IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Sugarcane industry: by-product valorization for economic sustainability

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Abstract: Agro-industrial production and processing generate huge amount of by-product and waste resulting in significant environmental impact and a great deal of investment being incurred during its storage and disposal. Therefore, proper management and efficient waste utilization is essential for environmental sustainability and human health. Sugar industry is said to be the second largest agro-processing industry next to cotton textiles, playing significant role in the growth and development of India's economy. During the processing of sugar, sugar mills generate several waste such as molasses, bagasse, filter cake, waste water and boiler ash. Utilization of these waste generated from the sugar industry and converting them into value-added by-products is of paramount importance. Since the market price of sugar remains volatile and at times fall below the production cost, innovations and diversification to produce more value-added products i.e. converting "waste to resource" may help the sugar industry to have a better economic sustainability as compared to being a stand-alone sugar factory. The paper elaborates on innovative ways to utilize the by-products and waste of the sugar industry thereby adding value to the existing product line and lowering dependency on revenues from sugar. Improvement in product quality and such innovative management of waste may accelerate the growth of the sugar industry as well as help in maintaining clean and healthy surroundings and providing quality product as per consumer need.

Keywords: Agro-industry, value-addition, by-product, diversification, sugar industry.

I. INTRODUCTION

Agriculture forms the backbone of the Indian economy supporting about 70% of the total population and also contributing significantly to the GDP of the country. Agriculture, thus holds a significant stature in social, political and economic affairs. Sugarcane is one of the major cash crop in India where more than 50 million farmers are directly or indirectly dependent on the sugar or sugar based industries. India in amongst the top ranked country for sugar production (expected production during 2020-21 being 30 MMT) and consumption (around 26 MMT) with production being next to brazil. The industry on & off encounters issues of economic sustainability to the extent that the issues of pending cane prices arrears become a burning issue attracting the government. Indian sugar industry through its tireless experience has learnt a lesson and is in the process of transformation from being a standalone sugar factory into being an integrated complex having facilities for power export and ethanol production.

The importance of by-product utilization beyond power and ethanol has been realized by the industry as better management of by-products could be a promising asset to the sugar industry as a whole. The by-products of the sugar industry whose potential have not been explored to its maximum, have huge scope to be converted in to value-added products through innovative approach and thereby would yield more income to the industry through sale and marketing of such innovative and attractive products rather than sugar. There is a long way to go as it is well said that Rome was not built in a day similarly changes don't just happen overnight, but a thought process is required to be initiated so as to see a self-sustainable sugar industry in times to come. The potential of revenue generation through utilization of various by-products viz. bagasse, filter cake and molasses is to be taken up in an innovative manner besides developing technologies for converting huge amount of surplus water into good quality water to meet human needs and earn revenue. In fact, sugar industry is to be converted from a single product factory to multiproduct factory.

II. SUGARCANE VALUE CHAIN – EXISTING SCENARIO AND WAY FORWARD

As evident from last couple of years, India has grown to be a major sugar producing geography. Sugar is highly fungible with comparatively small portion of production being amenable to special sugar market. Several policy interventions in regard to facilitating sugar export, and fixation of 'Minimum Selling Price' of sugar by the government has helped the sugar industry to be economically viable but still 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. Figure 1 gives a brief idea of how the by-products of the sugar industry are being utilized in traditional manner.

Primarily sugarcane is processed to obtain sugar, the fibrous residue known as bagasse is majorly used for cogeneration, molasses is mainly diverted for animal feed or used by distilling industry and filter cake being utilized for production of cane wax or are being used as fertilizers. Indian sugar industry is an industry with immense potential. It is an industry where every product and by-product can serve as a potential and economic raw materials for other manufacturers for production of numerous value-added, bio-based products that may have great market prospect and acceptability amongst consumers as well. There are some countries who have maintain competitiveness through diversification for instance, Mitr Phol's total revenue generation from sugar alone stands for around 42% only, while remaining 58% revenue generation is through by-product diversification. In a similar manner, Kaset Thai International Sugar Corporation (KTIS) aims high in reducing its revenues from sugar to 50 % from 80 % by investing into co-products. Therefore, Indian sugar industry too should start thinking outside of the box, bringing a change in the way the industry looks at the market as well as at its customer is necessary for its survival in present times. There is plethora of possibilities and challenges for sustainable innovations that the sugar industry can look upon in times to come whose potentials are yet to be harnessed to the maximum possible extent (R. PJ Manohar 1997). Keeping this in view figure 2 illustrates the possibilities and futuristic approach for better utilization of product and by-product that the sugar industry may think upon for better survival in the market. The model as given in figure 2 gives an idea about the bio-refinery concept the industry must adopt. Such model would help the industry to explore food sector, as well as healthcare sector and also the nutraceutical market as well.

