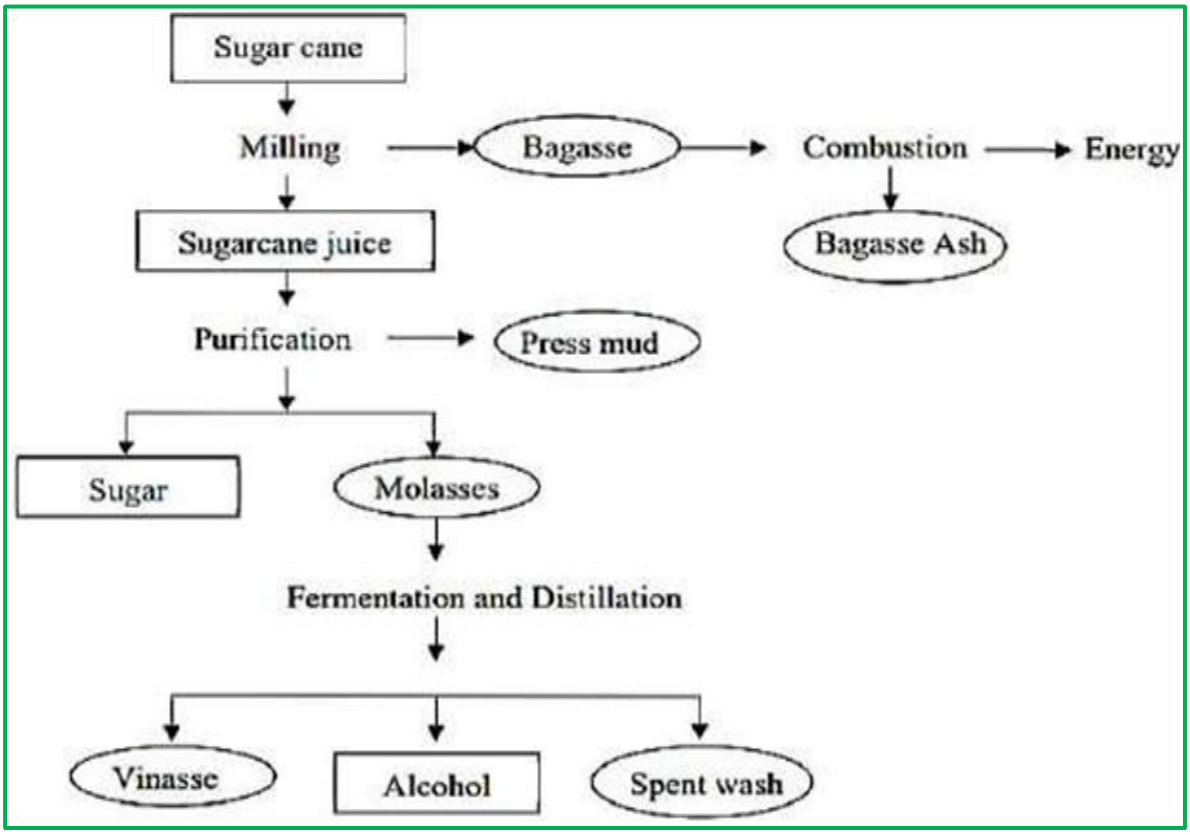
For sugar production, the broth undergoes several treatments involving chemical reactions (with added substances) and physical techniques (such as sifting, heating, and flashing). These steps aim to remove non-sugar components, colloids, turbidity, and color while enhancing sucrose recovery and product quality. The broth is then heated to sterilize it, complete reactions with the alkalizing agent, coagulate insoluble impurities, and remove gases. The treated broth moves to a decanter or clarifier, where flocculated impurities, known as sludge, are separated. The clarified broth flows out from the top, free of most impurities. The sludge is combined with bagasse and filtered to recover residual sucrose, while the remaining filter cake is used as fertilizer in sugarcane fields.

