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SUGAR INDUSTRY BY PRODUCT USED IN AGRO INDUSTRY

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ABSTRACT
Although world prices for sugar and petroleum products have shown spectacular variations since 1973, the long term outlook is very likely to be a gradual increase in the price of all fossil fuels and stagnation, at best, for the price of sugar.

KEYWORDS: *Bagasse, Molasses , pressmed.*

1.INTRODUCTION
This gloomy prospect explains, to a large degree, the renewed interest in the byproducts of the sugarcane industry which has developed in the last ten years and which has shown that the optimal use of byproducts can provide a non-negligible support to the sugarcane industry, although it could not, by itself, completely redress the difficult situation sugar is presently experiencing.

The four main byproducts of the sugarcane industry are cane tops, bagasse, filter muds and molasses (Figure 1).

If we accept that the present world production of sugarcane has reached the 60 million tonnes level, then the quantities of these byproducts produced yearly are approximately the following:

Cane tops	200 million tonnes	(fresh weight)
Bagasse	60 million tonnes	(bone dry weight)
Filter muds	5 million tonnes	(air dried weight)
Molasses	16 million tonnes	(at 80 percent DM)

Reliable statistics are not available to show the detailed end uses of these byproducts on a world basis, but although their utilization will be considered later in more detail, as a very rough picture of their trade we can say that at present cane tops and filter muds are largely ignored; that bagasse is used internally mainly as fuel to generate steam in the sugarcane factories and a small fraction to produce pulp and board; and that molasses is exported either as such for animal feed or after transformation as rum, potable alcohol or industrial alcohol.

2. VALUE UPGRADING AND PRICE LEVEL OF BYPRODUCTS
There are many end uses to which the byproducts of the sugarcane industry can be put - probably more than 150. But many of them, under present technological and marketing conditions would be of

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negligible economic interest. Figure 1 presents about 38 end-products which we consider as potentially important or which have proved, under normal circumstances, of economic interest.

It should be pointed out that, as a general rule, maximum value upgrading goes with more complex processing characterized by capital intensity, sophisticated technical know how and competitive markets. Maximization of profits is not automatically linked with process complexity and depends much more often on advantages local conditions or the proximity of a remunerative export market.

Although "small" may be rarely "beautiful" when dealing with byproducts, the simpler operations are often the more profitable.

As an example, molasses can simply be exported as such and earn some US$ 25 to 30 per tonne. However, by transforming the molasses into citric acid (worth say US$ 1 600 per tonne) about 330 kg of citric acid worth US$ 528 would be obtained from one tonne of molasses, i.e. about 18 times more than the previous operation. We must point out however that it is generally much easier to find a market for 30 000 tonnes of citric acid (worth US$ 750 000) than it is to find a buyer for 10 000 tonnes of citric acid (worth US$ 16 000 000). The market price of the byproducts of the sugarcane industry varies from country to country with cyclical increases and decreases.

i. Cane tops have no real market value. They can be compared to fair quality fodder with an average feed value, when fresh, of about 2.8 megajoules of metabolizable energy per kilo of dry matter. However cane tops should be collected and transported from the cane fields to the feedlot and their value to the cane producer could probably be no more than US$ 10 per tonne of fresh cane tops.

ii. The price of bagasse is generally related to its fuel value. Thus since 1 tonne of mill-run bagasse can be replaced by 0.173 tonne of fuel oil, worth US$ 80/tonne or again by 0.263 tonne of bituminous coal worth US$55/tonne, it can be said that bagasse is worth between US$ 13.8 and 14.5 per tonne (mill-run weight, 50 percent moisture content) and a figure of US$ 15 can be used as a rounded representative average.

iii. Filter muds have no set market value and since they are used almost exclusively as fertilizer, it is reasonable to utilize their fertilizer value which stands at present at about US$ 10 per tonne of air dried filter muds (30 percent moisture).

3. MAIN UTILIZATION OF BAGASSE

Bagasse is the fibrous residue of the cane stalk left after crushing and extraction of the juice. It 980 consists of fibres, water and relatively small quantities of soluble solids - mostly sugar. The average composition of mill-run bagasse is the following:

Fibre (including ash) 48.0 percent
Moisture 50.0"
Soluble solids 2.0"

The fibre consists mainly of cellulose (27 percent), pentosans (30 percent), lignin (20 percent) and ash (3 percent).

