A FLEXIBLE PROCESS FOR MANUFACTURING SUGAR UTILISING ALL COMPONENTS OF THE SUGARCANE

By

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Abstract

ANCIENT Hindu mythology has the idea of a Kalpavriksha, a miraculous tree that did not have a single part or component without some use or benefit. In other words, every single component of it could be put to some use, some way or the other. Could sugarcane become a veritable Kalpavriksha of our times, by proving to be beneficial for all? Sugarcane has three components: first, the main stem, secondly, leaves and trash and, lastly, tops and roots. The sucrose content is the highest and impurities are the lowest in the main stem. Hence, the main stem is the best source of sugar. Although the other components also have sucrose, they contain impurities like reducing sugars, ash, and polysaccharides in large quantities. Mostly, current practices at sugar factories do not ensure sufficiently rigid control over the presence of these different cane-components in their supply of sugarcane. This creates various problems. Basically, it interferes with the entire sugar-manufacturing process; in turn, it increases the cost of production as well as sugar losses, eventually resulting in inferior sugar quality. However, these different components could be put to excellent alternative uses. For example, the leaves and trash have higher calorific value and can be profitably utilised for cogeneration. Similarly, the substantial reducing sugars in the tops could be fermented to produce good quality alcohol. The impurities that are doubtless present in these components do not hinder either cogeneration or fermentation. These specific potential merits of the individual components of sugarcane need to be given due consideration and subjected to appropriate alternative processes, with a view to minimising losses and costs and improving quality as well as enhancing profitability of the sugar industry. This would entail only a few modifications, both in the sugarcane harvesting system as well as the sugar manufacturing process. Primarily, the latter needs to be made a flexible or differential process. By adopting such a flexible process, sugar factories would simultaneously produce good quality sugar as well as alcohol, even as they would be able to augment cogeneration. The cumulative result would be enhanced profitability of sugar manufacturing as well as enhanced sustainability of factories.

Introduction

At present, 'purity' (of juices) is almost the sole focus of the sugar industry. All calculations in the industry as well as all decisions—including those about selecting a cane variety or about process modifications—are driven by this single factor. A good example would be the extraction process, in which sucrose extraction is almost the overriding consideration, although it is known that sucrose extraction cannot be increased without a corresponding increase in non-sugar extraction. Indeed, whether higher extraction is beneficial or not is a matter of debate. Extraction of non-sugars also increases molasses formation, which is not the aim of the process.

Sucrose is present chiefly in the main stem, or the middle and bottom portion of the stalk of the sugarcane, which contains very few impurities including colour; hence, it is by far the best source of good-quality sugar.

In contrast, the top portion of the plant contains reducing sugars in appreciable quantities, but also considerable sucrose. It is a moot point whether crushing the tops enhances sugar production. Reducing sugars help microbial growth as well as increase molasses formation. This is another delicate issue, as
reducing sugars are known to improve molasses exhaustion. However, there is no doubt that all reducing sugars end up as molasses. Reducing sugars are degraded during the process to various metabolites including acid and thus do not end up in molasses as reducing sugars. This actually amounts to loss of material potentially useful or beneficial for alcohol generation. In short, reducing sugars are not really needed for sugar production, but can be very useful in alcohol generation or other microbial fermentation processes. Furthermore, these microbial fermentation processes are not hampered by the presence of the organic or inorganic impurities that are likely to be present in the tops, trash, leaves and roots of the sugarcane.

Trash, leaves and roots contain many, impurities, very high colour, some reducing sugars and an almost negligible amount of sucrose. These multiple impurities have an adverse effect on sugar quality as well as on recovery. However, the calorific value of the leaves and trash is more than that of bagasse. Thus, it is an important biomass that can be used either for cogeneration or for improving soil fertility.

