

Innovative Futuristic Approach for Sustainable Sugar Industry

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Abstract:- In modern era and lifestyle where everything changes with the blink of an eye, carrying on with conventional systems may not yield any measurable benefits to the Indian sugar industry. Amidst all challenges relating to production of high-quality sugars to compete in the global and international market, surplus sugar disposal, sugar exports, changing dietary patterns and drift in the consumer preferences has indeed led the industry to think beyond sugar towards product innovation viz. cane juice preservation, special sugar production, smart packaging of sugar, branding of sugar, production of low GI, multivitamin sugars, fortified, flavoured and other special sugars, production of bio-plastics, edible molasses etc., thereby achieving a good nutritional status and emerging as economically stable, self-sustained industry catering to the growing needs and requirements of the market as well. There should be advances in research and development of novel technologies for economic and sustainable conversion of the industry's resources into energy and value-added products which ultimately support the development of agro-based industrial sector with a more profitable, sustainable and environmentally responsible sugar system.

Keywords:- Urbanization; Nutritional Status; Fortification; International Market.

I. INTRODUCTION

Like many other industries, Indian sugar industry also faces critical economic sustainability issues on & off. There are several internal and external factors governing the prices of the sugar in the market resulting in sugar prices which are not lucrative all the time. Relatively lower and wavering profits for sugar both in national and international market, issues relating to disposal of surplus sugar, recent trends to produce renewable bio-based products in replacement of those derived from petroleum sources thereby reducing stress on environment, and increasing consumer demands for 'green products' are putting immense pressure on the sugar industry to diversify its strategies for sustainable future. There is plethora of possibilities and challenges for sustainable innovations in times to come whose potentials are yet to be harnessed to the maximum possible extent. Industrialists, technocrats and engineers play a vital role in bringing a radical change towards a smarter and profitable society with improved 'quality of life' for all stakeholders involved.

It is often believed that in order to have maximum customer satisfaction, the industries are required to invest more, but it's all about perception and misconception that exists in the economy. Since every industry is 'customer oriented and 'customer driven', there are examples where it is seen that there is immense potential for both cost cutting and growth of the industry/sector if one invests wisely in accordance with customer needs and customer experience. Bringing a change in the way an industry looks at the market as well as at its customer is necessary for its survival in present times. It is evident that there is a great deal of pressure to produce sugar in a sustainable way keeping in view the quality requirements for both national and international market is mounting on all parts of the value chain, from producers through to consumers. In regard to this, there is a need for the sugar industry to shift from the conventional routes of producing only sugar of a particular quality into having assorted products with high quality that would not only prove befitting to the industry but also would satisfy the wants of the consumers at the same time keeping pace with the competition in the anticipated market.

India now accounts for being the largest sugar producing geography with production of around 33 MMT. Sugar is highly fungible with comparatively small portion of production being amenable to special sugar market. Currently, Indian sugar industry is in the phase of excess sugar production to the extent of 6.5-7.0 MMT, carrying sugar surplus of about 14.2 MT at the end of season 2018-19 after due considerations for sugar exports of about 3.5 MT. Policy interventions for facilitating sugar export, and fixation of 'Minimum Selling Price' of sugar by the government has helped the sugar industry but there is a long way to go for achieving economic stability & sustainability in times to come. The need of the hour is for better allocation of the present resources in making assorted product line that provides the industry as a cushion for its better survival.

Change is a part of life therefore, up-gradation of the existing technologies for cleaner, greener processing, plant and process expansion for greater deal of value-added products is the right call the sugar industry technocrats must take without any second thought, with a holistic approach to achieve cleaner, greener, natural and nutritive product, process and policy. Innovations like sugarcane juice preservation, fortified sugars, multi-vitamin sugars, low GI sugars, use of filter cake for the production of Bio-CNG, cane wax, trade of molasses as edible molasses, molasses/ethanol-based chemicals, use of bagasse for particle board manufacturing, as dietary fiber, surfactants,

eco-friendly cutlery in addition to co-generation, production of bio-plastics etc. would not only be beneficial for the industry but will also act as a win-win situation for both the consumers who happen to be the main driving force for revenue generation and also these innovations would have no harmful impact on the environment.