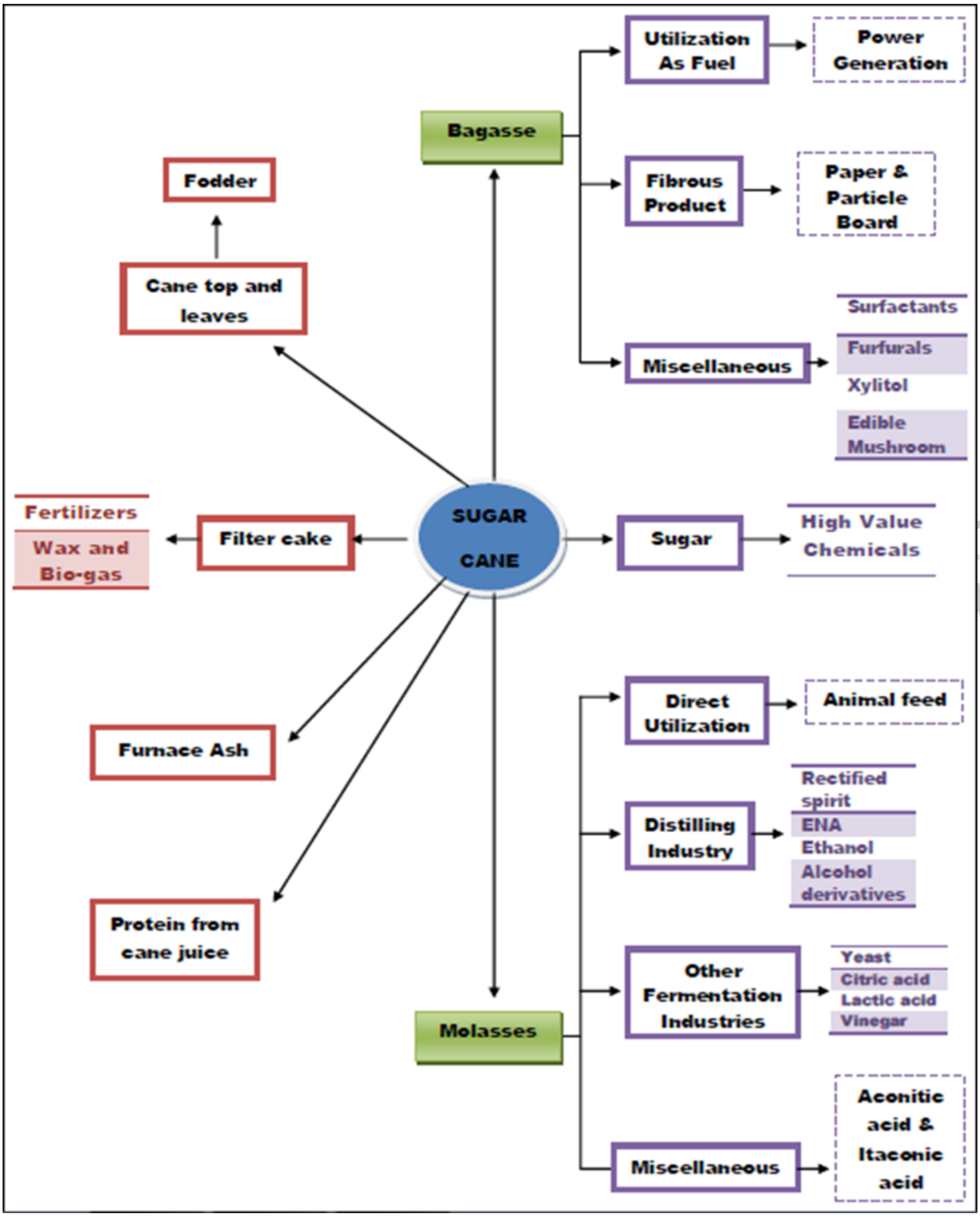


Fig 1: Utilization of products & by-products of sugar industry (existing scenario)