Long-established practices in the sugar industry permit the entry of all these impurities into the process and then attempt to minimise their effects by various (equally long-established) methods, such as cane-burning and manual cleaning of harvested cane. It is a common observation that cane burning gives better recovery (except when harvest is delayed) because the impurities from the leaves and trash are thereby eliminated (Godshall, 2002). Similarly, there are reports of 0.5% more recovery as a result of manual cleaning of harvested cane where the tops, leaves and trash are separated and removed (Krishnan, 2003).

What needs to be understood is the fact that the only reason for such higher sugar recovery is the reduction in impurities as a result of the removal of the tops, trash and leaves from the process. Therefore, the industry needs to pay more attention to the impurities for achieving better sugar recovery. That is to say, efforts should be made, first, to forestall the entry of impurities into the process and, secondly, to reduce the formation of impurities within the process. (An example of the latter is the microbial metabolites that harm sugar processing in two ways: they consume sucrose for their own formation and they take the sucrose to the molasses). It is no exaggeration to say that it is the impurities that decide the fate of the sucrose: whether it would end up in a sugar bag or in a heap of molasses.

The most beneficial way to take the impurities out of the process, it is submitted, would be to channel them towards more desirable alternative uses, most importantly, cogeneration and alcohol generation.

Cogeneration, of course, is already undertaken fairly extensively. Electricity is generated during the off-season by using the stored bagasse. The main problem in such co-generation units run by sugar factories, especially in India, is the non-availability of bagasse sufficient to run a plant during the entire off-season. The cost of collecting other biomass from elsewhere is very high and the length of the off-season is very long, very often more than six months. Consequently, there is no power generation for about two months. This has impaired major developments in cogeneration in India and other developing countries.

The practice of mixing ethanol with petrol and the possibility of its use in diesel have increased the requirements of fuel-grade alcohol. This has given a boost to the economy of sugar factories. Alcohol is largely generated from molasses and efforts are being made to meet the increased demand by using other raw materials, including juice and B molasses. The sulfur content in alcohol made from molasses from the double sulfitation (plantation white sugar manufacturing) process is high and can be troublesome in accepting it for fuel addition.

This is where one thinks of sugarcane as Kalpavriksha, the ancient Hindu mythological concept of a miraculous tree that did not have a single part or component without some use or benefit. In other words, every single component of it could be put to some use if only one had the imagination and the inclination. The sugarcane plant can well be a veritable Kalpavriksha of our times if we put each of its components to appropriate differential use, with a view to optimising their respective merits and consequently maximising their benefits to us.

The suggested flexible process

Considering the benefits of individual parts of sugarcane as indicated above, it is possible to subject them to separate or differential processing, with specific alternative objectives or end-uses in view, right at (and from) the point of cane harvesting. Such differential processing would entail only a few modifications in the existing sugar factories. Yet it would arguably go a long way to minimising if not eliminating the hindrances in the production of good quality sugar and other products, even as it would reduce overall costs, thereby improving profitability. This is particularly important for sugar factories in developing countries like India. What follows is a possible model of such differential processing:
1. The farmer would be advised to bring the whole cane to the factory — with only one bottom cut for harvesting, without de-topping or de-trashing.

The advantages of adopting this procedure would be as follows:

a. It would minimise harvesting time since there is only one cut and no cleaning. Consequently it would reduce the labour required and therefore labour costs.

b. It would minimise post-harvest sugar losses from deterioration as the cut area is halved. Post-harvest deterioration is perhaps the greatest loss. Several studies suggest that more than 0.5% sugar on cane is lost during this period (Kulkarni, 2000; Solomon et al., 2001; Morel du Boil, 2001). The microbial metabolites that are produced pose problems in the process and are responsible for further sugar loss as well as inferior sugar quality. The suggested single-cut harvesting would substantially reduce these problems.

c. As trash and leaves would be carried to the factory along with the cane, the factory would have ample supply of biomass available for cogeneration. The corollary would be that there would be no need to collect other biomass from other sources for the purpose of cogeneration. The exorbitant costs incurred for such biomass collection would thus be saved.

