PRODUCTS AND BY-PRODUCTS OF SUGARCANE IN PAKISTAN

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ABSTRACT

Sugarcane is one of the leading commercial crops of Pakistan and plays a significant role in national economy by sustaining as largest organized agroindustry. Sugar sector contributes significantly in revenue generation and sustainability to our GDP. Handling and management of these byproducts are huge task because those require lot of space and storage. As the sugarcane plant growth advances toward maturity, sugar is gradually stored in cane stalks. During harvesting mature cane stalks are possibly cleaned of tops and trash and brought to the sugar factory. For sustainable growth in income of sugarcane farmers, it is essential that sugar and by-products witness higher growth as compared to the growth in revenue from sugarcane. The current study highlights the demands of sugarcane by products and their effective utilization for profitable and sustained income to sugar industry.
Key words: Sugarcane, Byproducts, Pakistan

INTRODUCTION

Sugarcane is one of the leading commercial crops of Pakistan and thereby the largest sugar market of the world in terms of volume. Since from 1947, when sugarcane production was traced in Pakistan (12.8 million tonnes), and today, where Pakistan is the sixth largest producer in the world, sugarcane production was (86.96 million tonnes) has come a long way. Owing to the agro-climatic suitability of cane cultivation and subsequent development of sugar industry, sugarcane cane cultivation in Pakistan has seen rapid stride. Widely accepted as the original home of sugarcane (Saccharam species) and world's largest consumer (8th), area under sugarcane cultivation was 1.164 million ha, production of 80.96 million tonnes with productivity of 69.55 tonnes/ha (Annual Report of PSMA, 2021).

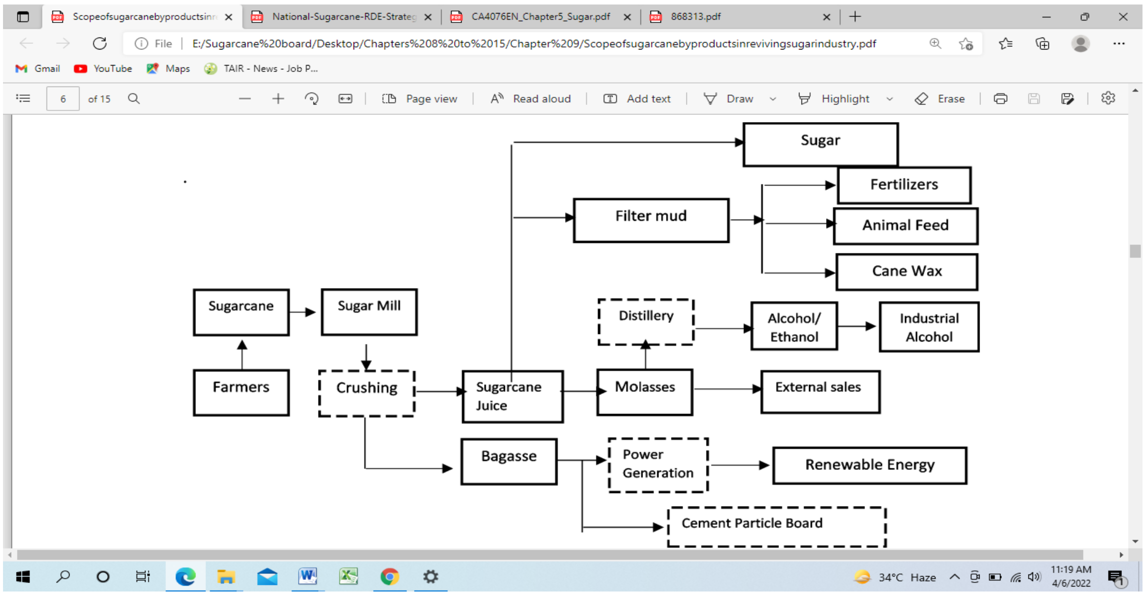
Brazil is amongst the top sugarcane producing country in the world. With decreasing amount of sugarcane production the next five major countries were India, China, Thailand, Pakistan and Mexico (Sarwar *et al.,* 2010). In Pakistan, after textile industry, sugar industry is the second largest industry. Its importance in day to day life adds its value. In this respect, it has the lot of importance in Pakistan's Agriculture.