In light of the above-mentioned scenario, the paper provides a review of the possibilities and innovative approaches and solutions that the future holds for the Indian sugar industry in times to come so as to remain economically viable, self-reliant and self-contained.

II. BEYOND SUGAR - SUSTAINABLE APPROACHES TOWARDS VALUE-ADDITION

In line with the shared vision of moving forward, the sugar sector has a number of transformational opportunities which have remained largely untapped. The industry has the potential to cater to the large and growing domestic sugar market as per its requirement and emerge as a self-sustained industry by providing better products and creating value addition. Some of such innovative approaches are discussed herewith:

A. Sugarcane Juice Preservation

The complex attitude of consumers towards food commodities often linking food to health has caused a tremendous shift in the market. A study conducted by grand view research in 2018 indicates that the Indian soft drink industry since past two years has seen growth (CAGR) @ 11% and 5% in terms of value and volume respectively with around 5.9 billion liters of soft drinks being consumed in a year. Studies also report that non-alcoholic beverage market has a value of about USD 3,266 million in 2018 and is further expected to grow at a CAGR of 17.6% till 2020 [1].

With the increasing rates of obesity, on the behest of World Health Organization (WHO) many countries have imposed sugar tax on drinks containing sugar. For instance, introduction of 10.0% tax on sugary beverages in Mexico led to 6.0% average reduction in its purchase during 2014 [1]. It is obvious that it would affect the consumption rates of carbonated drinks over the subsequent years. Likewise, with the changing lifestyle and eating habits of the consumers, it has been observed that there has been a switch towards fresh juice drinking habit, and the market has seen a decrease in sales of carbonated drinks in various countries [2]. While the market for energy drinks is expanding and is expected to grow further, the drink manufacturers have a challenge of supplying drinks that consumers feel are safe to consume as there has been a lot of discussion on ill effects of such drinks and health risks associated with them.

As per the report published by MoFPI in 2017, natural health drinks are considered to be one of the fastest growing sectors in FMCG market with annual growth of about 22% [3].

One such natural health drink is the traditional sugarcane juice which has a potential & assured market looking to its benefits and liking amongst the consumers. Out of the envisaged routes, bottling of natural sugarcane juice or cane juice fortified with ginger and lemon etc. is considered as a very promising approach for sustainable market in present times. Being rich in iron, calcium, potassium, proteins and carbohydrates, sugarcane juice has several benefits such as – it acts as a diuretic and helps maintaining proper functioning of the kidney. Sugarcane juice is also reported to help strengthening liver and thus it is used as a remedy for jaundice. Further, being rich in minerals, sugarcane juice helps in preventing tooth decay [4].

Sugarcane juice gives instant kick of energy and also suppresses thirst and hence is a very popular drink in summers. Despite being rich in sugar content, sugarcane juice is good for diabetic patients, reason being that it contains natural sugars that have a lower glycemic index thereby preventing sudden rise in blood glucose level. Therefore, sugarcane juice may act as a substitute of aerated drinks for diabetic patients. However, type-2 diabetic patients must consult with the doctor before consumption and should keep the intake to a minimum. Sugarcane juice is also very essential when it comes to the skin health. Glycolic acid present in sugarcane juice helps prevent ageing, keeps the skin hydrated reduces blemishes and acne. While there are several advantages of sugarcane juice, it is important to ensure that the extraction of the juice is done in a hygienic manner. Therefore, the industry may focus on processing and packaging of sugarcane juice keeping the shelf life and conscious consumers in mind [5,6].

B. Speciality Sugars

Sugar is used as an additive in various food applications. Demand for 'green labelled', 'natural ingredients rich' food products is gaining momentum in national and international market and with strong healthier and natural food consumer base, the demand is expected to grow in the anticipated market. With sugar industry having surplus sugar in hand, diversion of this excess lot towards production of specialty sugars may be one of the favourable approaches towards value-addition.