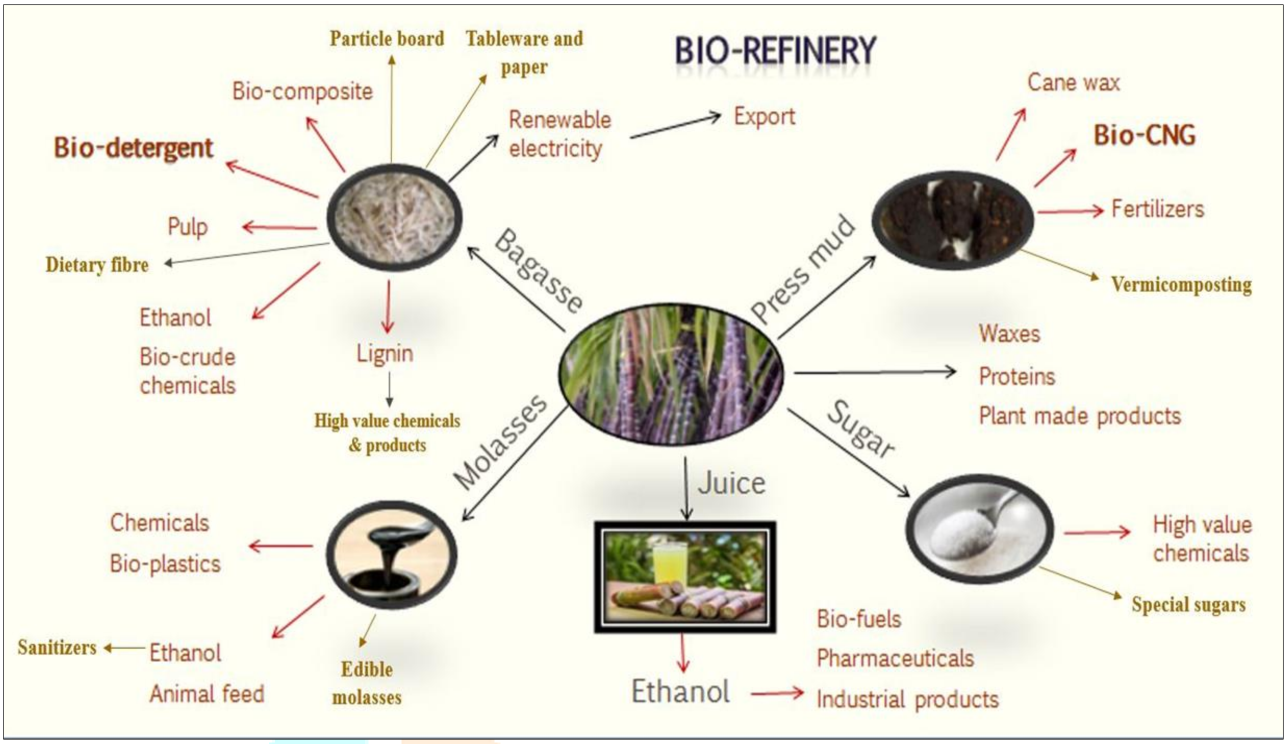


Fig 2: Bio-refinery concept for sustainable sugar sector

III. INNOVATIVE APPROACH TOWARDS BY-PRODUCT UTILIZATION FOR SUSTAINABLE SUGAR INDUSTRY

3.1 BAGASSE

During the processing of sugarcane for manufacture of sugar, the fibrous biomass left after the extraction of cane juice is termed as bagasse. This fibrous biomass is considered as one of the most important by-product of the sugar industry in terms of volume (28 – 32 % on cane). Usually sugarcane bagasse is used as a fuel for production of steam and electricity which is further utilized by the sugar factories itself and to some extend even exported to the grid. With the passage of time, the charm of bagasse based co-generation and export of power to grid was fading away as result of reduced power tariffs due to competition with tariffs offered by power generated through non-conventional energy resources and therefore a more comprehensive attitude was required for proper disposal of such huge voluminous by-product. Bagasse, a lignocellulosic biomass is generally composed of cellulose 23 %, hemicellulose 12.3 %, lignin 9.9 %, fat and wax 1.8 % and many other elements such as carbon 48.7 %, hydrogen 4.9 %, nitrogen 1.3 %, phosphorus 1.1 %, ash 2.4 % (P. Ashok 2000). 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. As bagasse is primarily used for fuel, it also finds its application for several other purposes likewise paper and pulp making or it is also seen to be used in cattle feed as well (M. Narendra & K.K. Anoop 2019). With great concerns of consumers towards environment, there has been a shift in the use of disposables and non-plastic materials for packaging that are bio-degradable, low cost incurred for their manufacturing. This trend has led an altogether different sector for efficient utilization of bagasse. Present times have shown various manufacturers jumping into the production of disposables, tableware's, bottling, packaging materials, particle board etc. that are processed using bagasse (Poopak, S. & Reza, A. R. 2012). The illustrations as given under figure 3(a) to 3(h) given a board perspective of attractive use of bagasse for various consumer friendly products.

Fig 3 (a) Multiple bagasse products: - tableware, paper, packaging, bottles, MDF board, plastic composite resins

Fig 3 (b) bagasse tableware/dinnerware- disposable plate, bowl, tray, cutlery

Fig 3 (c) Bagasse paper: - Photocopier paper, kraft, printing, tissue, toilet, wall paper, bags, cardboard

Fig 3 (d) Bagasse packaging: - food, fruits, eggs, beer, perfume, deo, cosmetics

Fig 3 (e) Bagasse bottles: - mineral water, milk

Fig 3 (f) Bagasse bottles: - milk, water, wine, oil, medicine

Fig 3 (g) Bagasse board: - MDF, HDF, panel, walls, designer panel, furniture