The calorific value (CV) of bagasse is given by the formula:
Net CV = 18 309-31.1 S-207.3 W-196.1 A (expressed in kJ/kg)
Where
S = soluble solids % bagasse
W = moisture % bagasse, and
A = ash% bagasse,.
If W = 0, S = 2 and A = 3, then the net CV of bone dry bagasse = 17 659 kJ/kg.
If W = 50, S = 2 and A = 1 1/2 then the net CV of mill run bagasse = 7 588 kJ/kg.

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Bagasse is used for the generation of steam and power required to operate the sugar factory. А этом typical factory producing raw sugarcane require, per tonne of cane, about 35 kWh and 450 kg of jelleen exhaust steam. Much progress has been achieved lately and, with continuous operation of the pans, crystallizers and centrifuges and an efficient evaporation station, a modern raw sugar factory can now operate with 30 kWh and 300 kg of exhaust steam per tonne of cane. Such a factory can save 50 percent of the bagasse it produces and this bagasse can be used to produce electricity for the grid or saved as raw material for the production of paper, board, furfural, etc.

(a) Electricity

The more straightforward solution is to produce electricity from the bagasse saved via a high pressure boiler and condensing turbo-alternator. This solution has found favour in a number of cane producing countries such a Hawaii, Australia, Reunion and Mauritius and with modern equipment some 450 kWh can now be produced per tonne of mill-run bagasse. A typical example of this use is given in Table 1 and if mill-run bagasse is priced at US$ 15 per tonne, electricity can be generated on a year round basis, at a cost of approximately US cents 6 to 8 per kWh, which should proveniwollot competitive with the ruling price of electricity in most Third World countries.

To be economical, the generating station must work on a continuous basis, say at least 7 800 hours yearly. This will imply bagasse storage to be able to generate during the intercrop period. Various methods have been tried: dry and wet bulk storage, bale storage and pelleting.

Dry bulk storage has proved uneconomic and is not suitable for large tonnages. Wet bulk storage does not apply and is utilized when bagasse is to be used for pulp production. Pelleting is still being tested in Hawaii and in Mauritius, but appears expensive per tonne of bagasse handled. Thus bale storage, which is presently the most widely used method seem the reasonable choice, although it requires a substantial storage area and can lead to annual losses of 10 percent of more of the bagasse stored.

The generation of electricity from surplus bagasse is undoubtedly the easiest and best utilization of this byproduct for most cane-producing Third World countries. However, as local conditions vary extensively the possibility of utilizing surplus bagasse to produce particle board, paper, furfural, or methane will be briefly considered.

(b) Particle board

The production of particle board from bagasse is a well-proven technology but it has to compete with plywood and fibreboard. Its main difficulty is the high cost of imported synthetic resins which serve as a binder to the bagasse fibres composing the board. Also the board's optimal thickness is about 15 mm and further it cannot be used for outdoor purposes so that its main market is limited to inner wh partitions and furniture. of noillim St 22

In the last few years a process has been developed in the Federal Republic of Germany whereby oas Portland cement replaces the urea formaldehyde resins, which enables this cement-bonded particle board to be used for exterior walls, roofing, etc. and thus increases significantly its market appeal. Note however that the bagasse utilized should not contain more than 0.5 percent of sugar on a bone dry basis. Otherwise the end product would not be satisfactory. Table 2 gives some indication of the comparative economic data for resin and cement particle boards made of bagasse.

(c) Paper

Good quality wrapping and magazine paper can be produced with a high percentage of depithed all ori bagasse as raw material. The availability of a fair size internal market, sufficient surplus bagasse and fair quality industrial water are the usual constraints, apart from the high capital intensity of paper M (0) plants and the necessity to handle polluting effluents.