Industrial sugar has a huge market for industries like bakery, dairy, confectionery, beverages, canned & frozen foods etc. Amongst them, confectionery is said to be the largest and the most fast growing sector because of its variety of application and broad spectrum of products such as marmalade, chewing gum, sweets, candied nuts, chocolates, and chewing gum. Increase in confectionery industries, rapid inclusion of specialty sugars in various cuisines and availability of hundreds of varieties are boosting the market of specialty sugars at a healthy CAGR. Technological advancements and growing population significantly contribute towards the growth of the specialty sugar market in global perspective.

With the modern concept of value-addition, specialty sugars are emerging as a swing and also acting as a brand value for the companies. Specialty sugars are high quality high premium sugars with increasing domestic (approximately 250000 MT per annum) and worldwide demands. Various kinds of special sugars such as breakfast sugar, caster, icing sugar, cube sugar, natural cane sugar, various kinds of brown sugar, pharma sugars may give rise to an incredible opportunity for companies to substantially drive their profits [7]. Production of various kinds of flavoured sugars like orange, ginger, lemon, butterscotch, cinnamon etc. has immense potential due to their wide range of application such as use in bakery recipes, candy making and many more. It can also be used in coffee bars, dessert toppings, sugar bulk bars, baking, salads, cocktails, mock-tails and coating of various products. To further add to the shelf, value-addition to sugar, considering the nutritional aspect of the consumers, sugars such as low-GI sugar or multivitamin sugar can also boost up the market of specialty sugar [8]. Innovations in food science & technology that not only addresses the escalating demand for food but also come up with new products, processes, and packaging developments in the food business and balance taste with nutrition is the need of the hour. Keeping this in view, one such possible innovation could be co-crystallization of sugar with nutrients. Such approach offers flexible, simple and economic means of value addition. This encapsulation technique provides a practical means to enhance the properties of the original material and therefore enhance the product line of the industry.

C. Jaggery

The never ending demand for food has been greatly influenced and steered up by emergent trends in food processing sector, particularly with the growing focus on health and wellness of the consumers. Modernization in food technology that not only cater to the substantial increase in the demand for nutritious food but also that brings in novelty products, processes and packaging to the existing culture of manufacturing in the industry is the need of the hour. Approaches like these would give a tremendous boost to the sugar industry towards a significant drive to their profits. With trends such as elimination of synthetic and artificial ingredients, replacing them with organic, naturally occurring ingredients have paved way for the companies to offer more transparency in the nutritional aspect of their product and also elaborating their product line using prevalent food habits thereby making themselves competitively more strong than the other players in the anticipated market, also capturing huge health conscious consumer base.

Considering this, one such product 'jaggery' has immense growth potential both in national and international market due to its high nutritional and medicinal values. Jaggery is used for direct consumption or as a sweetening agent for preparation of various dishes [9]. Jaggery is said to

be the unrefined natural non-centrifuged sugar which is processed with the use of natural clarificants of vegetable origin. However, at present, it is being produced in the country by un-organized sector in small units using unwanted chemicals and processing it in rather unhygienic conditions. Jaggery is also referred to as "medicinal sugar" finding its application in ayurvedic medicines for curing infections. Since nearly 70% of global production is being done in India, jaggery industry supports a huge rural economic system providing employment to millions of people. Amongst various value-added products from the sugar industry, jaggery processing and packaging in sustainable, hygienic and environment friendly way would help the sugar industry to strengthen its revenue base and also its status in the market [10,11].