Fig 3 (h) Bagasse resin composites: - (bio plastic) resin for multiple industrial products: - automobile parts, chair, dustbins, pen, mobile, computer

Sugarcane bagasse contains complex lignocellulosic material which can be used as low cost energy and carbon source for fungal cultures. Generally, fungi are grown on potato dextrose agar (PDA), Sabouraud dextrose agar (SDA), or Cornmeal agar (CMA) which is very expensive. Basically every fungus requires carbon, nitrogen, and energy source to grow and survive. Studies have shown that sugarcane bagasse may meet these requirements and work as a fungal growth medium and can replace expensive media in the market. As per the studies conducted, one quintal of bagasse could yield approx. 87 kg of oyster mushroom (*pleaurotus sajorcaju*) and about 80 kg of white button mushrooms (*agaricus bisporus*). To add to the shelf, sugarcane bagasse may be seen as a rich source of dietary fibre but its major limitation is its low digestibility which is due to association of lignin with cellulose and hemicellulose. Lignin is said to reduces the digestibility of cellulose and hemicellulose by physically protecting them against enzyme degradation. Efforts are being made to overcome this difficulty by using number of chemical and biological treatments towards delignification. Therefore, in times to come, sugarcane bagasse fiber may serve as one of the most popular nutrients in the nutraceuticals industry.

Bagasse being a lignocellulosic material comprises of cellulose, hemicellulose and lignin. While on one hand the cellulose and hemicellulose component of this by-product is being exploited for value-addition and is being utilized to its maximum extent possible for production of products viz-a-viz cogeneration, production of dietary fiber, paper and particle board, paper etc. the lignin portion is often left unexplored and untouched. Several literatures have shown that while cellulose and hemicellulose portion of bagasse are of great use for making different value-added products, the lignin portion of bagasse also serves as a base for various high value chemicals as shown in figure 4. Studies and market survey have shown that lignin is the upcoming name which has huge potential for manufacture of numerous aromatics and different kind of polymers (Gourav Dhiman 2019). The market for lignin based high-value products is expected to grow at the rate of 3.42% during the period 2018-2023 from current 974.6 million, where it may form a major share in the cement industry as a cement additive. From a global perspective, Europe is expected to be the major market player for lignin-based products which at present accounts for about 34 % of the total market share. In a nutshell, innovation and advance research in the field of lignin bio-refinery holds immense potential in near future.