Up to now the production of newsprint from bagasse has proved difficult and uneconomic, but there ven are constant advances in technology and bagasse newsprint may become feasible within the next ten years, especially if mixed with a fair percentage of waste paper. Also the production of magazine or note

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paper on a small scale has been investigated by Western (1979) and the experience gained in India seems to confirm the feasibility of plants producing as little as 15 tonnes of bleached pulp per 24 hours.

The process generally favoured for the production of bagasse pulp is the Kraft process using sodium sulphate. The actual sulphate cooking liquor contains a 4:1 mixture of caustic soda and sodium sulphide. Typical yield on bone dry depithed bagasse, to be expected with the Kraft cooking process is 48 percent for the final bleached slush pulp. Production cost, with depithed and 90 percent drynsla ed bagasse at US$ 30/tonne, would be around US$ 340 per tonne of bleached slush pulp. Water bns nlio requirements would be about 200 m3 per tonne of pulp. Indicatively, the capital cost for plant and equipment would be about US$ 12 million for a 50 TPD factory.

The production of pulp and paper from bagasse is not advisable as the main use of byproducts by it bris Third World countries, unless very favourable local conditions exist. It is a relatively demanding technology best approached after gaining experience with simpler bagasse processing as called for in electricity generation or particle board manufacture.

(d) Furfural

Furfural is a colourless, inflammable, volatile, aromatic liquid produced from a number of plant materials containing pentosans - in the case of bagasse, 90 percent being xylan. With acid hydrolysis the xylan yields xylose which subsequently loses 3 water molecules to form furfural according to the following simplified equation:

$$C_5H_8O_4 + H_2O \text{ --- } C5H_{10}O_5 \text{ --- } C_5H_4O_2 + 3H_2O$$
$$\text{Xylan} \qquad \text{Xylose} \qquad \text{Furfural}$$
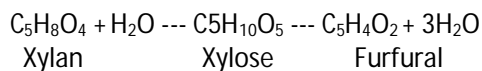
In practice about 25 tonnes of mill-run bagasse are required to produce 1 tonne of furfural.

Furfural has many industrial uses, one of them being as a selective solvent for the refining of lubricating oils and another as an intermediate in the production of nylon 6.6 and resins used for moulding powders.

Furfural on hydrogenation yields furfuryl alcohol which can produce inexpensive, heat-stable and corrosion-resistant resins. Furfuryl alcohol is also used in the pharmaceutical, fungicide, insecticide and solvent fields. Table 3 gives a summary of production variables of furfural from bagasse.

Capital cost for a 5 000 tonnes/yearly plant, generally considered as the minimal economic capacity, would be about US$ 9 million and the production cost about US$ 450 per tonne of furfural.

It should be noted that about 35 tonnes of steam are required to produce one tonne of furfural, hence the importance of utilizing the lignin rich hydrolysate which is left over from the process to generate steam in a special boiler. Low pressure steam will be available as surplus and could be used in an adjoining distillery.

Furfuryl alcohol is produced by the catalytic hydrogenation of furfural. Starting from bagasse, a plant to produce 4 500 tonnes yearly of furfuryl alcohol would cost US$ 12 million to US$ 13 million and would require some 150 000 tonnes of mil-run bagasse. The production cost would be about US$ 1 250 per tonne of furfuryl alcohol.

As stated earlier, the production of furfural and/or furfuryl alcohol from bagasse for the production of pulp and paper is relatively complex. The two newcomers to this activity, namely South Africa and the Philippines, have had some initial problems but while the former overcame them and in fact has doubled its initial production capacity, the latter has not been able to find remunerative markets and has been out of production for the last three years.

For the time being, therefore, production of furfural from bagasse should not be given high priority on the list of byproduct industries to be developed by Third World countries.

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(e) Methane

Much has been written on the production of methane or biogas and very often sugarcane producers have been under the impression that a good opportunity was being lost in the production of an economic gaseous fuel from their surplus bagasse.

Methane (CH4) and carbon dioxide are the main gaseous products of the anaerobic methane fermentation of waste and cellulosic materials. Theoretically 1 kg of cellulose would produce 415 litres of methane, but in practice the process is less efficient with a complex three-stage reaction operating in cascade and not always easy to manage.