Sugarcane is considered as the crop for the future and contributes significantly to the GDP. Out of this, nearly 60% is paid to the sugarcane farmers by the sugar mill as prices of cane. Sugar mills process the harvested sugarcane and has the benefits of obtaining multiple products and by-products which are the potential raw materials for several (the extractive, chemical and bio-chemical) industries, including alcohol and power. Despite the growing importance of sugarcane, there are some inherent challenges in this sector.

Commercial Uses

Sugarcane once harvested from field goes to crushing, and the main product obtained is refined sugar, by processing its sucrose content. During the processing of sugarcane in a sugar mill, a set of by products are produced. These include, bagasse, molasses, ethanol and filter mud/Press mud. It is estimated that 100 tonnes of sugarcane produce 14.3 tonnes of raw sugar, 30 tonnes bagasse, 5.2 tonnes filter cake, 2.6 tonnes molasses and 50.7 tonne wastewater (Allen *et al.,* 1997, Partha, N. *et al,* 2016). The process of extraction is outlined below;

Figure-1 By Products of Sugar Industry



Source: Chakraborthy, M. and P. S Priya (2020).

1 Bagasse

It is the dry fibrous residue left after the juice extraction from cane stalks. During the milling process in mill tandem it is separated aside and stocked for further use to release steam and generate electric power for sugar mill's operation in a number of countries like Australia, Brazil and Mauritius (Deepchand, 2016). Sugarcane produces two types of bio-mass, sugarcane bagasse and cane trash. Fresh cane bagasse is 30–32 % of the weight of cane crushed and is composed of 48 % fiber (having 50 % moisture), and 2 % soluble matters. Complete analysis of fiber shows the following ingredients (Patorau, 1986).

Cellulose:	45 - 50 %,
Hemicelluloses:	20 - 25 %
Lignin:	18 - 24 %,
Sugars:	2 %
Wax:	1 %,
Ash:	1 – 4 %

2.1.1 Bagasse use as energy:

Bagasse is a primary fuel for sugar mills; when burnt it produces sufficient heat for production of steam to use as energy and generate electricity for various mechanical and processes operations. According to Patorau, 1986, a typical sugar factory requires 35 kWh and 450 kg of steam per ton of cane. A modern factory would require 30 kWh with 300 kg steam per ton of cane and save 50 % of its bagasse. According to Isabirye *et al.,* (2013) the energy output of bagasse is shown as under:

Bagasse production: 30 % of cane crushed

One ton of bagasse produces 2 tons of steam

5 ton of steam produces 1.0 Mwt of electric power

Thus, 2.5 ton of bagasse would produce 1.0 Mwt of electric power.

On crushing cane of 13 % fiber usually 20 % of bagasse is saved as surplus

Introduction of new technologies has made it possible to have maximum efficiency in steam production with its least utilization for energy production. By inducing some improvement in steam generating system bagasse saving has now been increased to 30 % and by using high temperature high pressure boilers with steam turbines, bagasse savings are reported to be more than 40%. The new technologies help generate extra electricity with lesser bagasse use. Thus, a sugar mill of 10,000 TDC capacities would produce steam and power of 10–12 MWht for its own variable need and at the same time, it saves huge stock of bagasse that can extend the operating duration of boilers for co-generation of equivalent load of electricity beyond the cane-crushing season of sugar mills. It has now been made possible to save tremendous quantum of bagasse for co-generation of electricity and its delivery to national Grid.