d. To be sure, some disadvantages in adopting this particular method might also be visualised:

e. It could pose problems in transportation due to the rise in bulk volume, especially in places where mechanical cane harvesting practices are followed. Mechanical modifications would be necessary for effecting the single bottom cut and for loading. This would increase cane transportation cost.

f. It would increase the weight of the cane by more than 15%. This is good for the farmer if he is paid on weight alone, but the factory may not like to pay for the trash.

g. Many farmers may like to have the leaves back, to use as feed for their cattle. In that case, the leaves could be returned to the farmers in his emptied containers after cleaning the cane in the factory and there will not be payment problems as the factory pays only for clean cane. This is being practised at a private sugar factory in Andhra Pradesh, India.

h. Farmers with large land holdings and from developed countries would like to have trash blanketing as a means of suppressing weed growth and improve soil organic matter. Something would need to be done to augment the organic matter in the soil (Thorburn et al., 2004) after such single-cut cane harvesting, as no trash (which retains the organic matter in the soil) would be left in the field. This can be solved by diverting excess bagasse from power generation for composting with pressed mud and distillery effluent. This is possible when one diverts the entire secondary juice to fermentation without heating (which will save a good quantity of bagasse). Such compost is known to improve soil fertility.

2. The tops, leaves and trash would be separated in the factory, either manually or mechanically. The advantage of manual cleaning here would be that proper cleaning would be ensured. On the other hand, more labour would be required, entailing an increase in labour costs. This is apparently a disadvantage, but considering the saving in labour costs because of the single-cut harvesting, the net additional costs might possibly be very moderate.

Countries that follow mechanical harvesting will have to go for two-stage harvesting, rather than the present practice of using a combined harvester which both cuts and cleans the cane in the field. Only cutting and loading arrangements will have to be made in the field and billeting/cleaning operations will have to be made in the factory. One can think of a dry as well as a wet cane-cleaning system with a view to improving cleaning/impurity removal. Such a system will have another advantage for mechanical harvesting since there will not be any ‘cane loss’ which is about 5% with a good trash removal system (Davis and Schmidt, 2004). This ‘lost cane’ will be crushed, along with the trash and leaves, in the later mills and the juice will be used for fermentation.

3. Such properly cleaned cane would be fed to the milling tandems, via the main fiberisor/preparatory devices, using a proper rapid-acting biocide for cane sanitation. The crushing of such clean cane is likely to have multiple positive effects, such as higher crushing rate,
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3. Such properly cleaned cane would be fed to the milling tandems, via the main fiberisor/ preparatory devices, using a proper rapid-acting biocide for cane sanitation. The crushing of such clean cane is likely to have multiple positive effects, such as higher crushing rate,
high CCS, lower bagasse moisture (greater extraction) and higher juice purity (low impurities). The cumulative result would be more sugar production. Experiments conducted at the Mossman Central Mill in Australia have shown that adopting such a process can augment income by about AUD$0.50 per tonne of cane (Kent et al., 2003a,b).

4. The tops, trash and leaves would be fed to the second or third mill, via another fiberisor and by a separate carrier. Use of a rapid-acting biocide would be necessary just before the material reaches the fiberisor. Use of a proper mill-sanitising biocide is also essential to keep microbes under control. Very hot maceration/imbibition water would be used to increase extraction efficiency and collect the secondary juice separately.

5. The secondary juice, being less impure than molasses, can be used for various fermentations (Godshall, 2001), using proper microorganisms. Many of the microbial fermentation processes cannot use molasses as a source of carbon and energy due to the high amount of impurities including caramel. However, the secondary juice also has other known uses, such as:

a) The secondary juice is diverted without heating, liming or clarification directly to the fermentor for alcohol generation. Molasses can be used, if necessary, to adjust brix. Proper biocides used for cane sanitation and mill sanitation will not have any adverse effect on yeast growth and contamination problems could thus be avoided.

b) The secondary juice can also be taken for production of raw sugar separately, where sulfur is not used; so molasses will not have any sulfur and such molasses will have food grade value and, if used for alcohol generation, such alcohol will not have sulfur contamination.