Cellulose is, normally, easily digested by bacteria. However when it is combined with lignin, as in bagasse, it is degraded only with great difficulty. Hence a biogas digester in the sugar industry should be planned to operate mainly on distillery stillage or feedlot effluents with a small addition of surplus pith, and not on bagasse as the only or main raw material.

It is important, within the digester, to keep the ratio of carbon to nitrogen at about 25:1 and that of carbon to phosphorus at about 150:1. The sludge should be kept slightly alkaline, at about 7.5 pH, and the temperature should be maintained at about 35°C. The retention time would be about 20 days.

Biogas has a calorific value of about 22 000 kJ per kg (which is equivalent to 27 500 kJ per m3).

A 100 m3 digester can cost about US$ 50 000, with wide variations according to the sophistication of the arrangement. It could produce some 30 000 m3 yearly and the production cost can be etimated at about US$ 4 per GJ - while as a reference point tax-free gasoline is at US$ 8 to 10 per GJ. So while bagasse is not the proper feed for the production of biogas, other byproducts can be (d) considered, especially distillery sludge.

4. FILTER MUDS

The precipitated impurities contained in the cane juice, after removal by filtration, form a cake of varying moisture content called filter muds. This cake contains much of the colloidal organic matter anions that precipitate during clarification, as well as certain non-sugars occluded in these precipitates.

The weight of wet filter muds (80 percent water) averages about 3.4 percent cane.

Filter mud contains, on a dry basis, about 1 percent by weight of phosphate (P2O5) and about 1 percent of nitrogen. As a result it has been used, especially since the turn of the century, as a fertilizer. The filter mud also contains a mixture of waxy and fatty lipids in a ratio of 5:2 and refined wax can be extracted by appropriate treatment by solvents. It should be noted, however, that only 386 kg of refined wax, which could be roughly equated to carnauba wax, can be obtained from 1 000 tonnes of cane. The process is not commercially of interest under existing conditions and, as far as we know, only one plant is operating presently in India and on a small scale.

The use of filter muds as animal feed has been tried by a number of sugarcane producer territories but so far has not proved economically rewarding, the main constraints being the magnitude of the drying process involved and the low digestibility of the dried scums.

5. MOLASSES

The exportation of molasses as such is important in international trade and out of a total world production (beet molasses included) of 35.5 million tonnes in 1985-86, some 6.5 million tonnes were exported. The main importing countries, namely USA, Japan, Netherlands and UK, utilize the molasses largely for animal feed.

Molasses is the final effluent obtained in the preparation of sugar by repeated crystallization; it is the residual syrup from which no crystalline sucrose can be obtained by simple means. The yield of molasses is approximately 3.0 percent per tonne of cane but it is influenced by a number of factors and may vary within a wide range (2.2 to 3.7 percent). The specific gravity varies between 1.39 and 1.49, with 1.43 as indicative average.

The composition of molasses varies also within fairly wide limits but, on average, would be as follows:

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Water	20%	Other carbohydrates 4%
Sucrose	35%	Nitrogenous compounds 4.5%
Fructose	9%	Non-nitrogenous acids 5%
Glucose	7%	Ash 12%
Other reducing sugars	3%	Others 5%

A very large number of products can be derived from molasses. The question of animal feed from siliu molasses and other byproducts of the sugarcane industry will not be considered in our presentation and we will limit ourselves to describing briefly the main products of molasses fermentation that are of economic importane on an international scale, namely rum, ethyl alcohol, acetic acid, igso srl borilem butanol/acetone, citric acid, yeast and monosodium glutamate.

(a) Rum

Rum is the alcoholic distillate from the fermentation of cane juice, syrup or molasses. It has a characteristic taste and aroma. Its production derives from a simplified, but selective, ethylic fermentation and distillation, a number of esters and higher alcohols or "congeners" being present in the end-product.

Rum is generally produced at 76°GL and is diluted with water and sold to th public at 33 to 40°GL.060 One tonne of molasses would produce about 230 litres of rum (basis 100°GL). Table 4, based on Mauritius data, reasonably representative of Third World conditions, shows how the selling price A (5) builds up from producer to retailer. If the producer is also the bottler and wholesaler, the profit is substantial and rum prodution from molasses is, by far, the most profitable industry in byproducts utilization while being, at the same time, a provider of revenue to the government through excise tax. Yearly consumption of rum is probably more than 480 million litres (1985).