Ethanol production: the initial stages are similar to sugar production. The cane juice is evaporated to adjust sugar concentration and mixed with molasses to create the wort. This mixture is transferred to fermentation units, where yeast (Saccharomyces cerevisiae) ferments it for 6 to 10 hours, producing a fermented mixture called wine with an alcohol content of 7 to 10%. After fermentation, yeast is recovered and reused, while the wine is sent to distillation columns. Distillation, a physical method, separates the mixture's components based on their volatility, offering economic benefits through yeast reuse.

Various By-product of sugarcane

Sugarcane bagasse is a cellulosic agro- industrial byproduct released after crushing and extracting juice from the canes. It is pulpy residue and is fibrous in nature. In summer seasons, in local markets, we can see bagasse heaps at sugarcane juice corner. It is used as a bio-fuels or in industrial level;

It is used as a binding material. In general, bagasse contains major portion as cellulose, hemicellulose, and lignin are 47-52, 25-28 and 20-21 %, respectively. Apart from this 0.8-3 %, other compounds and ashes are pre-dominantly found (Rocha *et al*., 2011). It contains sugar, which is responsible for fast bio-degradable within 3 months. The application of bagasse in agricultural crop production system can be reduced the application rate of fertilizers. It produced organic acids, which mobilized the insoluble P from soil to soil solution in labile form. During application, it is suggested that these bagasse properly chopped; and applied one month prior to seed sowing in the field for proper decomposition.



Molasses: It is produced during sugar production from raw juice. It is a viscous liquid which can be separated by massecuite. It contains higher microbial activities used for the production of alcohol and/or ethanol, or fuel for ethanol. An average of 1 t sugarcane produces 23 L of molasses. Molasses is one of the most economically important byproducts of sugar industries. This has many industrial uses, viz., generation of alcohol, preparation of animal feeds, and food stuffs. Molasses containing large fractions of fermentable sugars which is diluted (three times) with good water and allowed to ferment in the presence of yeast culture (*Saccharomyces cerevisae*) either by batch or continuous process of fermentation. The fermentable sugars are recovered by the action of yeast as an alcohol (rectified spirit)/ethanol, leaving unfermented lower order sugars (such as dioses, trioses, tetroses, pentoses, etc.), water soluble amino acids, lignins, and other organic fractions, etc., in spentwash. The organic constituents present in higher concentration undergo reduction generating unpleasant odour.

Vinasse: Vinasse is the final by-product from the distillation of fermentation wine used to produce ethanol. It has a brown color that darkens with oxidation when exposed to air. This by-product is a significant and concerning liquid effluent in the agro- energy industry. For every liter of ethanol produced, approximately 10 to 15 liters of vinasse are generated. The challenge associated with this volume of vinasse stems from the toxicity of ethanol to the yeasts employed, which necessitates lowering the alcohol content during the final stage of fermentation. The efficient processing of sugarcane not only yields sugar but also generates a wide range of valuable by-products, such as bagasse, molasses, press mud, and bioethanol. These by-products play a significant role in various industries, including bioenergy, animal feed, and organic fertilizer production. Through advancements in technology and sustainable practices, the full potential of sugarcane can be harnessed to minimize waste, enhance economic benefits, and support environmental conservation. Moving forward, the integration of innovative processing methods and the development of value-added products will further contribute to the global economy and promote eco-friendly practices in the sugarcane industry.

Conclusion

The efficient processing of sugarcane not only yields sugar but also generates a wide range of valuable by-products, such as bagasse, molasses, press mud, and bioethanol. These by-products play a significant role in various industries, including bioenergy, animal feed, and organic fertilizer production. Through advancements in technology and sustainable practices, the full potential of sugarcane can be harnessed to minimize waste, enhance economic benefits, and support environmental conservation. Moving forward, the integration of innovative processing methods and the development of value-added products will further contribute to the global economy and promote eco-friendly practices in the sugarcane industry.