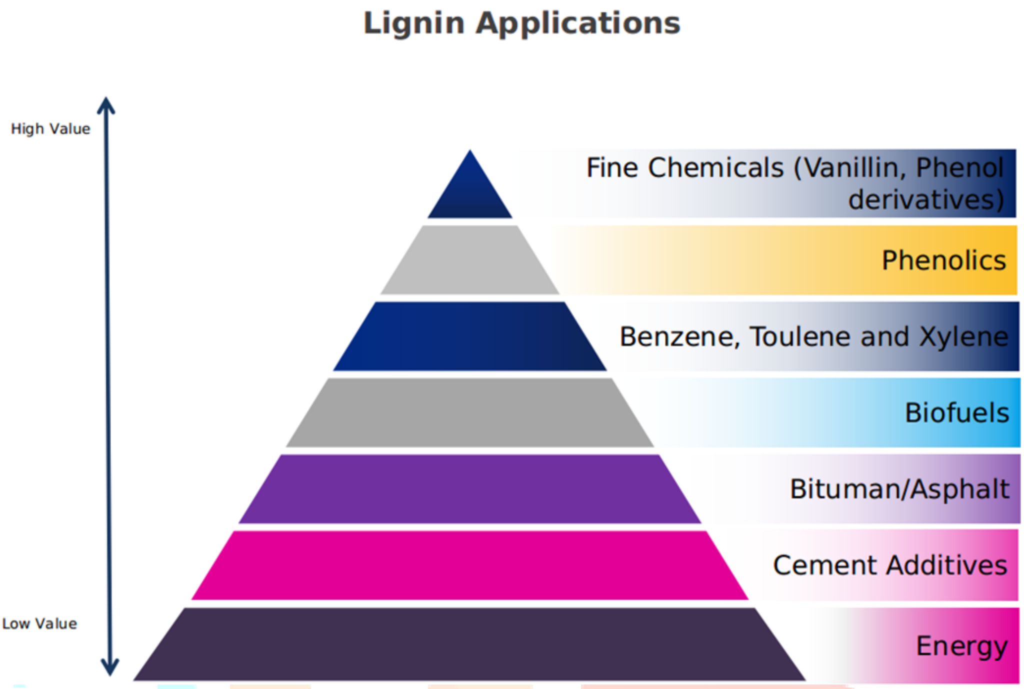


Fig 4 Utilization of lignin for high value chemicals

3.2 MOLASSES

Molasses is one of the most valued by-products of the sugar industry which is being used primarily by the distillation industry in India. Several value-added products like organic acids, enzymes etc. can be produced by utilizing molasses in a better and efficient way (R. PJ Manohar 1997). In present times keeping in view the lucrative price of ethanol for ethanol blending programme, molasses is being used primarily by the distillation industry in India. 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 (Gopal, A. R., & Kammen, D. M. (2009). 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.

Increasing energy demand, depleting natural resources and the need to reduce carbon dioxide emission has greatly increased interest for the use of biomass as alternative energy source. Bio-ethanol is most abundant bio-fuel for automobile transportation. The table no. 1 given below speaks for growing population of vehicles been added in the country over the years and hence the possible increase in emission.

Table 1 Automobile Domestic Sales Trends

Category	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**
Passenger Vehicles	25,03,509	26,01,236	27,89,208	30,47,582	32,88,581	33,77,436
Commercial Vehicles	6,32,851	6,14,948	6,85,704	7,14,082	8,56,916	10,07,319
Three Wheelers	4,80,085	5,32,626	5,38,208	5,11,879	6,35,698	7,01,011
Two Wheelers	1,48,06,778	1,59,75,561	1,64,55,851	1,75,89,738	2,02,00,117	2,11,81,390
Quadri-cycle#			0	0	0	627
Grand Total	**1,84,23,223**	**1,97,24,371**	**2,04,68,971**	**2,18,63,281**	**2,49,81,312**	**2,62,67,783**