(b) Ethyl alcohol (C2H5OH)

Ethyl alcohol is amongst the most important fermentation products and is derived from three types of raw materials:

* Sacchrine products - mainly molasses, but also cane juice
* Starchy products - mainly maize
* Cellulosic products - mainly waste sulphite pulp liquor.

It is, however, still largely produced synthetically from ethylene derived from petroleum.

Under Third World conditions, the production cost of ethanol (the common name for ethyl alcohol) from cane molasses in a modern and fair size distillery - of say 60 to 80 000 litres per 24 hours - would depend significantly on the price of molasses:

* .With molasses at US$ 75 per tonne, the cost of ethanol would be US cents 45/litre
* .With molasses at US$ 50 per tonne, the cost of ethanol would be US cents 36/litre
* With molasses at US$ 25 per tonne, the cost of ethanol would be US cents 27/litre

With fair quality cane molasses some 240 litres of ethanol (100°GL basis) should be obtained from one tonne. If cane juice is utilized instead of molasses, production would be 72 litres per tonne of cane (which is also approximately 100 litres per tonne of juice).

* With juice at US$ 20 per tonne, the cost of ethanol would be US cents 48/litre
* With juice at US$ 15 per tonne, the cost of ethanol would be US cents 41/litre
* With juice at US$ 10 per tonne, the cost of ethanol would be US cents 34/litre

An initial estimate of the capital cost of a distillery producing industrial alcohol with a normal capacity ranging from 50 000 to 150 000 litres/24 hours would vary between US$ 80 and 140 per daily litre capacity, depending on whether the distillery is annexed to a sugar factory and benefits from the steam generating department or whether it is an independent distillery having to provide its own energy and steam. If the end product is refined potable alcohol (96°GL) or anhydrous (99.8° GL) alcohol, the capital cost would be slightly higher.

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One of the main difficulties of large capacity distilleries is the efficient handling of their effluents (also called slops, vinasse or stillage) since 13 litres of slops are produced from every litre of ethanol. The recently developed Swedish process of Biostil, by Alfa Laval, is a great improvement since it reduces the weight of stillage by 60 percent and is thus finding increasing favour among alcohol producers.

However even this reduced tonnage of stillage has to be treated and the two processes generally utilized are either evaporation plus incineration to recuperate the potash in the stillage, or anaerobic digestion. For the treatment of 1 000 tonnes of slops per 24 hours the capital cost for the first method would be about US$ 7 million and the net operating cost US$ 100 000 yearly. For the anaerobic method the capital cost would be about US$ 4 million and the net operating cost US$ 600 000 yearly.

The relatively high cost of gasoline and the recent tendency to decrease atmospheric pollution by progressively replacing leaded gasoline by ethanol extended gasoline has created a significant demand for ethanol, especially when taking into consideration the large-scale Brazilian Alcohol Plan.

However conditions vary from country to country and, for a large number of cane producing countries, present conditions indicate that ethanol is still a relatively expensive product compared to tax-free gasoline. Figure 2 shows how a rough choice would be made, according to the local prices of molasses (or cane juice) and gasoline. It assumes that a vechile running on industrial ethanol would consume 15 percent more volumetrically than when running on gasoline.

(c) Acetic acid (CH3COOH)

Acetic acid is a colourless liquid with a characteristic pungent odour and a sharp acid taste. Its density is 1 049 g/l. Vinegar is a condiment made from sugary or starchy materials by alcoholic and subsequent acetous fermentation. It contains at least 4 percent of acetic acid.

Acetous fermentation is aerobic and the modern submerged fermentation process requires the thorough airing of the vinegar bacteria - Acetobacter. From 100 litres of absolute alcohol some 950 tres of vinegar with 10 percent acidity can be produced. The capital cost for a 200 000 litres per annum vinegar plant is approximately US$ 500 000 for the main items of equipment. Acetic acid finds large scale utilization in the production of acetic anhydride, cellulose acetate, vinyl acetate, etc.