The respective advantages of the two options (and one possible disadvantage of the second option) for using the secondary juice may be briefly stated as follows:

- The first option will be more economical from the energy point of view and it does not call for many modifications, except for one pipeline from the second mill juice collector to the distillery. The fermentation tank will function like a clarification station, as the juice will be held for more than 20 hours for fermentation, and alcohol generated will have similar effect of floc formation as high temperature in a normal clarifier.

- Such a system will have very negligible sugar/alcohol losses in the filter cake and the presence of yeast will enhance the fertiliser value of the filter cake.

- The process can be easily adapted to a continuous fermentation process.

- The second option will require another set of boiling house equipments, crystallisers, centrifuge, etc and will not have the advantage of energy economy.

- However, the second option will have the advantage of higher price of sugar and could be executed depending on the prices of alcohol, sugar and power.

6. The primary juice, or the first mill juice, which has the least impurities, would be used for sugar manufacturing with the usual process. Due to lower impurities, the requirement of chemicals will be reduced substantially and the quality of the sugar produced will improve. There will be very low molasses production and very good quality sugar can be manufactured without using SO₂ for syrup discoloration.

7. Trash and leaves have more calorific value and will help co-generation. Use of 30% less steam due to diversion of the secondary juice will have huge impact on bagasse saving for use in the off-season for power generation and composting.

Conclusion

Admittedly, this paper might come across as a tabulation of ideas. However, the aim of the paper is precisely to put forward ideas, some of which have no doubt been expressed at various fora earlier, but some are arguably novel. Not merely detailed technical analysis and detailed analysis of the economics, but, indeed, extensive pilot studies/projects would be needed. They could and would be undertaken in due course. Needless to say, both the technical requirements and the economics would vary from place to place and time to time.

The suggested flexible process, I believe, puts forward a number of viable options that could make sugar factories more sustainable. If adopted, it would have good overall impact on the economy of the
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The need for augmenting power generation can hardly be overemphasised, especially in developing countries. Sustainable power generation by sugar factories would be feasible due to availability of biomass in sufficient quantity.

The quality of the secondary juice is also much better than that of the diluted molasses from the normal process. The alcohol generated can be used for making potable liquors or mixing with petrol/diesel. Incidentally, pollution will also be reduced.

Thus, use of all components of sugarcane, on their own merits, in the flexible or differential process outlined above, will give a boost to the economy of the industry, benefit farmers and make individual factories as well as the industry as a whole, more profitable, self-sufficient and sustainable.

REFERENCES


UN PROCEDE VERSATILE POUR LA FABRICATION DU SUCRE AVEC TOUTES LES COMPOSANTES DE LA CANNE

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MOTS CLES: Sucreries Durables, Utilisation de la Biomasse,