A study conducted by Agricultural & Processed Food Products Export Development Authority (APEDA) threw light on the importance of jaggery and reveals that while refined sugar mainly consists of glucose and fructose, jaggery contains glucose and sucrose and is a rich source of minerals and vitamins which lacks in the refined sugar [12]. The mineral content of jaggery includes calcium, phosphorus, magnesium, potassium and iron and traces of zinc and copper. The vitamin content includes folic acid and B-complex vitamins. Thus, other than being a good source of energy, it also prevents rheumatic afflictions; prevents disorders of bile; helps in relieving fatigue, relaxation of muscles, nerves and blood vessels; maintains blood pressure and reduces water retention; increases hemoglobin level and prevents anemia. It is also pertinent to mention that being the major jaggery producer; India has been recognized as one of the leading traders and exporters of jaggery to the world. Reports indicate that around 3, 13,826.00 MT of jaggery worth Rs. 1,606.08 crores/ 230.03 Millions USD has been exported by India in the year 2018-19. The major bottleneck faced by the jaggery manufacturing sector in India is lack of proper infrastructure and manufacturing facilities for jaggery processing and packaging, limited resources for product innovation, insufficient price dissemination and a sense of responsibility amongst manufacturers. Traditionally jaggery is made by processing the sugarcane juice in open pans into jaggery moulds of different sizes. Other than jaggery moulds, various other forms viz. solid, liquid, powdered, granular form of jaggery can also be made to elaborate the product line. Also for value-addition, vitamin C infused jaggery, flavoured and other various types of jaggery can also be made available to the consumers. Such innovations will indeed add more value to the present system in times to come and would definitely prove to be beneficial for both the farm and the folk and last but not the least would give added revenue to the sugar industry as well. However, the processing shall require to be carried out under hygienic conditions carrying out higher level of filtration and setting up mini jaggery plants using steam as heating media [13].

III. POTENTIAL USE OF BY-PRODUCTS OF SUGAR INDUSTRY THROUGH INNOVATIONS

The most important environmental challenge faced by the world is management of the waste which is generated from various agro processing industries. Now-a day's emphasis is given on minimization of waste and increasing revenue generation through by-product value addition. Several researches are being focused towards converting sugar industry on flexible bio-refinery concept aiming at successful conversion of technologies for efficient utilization of sugarcane biomass that will become an essential component for a sustainable sugar industry.

A. Potential use of Sugarcane Bagasse

Fibrous bagasse is one of the most important by-product from the sugar industry in terms of volume (28-32% on cane). Primarily sugarcane bagasse is used as a fuel for steam and electricity generation which is further utilized by the sugar factories itself or is exported to grid. With the advent of time apart from using it as a fuel for boilers, bagasse had its application in making of paper and pulp and numerous other value-added products. This is considered of paramount importance as bagasse based co-generation and export of power is losing its charm as a result of reduced power tariffs due to competition with tariffs offered by power generated through non-conventional energy resources [14]. This by-product being widely available, cheap and also being environment friendly can be a potential source to a huge number of products and therefore its potential is to be fully harnessed by the industry in order to add benefits to the present system. Several literatures have reported the use of this lignocellulosic biomass fraction for manufacture of number of products of high market potential, viz., production of bio-ethanol, furfurals, dietary fiber, mushroom, surfactants, cosmetic ingredients and graphine oxide etc. With increasing concerns on environment and ecological wellbeing and increasing use of conventional non-biodegradable, non-renewable sources of energy, there has emerged a need for technologies and approaches for sustainable and environment friendly products and processes [15]. To throw light on the above thought, studies have been reported about the use of bagasse in manufacture of new bio-degradable plastics. This search for biodegradable plastics evolved as a result of the emerging environment concerns and also for the purpose of replacing petroleum based products from the ecosystem. Studies report that the only constrain in manufacture of such high quality plastics is the cost of production i.e. the cost associated with the carbon source for the production of the bio-polymer. A recent research published describes production of bio-polypropylene (bio-PP) by utilizing various biomasses, mainly crop residue, to produce iso-propanol (IPA) which further undergoes dehydration to form polypropylene monomer [16]. This novel bio-PP has wide range of application such as food packaging products, spanning automobiles parts to medical care products, etc. Several literatures suggested the efficient use of agro-residue such as sugarcane bagasse for production of poly hydroxyalkanoates (PHA) [17]. Since more than 50% of the cost of production is accounted by the carbon source, the effective use of these

agricultural waste would help in its excessive management and also would help the industry to balance their situations.