#Only Aug 18 -March 2019 data is available for 2018-19

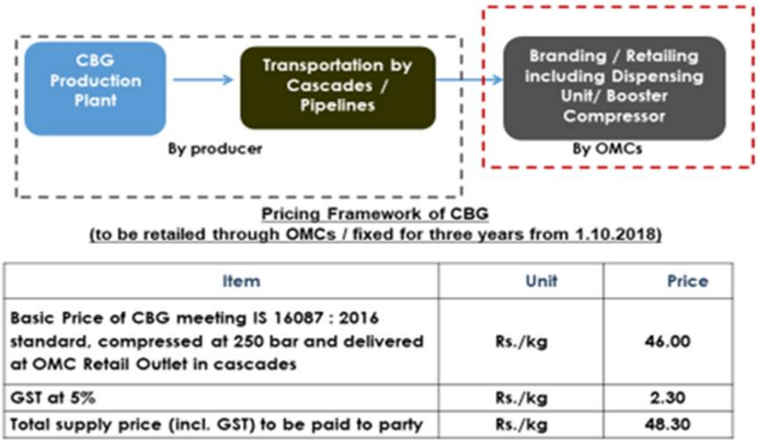
Although there are many factors which contribute to air pollution, but the quantum of vehicular emission cannot be ignored or underestimated. Unfortunately, out of the 50 most polluted cities of the world, 25 cities are in India as reflected from their poor air quality index (AQI). Bio-ethanol, being a clean and green fuel can play a dominant role in pursuit of reducing emission levels providing a relatively cleaner environment. Example of Brazil is before us which speak for drastic improvement in the air quality after adoption of the EBP 27 programme. In a report published by Indian Sugars (Indian Sugars 2020) União da Indústria de Cana-de-Açúcar UNICA mentioned that Brazil has seen success cases in its large cities with improved pollution levels (particulate matter) close to the World

Health Organisation levels. Such levels were achieved mainly due to adoption of ethanol by Brazil in vehicle fuel. Therefore, India too can improve its air quality levels by introducing a mandatory ethanol blend and diverting a part of its sugarcane production to produce ethanol fuel. More diversion of cane towards ethanol rather than sugar would help reduce the glut in the sugar market and greater use of the biofuel would reduce India's dependence on crude oil imports, ensure energy security, reduce pollution, and generate local jobs. Studies and reports reveal that India is determined for an ethanol blending target of 10% by 2022.

3.3 FILTER CAKE

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 (A. Sanjay et. al 2019). 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 (P. Renato de Mello et. al. 2013).

An emerging trend to utilize the press cake for production of Bio-gas or Bio-CNG is gaining momentum in coming times. The press cake since contains appreciable proportion of biodegradable organic matter which has very good potential for the production of biogas. The biogas produces as a result of anaerobic reaction of various degradable substrates including press cake serves as clean energy and may also prove to be a value added product from the by-product of the sugar industry (A. Sanjay et. al 2019). 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. The Ministry of Petroleum & Natural Gas has already pronounced a business model as per Fig. 5 below.



Item	Unit	Price
Basic Price of CBG meeting IS 16087 : 2016 standard, compressed at 250 bar and delivered at OMC Retail Outlet in cascades	Rs./kg	46.00
GST at 5%	Rs./kg	2.30
Total supply price (incl. GST) to be paid to party	Rs./kg	48.30

Fig 5: Business Model for CBG

As the sugar industry generates surplus amount of waste, these can be utilized as bio-resource for production of ethanol, animal feed, paper and many more resourceful products as detailed in the chapter. However, still appreciable amount of the by-products is leftover for disposal and could not be put to better use. For efficient disposal and sustainable utilization of such waste or by-product of the industry, vermicomposting is one such method which as per several studies have found to be an effective method to enrich the soil and farms with organic matter (Sherman, R. L. (2011).

Vermicomposting is a decomposition process wherein coupled action of earthworms and microorganisms on the waste and cow dung mixture takes place. Vermicompost is said to a peat-like substance or material which is highly porous and is enriched with plant nutrients that facilitate sustainable agriculture by supporting as essential nutrient growth media along with being a hub for several microbes. Using sugar waste alone does not support vermicomposting as the earthworms cannot survive in pure sugar waste. However, when mixed with cow-dung, sugar waste such as filter cake or bagasse may serve the purpose for successful vermicomposting process. Cow-dung being a rich source of microorganisms, enhances the overall nitrogen content of the Vermicompost (Nagavallemma et. al. 2006). Figure 6 illustrates the use of sugarcane bagasse and filter cake for vermicomposting. In a nutshell, vermicomposting a said to be a friendly, sustainable and economically viable alternate for utilizing organic waste such as filter cake from sugar industry (Saranraj, P., & Stella, D. 2014).