Procédé Versatile, Qualité du Sucre, Cogénération, Alcool Amélioré, Kalpavriksha

Résumé

Il existe dans la mythologie hindoue le concept du Kalpavriksha, un arbre miraculeux dont la moindre parcelle pouvait être utilisée à des fins bénéfiques. La canne à sucre pourrait-elle devenir le Kalpavriksha des temps modernes? La canne à sucre est composée de trois parties: la tige, les feuilles et la paille, et la tête et les racines. La tige ayant la plus forte teneur en saccharose et le taux le plus faible d’impuretés est la
source principale de sucre. Bien que les autres composantes de la canne contiennent aussi du saccharose, elles accumulent une très grande quantité de non sucre tels que des sucres réducteurs, des minéraux et des polysaccharides. En général, la présence de ces différentes impuretés n’est pas soumise à un contrôle rigoureux lors des opérations courantes à l’usine. Il en résulte des effets néfastes dans le procédé de fabrication, avec pour conséquence une augmentation du coût de production, des pertes en sucre et, éventuellement, la production d’un sucre de qualité inférieure. Cependant, ces différentes composantes pourraient être utilisées à bon escient dans des systèmes alternatifs. Par exemple, les feuilles et la paille qui possèdent une forte valeur calorifique pourraient être brûlées pour la cogénération. Les sucres réducteurs se trouvant dans les têtes de canne pourraient être fermentés pour produire de l’alcool de bonne qualité. Les impuretés présentes dans ces composantes n’interviennent nullement dans les procédés de cogénération ou de fermentation. Le potentiel de ces différentes composantes de la canne devrait être sérieusement considéré et elles devraient être soumises à des procédés appropriés dans le but de réduire les pertes et les coûts et d’améliorer la qualité du sucre, assurant ainsi une meilleure rentabilité de l’industrie sucrière. Cela impliquerait seulement quelques modifications par rapport au système de récolte de la canne ainsi qu’aux opérations à l’usine. Ce système devra être versatile afin de permettre la production simultanée de sucre et d’alcool de bonne qualité et en même temps d’augmenter la cogénération. Le résultat final d’un tel système sera une rentabilité accrue de la fabrication du sucre ainsi qu’une durabilité améliorée des sucreries.

UN PROCESO FLEXIBLE PARA PRODUCIR AZÚCAR
USANDO TODOS LOS COMPONENTES DE LA CAÑA DE AZÚCAR
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PALABRAS CLAVE: Fábricas Sostenibles, Uso de Biomasa, Proceso Flexible, Calidad de Azúcar, Cogeneración, Alcohol Mejorado, Kalpavriksha.

Resumen

LA ANTIGUA mitología Hindú tiene la idea de un Kalpavriksha, un árbol maravilloso que no tiene una sola parte o componente que no tenga uso o beneficio. En otras palabras, cada componente individual podría tener algún uso, de una manera u otra. ¿Podría la caña de azúcar convertirse en una verdadera Kalpavriksha de nuestros tiempos, probando ser beneficosa para todo? La caña de azúcar tiene tres componentes: primero, el tallo principal, Segundo, las hojas y basura y por último cogollos y raíces. El contenido de sucrosa es el más alto y las impurezas son las más bajas en el tallo principal. Por lo tanto, el tallo principal es la mejor fuente de azúcar. A pesar de que los otros componentes también tienen sacarosa, ellos tienen impurezas como azúcares reductores, cenizas y polysaccharidos en grandes cantidades. Adicionalmente, las prácticas actuales en las fábricas de azúcar no aseguran un rígido control sobre la presencia de estos diferentes componentes de la caña en su abastecimiento de caña de azúcar. Esto crea varios problemas. Básicamente, esto interfere con el proceso completo de fabricación de azúcar, lo que a la vez aumenta el costo de producción así como las pérdidas de azúcar, lo que eventualmente resulta en azúcar de inferior calidad. Sin embargo, estos diferentes componentes podrían ser puestos para otros excelentes usos alternos. Por ejemplo, las hojas y la basura tienen un mayor valor calórico y pueden sacárselas provecho para cogeneración. De manera similar, los importantes azúcares reductores de los cogollos podrían ser fermentados para producir alcohol de buena calidad. Las impurezas que sin lugar a dudas se encuentran en estos componentes no son estorbos en la cogeneración o en la fermentación. Estos méritos potenciales específicos de los componentes individuales de la caña de azúcar deben ser correctamente considerados y sujetos a adecuados procesos alternativos, enfocados a minimizar las pérdidas y costos y mejorar la calidad así como a aumentar la rentabilidad de la industria azucarera. Esto implicaría solo algunas modificaciones tanto en los sistemas de cosecha de caña de azúcar como en el proceso de fabricación de azúcar. En principio, este último proceso tiene que ser flexible o diferencial. Al adoptar ese proceso flexible, las fábricas de azúcar producirían simultáneamente azúcar de buena calidad así como alcohol, siendo aún capaces de aumentar la cogeneración. El resultado acumulativo sería una mayor rentabilidad en la fabricación del azúcar así como una mayor sostenibilidad de las fábricas.