During the year 2020-21, Pakistan sugar industry crushed 58.60 million tons' cane, while the sugar Industry has the installed capacity to

crush 82.88 million tons' cane in a working season of 135 days (Annual Report of PMSA, 2020-21). On the total installed capacity, the energy production potential is stipulated as under;
Cane crushing capacity: 82.88 million tons' cane
Bagasse production: 30 % of cane crushed = 24.864 million tons
Bagasse saving after meeting its own energy requirements; 40 % =9.9456 million tons

2.2 Energy cane

Coal, fossil fuel and wood have been the only source of heat energy in the past. Scientists are looking for new renewable energy resources, as 80 % of total world energy is being supplied from fossils. At constant production and consumption, the present known resources of oil are reported to exhaust in 35 years, natural gas 60 years and coal 150 years (Zafar, 2018). Besides the depletion of fossils fuel, its use creates serious environmental problems associated with global warming. With growing need for alternative energy, other than the fossils fuel, there has been resurgence in interest in biomass of field crops as a renewable energy source. Sugarcane is the most efficient convertor of solar energy into biomass, the bagasse, tops and trash that again become the source of heat release and generation of electricity. Cane breeders are planning for producing multipurpose cane for meeting the requirements of both sugar and energy.

The objective is to develop more vigorous and stout cane to produce more fiber than sugar. Sugarcane varieties typically have 12 – 14 percent sucrose and 13 – 15 percent fiber. Bagasse is obtained to the tune of 30 - 32 % the weight of cane crushed, having 50 % moisture. To make best use of sugarcane biomass for energy production, objectives are focused to develop varieties having 10 - 12 % sucrose with 22-24 % fiber. This will help save significant quantum of fiber (bagasse) in the process. The energy contained in cane bagasse is important alternative to address the expected shortage of fuel resources.

2.3 Cane trash

The cane trash including leaves and tops represent 15 % of the weight of cane stalk at harvest. Nevertheless, most of this is disposed of through burning and creating environmental pollution problem. In mechanized harvesting, cane crop in some countries is yet burnt ablaze and the next day, cane stalks are mechanically harvested for supply to sugar mills. In case of manual harvesting cane after harvesting is manually cleaned of its tops and trash. Some of the tops are taken away for animal feed and a little trash stays in the field. These tops and trash if collected from cane field can be utilized as a viable fuel supplementary to bagasse for combustion and conversion as co-generation of energy into heat or electricity. Some sugar mills in India manage to collect trash from cane fields and prepare 20 kg weight compact blocks and mechanically thrust these into the steam boiler hole for combustion (Malik, 2005).

In case of green cane mechanized harvesting almost 68% of cane trash is blown out of the cane and stays in cane field as trash blanket, while 32 % is taken to sugar mill together with cane as extraneous matter (Zafar, 2015). Researchers are planning to collect this field trash as bails and utilize it for energy purposes.

About 7–12 tons of cane trash can be obtained from one hectare and every ton of sugarcane trash contains 5.4 kg N, 1.3 kg P2O5 and 3.1 kg of K_2O and small quantity of micronutrients (Sing and Suleman, 1995). To enhance microbe's activities a layer of press mud compost can also be spread on cane trash with one bag of Urea per hectare, as a starter. In addition to thermal and electrical energy, which is obtained from sugarcane bagasse, dozens of by-products are being developed from this raw material. Some of the by-products produced from bagasse are mentioned hereunder:

2.4 Paper, Board, Pulp

Bagasse is utilized to manufacture different types of hard and soft boards, which are commercially used as a substitute of wood. Its use is very common for preparation of wide range of particleboards including win boards hard boards, and MDF boards. For the manufacture of furniture, doors and window and Amirah's, these boards have greatly replaced wood. This is getting cheap and more efficient than wood. Bagasse is further biodegraded for the production of pulp. Pulp is also utilized for production of writing paper and tissue paper, newspaper and preparation of boxes and molds.

2.5 Xylose sugar– xylitol, Erythritol

With some digestive techniques, it is getting common to produce energy free sweeteners from bagasse. Through microbial process, using yeast, hemicellulose from bagasse is hydrolyzed to xylose, which is then hydrogenated to produce xylitol. Xylitol is low caloric organic sweetener and is specifically used by diabetic patients. It has 40% low calories than sugar, prevents weight gain, and is a good alternative to sugar. Another low-calorie product erythritol has 0.25 calorie per gram compared to 4 calories per gram of sugar, it tastes very close to sugar. Glycemic index of erythritol is '0' compared to '6' in sugar.