(d) Butanol-acetone

The butanol-acetone fermentation is a true anaerobic fermentation brought about by various strains of Clostridium acetobutlicum. Maize and molasses are the main raw materials used.

Butanol (C4H9OH) is the industrial name given to N-butyl alcohol. It is a colourless liquid with a vinous odour and a density of 810 g/l. It is used, directly or indirectly, in lacquer solvent via its acetate and phtalate salts and also as a plasticizer, hydraulic fluid, and intermediate.

Acetone (CH3COCH3) is a colourless, volatile, inflammable liquid with a characteristic odour and a density of 792 g/l. It has a fair number of uses, the main one being as a solvent.

The fermentation process produces a mixture of butanol/acetone/ethanol in the ratio 65:30:5 which is separated by distillation. Approximately 500 kg of molasses would produce 65 kg of butanol, 30 kg of acetone and 5 kg of ethanol.

The economy of teh fermentation proces depends greatly on the cost of molasses and of stream since extreme sterility is required and steam usage is about half the weight of molasses. It is generally considered that synthetic plants producing butanol from acetaldehyde are more economical than fermentation plants; and this is confirmed by the fact that the production of fermentation butanol does not represent more than 10 percent of the total world production.

(e) Citric acid Citric acid is usually produced in the monohydrate form (C6H8O7H2O), the crystals of which are colourless and odurless, with a sour taste and readily efflorescent in dry air. They have a specific gravity of 1.542.

The fermentation process consists of a complex aerobic cycle and beet molasses has had more success as the main raw material than cane molasses. The mould used is Aspergillus niger andylle submerged culture fermentation is now preferred to the surface fermentation previously utilized. Aeration and agitation

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of the medium are essential and the addition of methanol appears beneficial when using cane molasses. The yield of citric acid is about 65 percent of total sugar used.

A plant to produce 2 500 tonnes of citric acid yearly would probably call for a capital cost of US$ 4 million.

Citric acid is one of the most verstile of the industrial organic acids, finding increasing uses in the food and beverage industries. Since there is no potential threat from any "synthetic" citric acid, the production of fermentation citric acid appears warranted in the larger cane producing countries where molasses is available at a fairly low price, and when the local market for soft drink, confectionery and pharmaceutical preparations is on the increase.

(f) Yeast

Yeasts are complex, protein-rich, living unicellular organisms that have been selected and isolated through research, and two strains are now mainly utilized, namely: Saccharomyces cerevisiae to produce baker's yeast and Torula utilis to produce feed yeast.

The assimilation of glucose in the aerobic biosynthesis of yeast can be approximately illustrated by the formula:

$$C_6H_{12}O_6 + NH_3 --- C_6H_7O_3NH_2 + 3H_2O$$
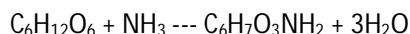
In practice the yield of yeast is much lower than the 80 percent indicated above and does not reach more than about 54 percent (including about 8 percent of ash).

Baker's yeast is normally produced from molasses, grains or potatoes. Feed yeast usually utilizes brewer's or distiller's stillage. These raw materials are not sufficiently rich in assimilable nitrogenous and phosphorus compounds and, usually the addition of inorganic ammonium compounds and phosphoric acid is necessary.

About 4 kg of molasses would be required to produce 1 kg of active dry baker's yeast (92 percent dry matter). Yeast is used in bread production at about 1 percent by weight of flour. On a dry matter basis, it contains about 44 percent protein.

About 4 kg of molasses would also be required to produce 1 kg of feed yeast (92 percent dry matter) which generally contains about 50 percent of crude protein.

In both processes adequate and fine aeration is important and some 15 m5 per kg of dry yeast are usually required.

Capital cost for a feed yeast plant would be about US$ 500 per annual tonne of yeast production. The production cost would be greatly influenced by the cost of molasses and could be very roughly expressed by the following equation:

$$y = 4x + 70$$

where y is the price of feed yeast in US dollars per tonne and x is the price in dollars of a tonne of molasses. Thus with molasses at US$ 50/tonne the production cost of feed yeast would be approximately US$ 270 per tonne.