It is also pertinent to mention that with the growing wood panel industry as a result of rising demands from the furniture sector, search for new raw materials has increased tremendously. Several literatures have reported the use of sugarcane bagasse in the production of particle board panels and when the quality of the above mentioned panels was compared with that of the conventional panels made using other materials, it showed promising results [18,19]. In a nutshell, along with adding value to the system, production of particle board using sugarcane bagasse would help in meeting the demands of the wood panel industry in terms of fetching raw materials as well as this approach would open new doors for both the sugar industry and wood panel industry to expand thereby reducing the dependency on timber and eventually would help in reducing cutting of forest thus preserving the ecosystem.

B. Potential use of Filter Cake

Sugar production being high energy and water driven process has a considerable impact on the environment. With a view to reduce the negative impact caused by the sugar industry, several attempts are being made mainly focusing on recycling and better utilization of industry's by-products. Amongst the by-products of the sugar industry, filter cake in particular is second main solid waste generated from the sugar industry with annual production of around 9-10.5 million metric ton [20]. Proper disposal of this by-product is of great concern for the industry. Its management, handling, storage and transportation becomes difficult due to high water content of filter cake and also its peculiar smell which causes insect and pest infestation. Filter cake is largely being utilized as bio-fertilizers and is used as compost in sugarcane fields. Since direct use of filter cake pose risk and several limitations, it is used with other fertilizers to improve the fertility of the soil, pH balance in soil, improve drainage and also to promote growth of healthy microflora to enhance soil quality for better crop management [21].

Several literatures have reported the use of filter cake as fuel along with bagasse in the sugar factories thereby adding economic value to the present state of the filter cake. Studies reported the potential use of filter cake as fuel. According to the literature, the lower heating value (LHV) of filter cake on wet basis is said to be around 8.8 MJ/kg while that of bagasse is around 9.95 MJ/kg, which means, about 1.2 ton of filter cake in energetic term is equivalent to one ton of bagasse. The studies concluded that the blend of filter cake/bagasse as boiler fuel for sugar factories is promising as it reduces the disposal, storage and management cost of filter cake. Environment impact of filter cake is also reduced as burning of filter cake results in release of CO₂ which has 20-21 times lower impact on environment towards global warming as compared to an anaerobic decomposition [22].

Another aspect which talks high on further exploring the potential of filter cake could be in manufacturing of cane wax. Waxes have been used in various applications such as

for making candles, as coating materials, in textile processing, rubber and adhesive industries etc. The waxes in present times are manufactured either from minerals, plant or animal derived materials, or by different synthetic means. According to studies reported by P. Manohar Rao, filter cake may present a good source for extraction of sugarcane wax as during the clarification of cane juice most of the wax and fats are precipitated and come along in the filter cake itself. However, there are certain constraints in the processing of sugarcane wax with respect to its properties as compared with carnauba wax which most of the carbon paper, polish, fabrics manufacturers use. Properties such as hardness of cane wax needs improvement and also oil retention and wetting property are required to be improved and worked upon. If such constraints could be worked upon, it may open a new area of economic value for the filter cake [23].

With the depleting natural resource and increasing demand for green and clean energy, there is indeed a need to look for positive alternatives that maintain the ecosystem balance and also cater to the need of the humans without affecting the natural resources. One such rational approach towards sustainability is adoption of bio-energy systems with a vision to save fossil energy [20].