2.6 Bio-plastic

Through some chemical degradation, sugarcane-bagasse is transformed into a commercial bio plastic product named as 'Bio cycle'. It is used to produce auto parts, packaging material, toys, credit card, tetra packs and bottle packing of some beverages (Coca Cola), Kitchenware, cutlery ware and disposable shopping bags. Unlike petroleum-based plastics, this product is completely biodegradable and compostable.

Sugarcane ethanol has also emerged as an important ingredient to substitute for petroleum in the production of plastic. It has same physical and chemical properties similar to regular plastic. Tiles, prepared from bio-plastic have gained household importance and are being used in kitchens and toilets.

2.7 Furfural

Bagasse can be transformed into furfural, which is a starting point for a large number of resins. It can be used to produce furfural alcohol, pharmaceuticals, mono chloro-acetic acid, propionic acid, maleic anhydride and some herbicides. Furfural is a colorless, inflammable, volatile aromatic liquid. It has many industrial uses, such as solvent for refining of lubricating oil. Also used in nylon production, as well as molding powders. Also used to produce furfural alcohol, which is utilized in pharmaceuticals, fungicides, pesticides and solvents.

2.8 Tops and trash

During harvesting, tops and leaves of cane stalks are left in the field. These are 15 to 25 percent of cane plant, including 5 to 7 % dry leaves and 13 to 20 % green tops. In early harvesting when cane is not fully mature, tops and trash constitute 20 - 25 %; with advance in maturity, this section is reduced to almost 15%. The cane juice is processed for its boiling, clarification, evaporation, condensation, crystallization to sugar and formation. The main products obtained during these process operations are sugar, bagasse, molasses and press mud. The quantitative output of these products from cane crop are displayed in the following figure. General output of a typical cane plant is as under;

Cane: 100 tons (including 15-20 tons' tops and trash

Sugar: 10 tons

Bagasse: 30 tons (20 tons used for generating energy for sugar mill operations, 10 tons used for other uses or cogeneration).

Molasses: 4 - 4.5 tons

Filter press cake: 3 - 3.5 tons

Water (in cane juice): 63 tons. Exhausted as steam during boiling and evaporation of juice; recycled for use during various processes. To be brief, leaving trash in the field, Sugar, bagasse, molasses and press mud are the main products of sugarcane. Sugar is marketed as such and is consumed in various ways. As for other products, through advancement in innovations dozens of commercial by-products have been formulated. Biotechnologies have been made available for the production of several by-products like ethanol, acetic acid, yeast, wax, xylose sugar, pulp, paper, boards, bio-plastic, furfural etc. Thus, besides direct use of the products several Co-product industries have been established. Now, by-products have more economic importance than sugar itself. Economic importance of Products and By-products of commercial importance are briefly mentioned as under;

2.9 Molasses

Molasses is dark viscous effluent obtained during preparation of sugar in its final crystallization and centrifugal stage. It is the residual syrup, from which crystalline sugar cannot be obtained by simple means. Normally, molasses yields 4–4.5 % of the weight of cane crushed in the factory. Simple composition of molasses is as under (Patorau, 1986);

Water: 20 %
other carbohydrates: 4
Sucrose: 35 %
Nitrogen compounds: 4.5 %
Fructose: 9 %
Ash: 12 %
Glucose: 7 %

Besides converting it to a number of by-products, it is directly utilized for producing ethanol, as an ingredient in cattle and poultry feed and as molasses-based fertilizer in field and garden crops.

2.10 Ethanol (Ethyl alcohol)

The molasses produced is just 4-4.5 % of the weight of cane crushed, appears to be a small fraction but is of great economic significance. Molasses containing a large fraction of fermentable sugar, is diluted three times with water and allowed to ferment in the presence of yeast culture (Saccharomyces cerevisiae), either by batch or continuous process of fermentation. The process completes in three continuous phases at around 27^0 C temperatures. On completion of the process in the 'still', alcohol vapors are removed as rectified spirit or ethanol, through fractional distillation in a specified column under reduced pressure. The solid and slurry remains at the bottom is spent wash/slops or vinasse and is composed of un-fermentable sugars, water-soluble amino acids, lignin and other organic fractions.