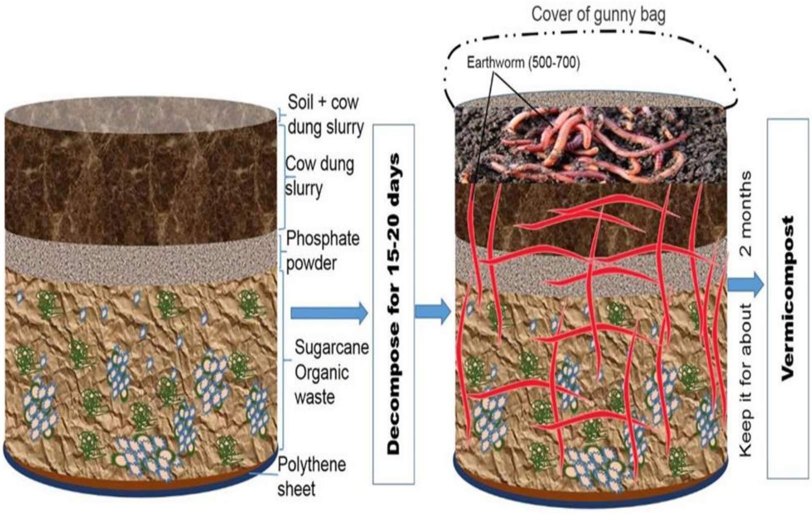


Fig 6: Vermicomposting using sugarcane filter cake and sugarcane bagasse

3.4 WATER

Sugar industry is tagged as grossly polluting industry for being the major water consumer and effluent generator. Approximately, 5-15 tonnes of water is required in order to cater to the process requirements for production of around one tonne of sugar. Around 15-20 % of water is rendered surplus as waste water. The waste water originating from different segments of the sugar factory viz. milling house, process house as well as boiler house all contribute together to form a great volume of waste water that the industry generates which holds potential to cause environment imbalance. It is said that the amount of effluent generated from the industry depends on the cane crushing capacity of the individual industry and the manner in which water usage is managed within the industry. For example, in India, around 200L of waste water is generated from one tonne of sugarcane processed by the sugar industry. So, an industry with 2500 tons crushed per day (TCD) capacity would result in generating around 90,000 KL of waste water for an average crushing season of 6 months (Ingaramo et. al. 2009). The waste water generated from the sugar industry is characterised by high biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total soluble solids. Proper disposal of this waste water from the industry is an area of concern worldwide.

Studies have shown several methods adopted for wastewater management of sugar industry for instance, a review published by Kushwaha revealed various advancements and upgradation in aerobic, anaerobic and physico-chemical treatment techniques (Kushwaha, J. P. 2015). The studies give a comprehensive idea about the primary, secondary, and tertiary treatment techniques of wastewater wherein physico-chemical treatment methods such as ultrasonic (US) and nanoparticle exposure were adopted. Still more could be done in this field, advance methods for example electrocoagulation, ozone treatment, ultrasonic membrane anaerobic system could be promising approached where the sugar industry could innovate and evolve. To conclude, as per requirement, innovative technologies could be adopted in the long run with a view to help sugar industry mitigate the problem of waste water disposal as well as stand as an industry that could return certain portion of the water to the society which in turn could be in any form viz-a-viz for irrigation purpose, water suitable for other human needs and even for drinking purposes. Therefore, the sugar industry can be a hub for 'bio-water'.

IV. CONCLUSION

A cohesive effort towards sustainable waste management, value-addition and utilization of by-products in an innovative manner may bring economic sustainability of the sugar industry. It is envisaged that sustainable waste management strategies may 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. The essence of success will be "attitude" to invest in a judicious way rather than building capacities. While quality raw material development shall be the priority, diversifications and integrations are considered to be the key to success.

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