One of the advantages of using bio-energy system is their low greenhouse gas (GHG) emissions compared to fossil-energy ones. There are various alternatives that can be adopted for alternative fuels but among them, bio-gas seems to be one of the most promising and best alternatives to the present fossil fuels. There are number of countries that have different bio-gas plant set-up in their vicinity and are in the process of installing more, for instance Italy has doubled the bio-gas plants in 2013 and is expected to increase further [24]. Considering filter cake % cane been about 3.5 and limited option available for its commercial exploitation, this by-product having substantial amount of organic material can be used for production of bio-gas, compressed biogas/bio-CNG. With proper investment and planning, this untapped potential can be harnessed which will also help in value addition for the sugar factories. Although a thorough study relating to the cost of production and the quality of the raw material is to be carried out.

C. Potential use of Molasses

Molasses is one of the most valued by-products of the sugar industry. In present times molasses is used primarily by the distillation industry. Although due to the recent pricing policy announced by the government of India, production of ethanol has gained momentum, but a part of the molasses can still be used for converting it to a value added product earning higher revenues as compared to those with ethanol production. Wide range of molasses as obtained from different sources exists in the market such as cane molasses, beet molasses and refinery molasses. Various MNC's are branding and selling edible molasses @ Rs. 1000/kg or so which is much higher than the normal price of molasses sold by the sugar factories. This edible molasses has wide application ranging from bakery product to enhancing flavouring properties in meat, herbs, chocolate,

spices etc. also help in fortifying sweets, savoury or spice flavours. Many innovative technologies and ideas can be explored to make this product more nutritious and more easily available in the market which therefore opens a new field for the sugar industry to prosper.

It is also pertinent to mention that many more value-added products like organic acids, enzymes etc. can be produced by utilizing molasses in a better and efficient way. For instance, literatures have shown potential use of sugarcane/sugar beet molasses in production of enzymes such as xylanases, invertases etc. that have numerous applications in the various industries. On one hand xylanases is widely used in several industrial and biotechnological application such as; it is used for wood pulp bio-bleaching, paper making, for making supplements in animal feed and for production of xylitol. It is also used in manufacture of various food and beverages and also for bio-ethanol production.

Studies have reported that xylanase enhance the bleachability of the bagasse soda pulp and also reduce the use of chlorine dioxide by 33%. On the other hand, invertase enzyme also play vital role in food industry for production of various artificial sweeteners, production of invert sugar. Invertase is also used in making honey, biosensors for sucrose detection etc [25]. Studies report use of sugarcane molasses as substrate for invertase production. Studies concluded that using by-product of the sugar industry i.e. molasses for invertase production by *A. niger* GH1 is attractive as it lowers the cost of production and also gives good yield of the enzyme [26].

Organic acids and their derivatives are used in various applications in food, beverage, feed production etc. Organic acids such as itaconic acids, citric acids, lactic acids etc. are widely used in resins, rubber, plastic, surfactant, solvent, food, detergent, cosmetic, pharma and chemical industries. They also find their application as anti-oxidising, flavouring, preserving as well as buffering agent in food, beverage, cosmetic industries. Several attempts have been made to find replacement of the expensive carbon source used for the production of such acids. Cheap alternative substrates such as sugarcane and sugar beet molasses seem promising. Lunelli et.al reported the use of sugarcane molasses as carbohydrate source for production of lactic acid with good yield of lactic acid of around 0.83 g/g [27].

IV. CONCLUSION

As the age old adage says 'little strokes fell greater oaks', similarly, several such sustainability initiatives, with a focus on production processes, environment and nutritional status should be taken up by the sugar industry in unison with the growing demands from health conscious consumers, food and beverage companies and also from international markets in order to remain economically sustainable and viable. Therefore, it is essential for the industry to expand their product line with innovative solution that keeps balance with the current market scenario. It appears essential to produce special sugars like fortified

sugars, mineral sugars, low GI sugar and sugarcane juice products providing nutritional value and also bringing value addition to the sugar factories. An integrated approach towards value-addition and utilization of by-products in an innovative manner as discussed appears to be a promising approach for economic feasibility and sustainability of the sugar industry. Therefore, it may be anticipated that such innovative strategies will contribute to efficient management of the triple bottom line components of environmental responsibility, economic return and social development for the overall growth and development of the sugar industry.

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