In present day economics, major role of molasses is the production of ethanol. One ton of fair quality molasses produce 240 liter of ethanol. It can also be directly produced from cane juice. Ethanol produced is 72 liters per ton of cane or 100 liters per ton of juice.

This ethanol is at present controlling the world trade as power alcohol. Brazil, which is the main supplier of sugar in the world trade, is at the same time a large producer of Alcohol. This alcohol is mixed with petrol at 20 % ratio to make the gasoline, which is more environmentally friendly. In case, over-production of sugar creates glut in the world trade, Brazil supports its economy by converting its market to ethanol, so much so that cane juice is directly fermented to produce ethanol without producing sugar. It may be emphasized that Government of Brazil has made it mandatory to blend 20 to 25 percent anhydrous ethanol with gasoline (Fabio and Matoso, 2015) and sugarcane ethanol represent 17.6 % of the country's total energy consumption (Anon,2009).

During 2020-21, Pakistan Sugar Industry produced 2.69 million tons of molasses (Annual Report of PSMA, 2021). The country has made a considerable breakthrough in producing ethanol from molasses. At present 21 distilleries are known to be in operation, which consume a large quantum of molasses produced from sugarcane and sugar beet in the country. These distilleries have the daily ethanol production capacity of 2.65 million liters. (Table- 1). Subject to prevailing market rates, ethanol or molasses have proved a big source of foreign exchange earnings in the country.

2.11 Yeast:

Yeast are complex, protein rich living unicellular organisms. Two types have been isolated, Saccharomyces cerevisiae to produce baker's yeast and Torub utilis to produce food yeast. 4 Kg. of molasses is required to produce 1 Kg. of dry baker's yeast.

Table-1 Names of Sugar Mills having ethanol production unit in Pakistan

Sr. No.	Name of Sugar Mills having ethanol production unit	Installed capacity, liters per day
1.	Al Abbas sugar mills and distillery Ltd., Mirwah, Mirpur Khas	165,000
2.	Ansari sugar mills and distillery Ltd., Maatli	100,000
3.	Chashma sugar mills and distillery Ltd., Dera Ismail Khan.	100,000
4.	Colony sugar mills and distillery Ltd., Phalia.	125,000
5.	Crystaline Chemical Industries, Sargodha.	100,000
6.	Dewan sugar mills and distillery Ltd., Dewan city, Sujawal.	125,000
7.	Frontier sugar mills and distillery Ltd., Takht Bhai	25,000
8.	Habib sugar mills and distillery Ltd., Nawabshah.	150,000
9.	Haseeb Waqas sugar mills and distillery Ltd., Nankana.	125,000
10.	Hunza sugar mills and distillery Ltd., Shahkot, Faisalabad.	125,000

11.	Khazana sugar mills and distillery Ltd., Peshawar.	25,000
12.	Matyari sugar mills and distillery Ltd., Matyari.	100,000
13.	Noon sugar mills and distillery Ltd., Bhalwal.	80,000
14.	Premier sugar mills and distillery Ltd., Mardan	46,000
15.	Premier Chemical Idustries, Sheikhupura.	425,000
16.	Shakarganj mills and distillery Ltd., Jhang.	325,000
17.	Shah Murad sugar mills and distillery Ltd., T.M. Khan.	125,000
18.	Saleem sugar mills and distillery Ltd., Charsada.	40,000
19.	Tandlianwala sugar mills and distillery Ltd., Kanjwani	125,000
20.	Unicol Pvt. Ltd. Mirpur Khas.	100,000
21.	United distillery Ltd., Sadiqabad.	120,000
	Total	2,651,000

Source: K. B Malik (2020).

2.12 Spent wash

It is also known as Stillage, spent wash, vinasse or effluent. It is a waste product of distillery industry producing ethanol and is produced at the rate of 13 liters per liter of ethanol. It is caramelized and cumbersome effluent, very difficult to handle due to very high BOD (40,000 ppm) and COD (80,000 - 100,000 ppm). It requires higher oxygen concentration for oxidation of the organic matter contained in it, therefore when it is discharged to a drain or river it ex-haust the dissolved oxygen affecting the flora and fauna present in the ecosystem (Pande and Sinha 1997). The organic constituents present in higher concentration undergo reduction, generating unpleasant odor. This is very noxious fluid with pungent smell and pollutes the environments. In its storage in open tanks, it even contaminates the ground water through its seepage and if disposed in open water drains it kills all the aquatic creatures. Spent wash is quite rich in micronutrients; contain large amounts of organic matter, Nitrogen, Phosphorus, Potassium, Sulphur and Calcium, besides high salt load of sulphates and chlorides of Potassium, sodium and calcium. Due to high acidic nature can be used as an amendment in alkaline soils. The economical solution to minimize the pungent smell of spent wash and increase the pH to a desired level is to treat the effluent water in lagoons. Lagoon treated spent wash becomes considerably safe to use as spray on fallow land before land preparation and also to apply in standing crop mixed with irrigation water. The distillery management had installed a project to dehydrate the effluent at high temperature; resultantly spent wash residue is dried as powder. The nutrients contained in the pack are shown in Table-2. During this process of dehydration, the high temperature steam produced is recycled, utilizing it in the sugar mill process house. It exclusively solved the pollution problem of distillery making the environment pollution free for the living being. The powder is rich source of nutrients and is sold in one, two and five kilo packs for orchards and vegetable farming.

Table-2 Composition of the spent wash powder

Nutrient	Percent	Nutrient	Percent
Moisture	9.42	Ferrous	0.02
Nitrogen	2.93	Manganese	0.03
Phosphorus	0.39	Boron	0.02

Source: K. B Malik (2020).

In Pakistan, some of the sugar mills like Habib (Be Nazeerabad) and Shakarganj (Jhang) have adopted sprinkling system of spent-wash on limited scale. The effluent is sprayed on sugarcane press mud and is manually stirred to mix the contents. Repeated application and stirring help to prepare a limited quantum of Bio-fertilizer. However, this technique needs to be improved.

2.13 Use of molasses as fertilizer

All the organic and inorganic fertilizers applied to sugarcane during its course of growth phases, are partly absorbed as macro and micro nutrients through plants roots. By termination of growth, a subsequent amount of the nutrients is available in sugarcane biomass and plant solute the cane juice. In case these products are used as fertilizer, all the nutrients contained in, are recycled back into soil. Detailed chemical composition of molasses is reproduced in Table-3.

Table-3 Composition of final cane molasses

Contents	Percent	Contents	Content %	Nitrogen %
Water	18.85	Aspartic acid	0.3740	0.0397
Total solids	81.15	Serine(asparagine)	0.5415	0.0722
Total sugars	48.87	Glutamic acid	0.0332	0.0032
Sucrose	31.76	Proline	0.0086	0.0011
Invert sugars	15.44	Glycine	0.0068	0.0014
Apparent purity	30.08	Alanine	0.0769	0.0124
True purity	39.14	Valine	0.0263	0.0033
Brix	89.76	Isoleucine	0.0118	0.0013
Pol	27.0	Leucine	0.0059	0.0006
Organic non-sugars	24.89	Tyrosine	0.0380	0.0029
Nitrogen	0.90	Phenylaline	0.0322	0.0027
Inorganic constituents (ash)	13.82	Cysteine	+	

Source: K. B. Malik (2020).

CONCLUSION

Sugarcane is one of the most highly remunerative crops which has encouraged farmers to expand acreage and increase production over the years. There is a dire need to expend the use of sugar industry waste. It is suggested that there is significant scope of expanding the growth of sugarcane by-products In Pakistan, use of sugarcane by-products were limited as compared to other countries like Brazil and India. A larger focus on full potential use of by-products will have a major bearing on the future potential of sugarcane crop.

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