The production of single cell protein (SCP) by microorganisms from hydrocarbons and carbohydrates can be considered as a natural extension of feed yeast production. Its high protein content (65 to 70 percent) and the possibility of using such "waste" substrates as cellulose, distillery slops and other effluents indicate a favourable commercial outlook.

(g) Monosodium-glutamate (C5H6O4.NH2Na.H2O)

Monosodium glutamate is an important commercial flavouring intensifier with a world production of about 250 000 tonnes/year. It is currently produced by the aerobic fermentation of molasses but there are also a number of synthetic routes available for its production, especially via acrilonitrile. In the fermentation process which is carried out in well-aerated submerged culture, the bacteria Micrococus glutamicus is utilized with molasses as raw material. About 4 1/2 kg of molasses are required to produce 1 kg of MSG

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which is worth about US$ 2.50/kg. There are approximately 30 companies producing MSG in the world with an installed capacity of about 325 000 tonnes/year. The larger producers are Japan, Republic of Korea, Taiwan Republic of China and USA.

It would probably be difficult for a small sugar producing country to enter this very competitive and well-supplied market, especially since the fermentation technique required is fairly sophisticated.

(h) Industrial alcohol as cooking fuel

Although this utilization will be of little interest to industrialized countries, bearing in mind the very large number of people who still use wood, or wood charcoal, in open ovens to cook their meals, and the critical problem of deforestation in many parts of the world and especially in Africa, consideration must be given to the efficient utilization of ethanol as cooking fuel.

A possible solution had been proposed by Moundlic (1979) but does not seem to have received the attention it should have attracted. The ethanol cooker envisaged consists of a fuel tank kept at constant pressure by a small volume of compressed CO_2. This causes the ethanol to flow evenly to a vaporization burner.

The thermal efficiency is about 58 percent while that of an open wood stove varities between 5 and, at best, 10 percent. In some African countries the amount of wood used by a family for cooking is about 4 1/2 tonnes yearly, producing about:

$$4\,500 \times 2\,530 \times 5/100 = 570\,000 \text{ kcal.}$$

The same heating value would be produced by:

$$\frac{570\,000}{6\,650 X\,58/100} = 148\,kg$$

i.e. about 188 litres of ethanol at 95°GL.

Table 1: Electricity from bagasse

		Best conditions	Moderate conditions
1.	Characteristics		
	- Boiler (46 Bar A, 440°C) capacity tonnes steam per hour	90	90
	- Turbo-alternator (condensing at 0.10 Bar A) capacity (MW)	20	20
	- Total capital investment for generating station in working order (US$ million)	9	11
	- Electricity generated yearly (GWh)	150	120
	- Weight of mill-run bagasse utilized (tonnes)	333 000	266 000
	- Acquisition cost of mill-run bagasse (US$ per tonne)	15	20
	- Average transport cost per tonne of bagasse (US$)	4	5
2.	Cost of electricity generated (in US$ cents per kWh)		
	- Depreciation and maintenance (10%)	0.60	0.92
	- Annuity repayment (0.16275 for 10 years at 10% interest)	0.98	1.49
	- Labour and administration (US$ 100 000 yearly)	0.07	0.08
	- Transport cost of bagasse	0.89	1.11
	- Acquisition cost of bagasse	3.33	4.48
	TOTAL GENERATION COST PER kWh	2.87	8.08
		say US cents 6.00/kWh	say US cents 8.00/kWh

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Table 2: 50 TPD bagasse particle board plant (per tonne of product)

		Standard resin board plant	New cement-bonded board plant	
1.	Inputs per tonne of product			
	Mill-run bagasse	3 tonnes	Depithed bagasse (50%H_2O)	450kg
	Urea-formaldehyde resins	80kg	Portland cement	600kg
	Hardener	8kg		
	Wax	6kg	Chemicals	25kg
			Water	250kg
	Labour	8 man- hours		6 man-hours
	Fuel oi	60kg		-

Table 3: Furfural from bagasse (Basis 1 tonne furfural)

Consumption		Production	
Bagasse (bone dry)	12.5 tonnes	Furfural (99%)	1 tonne
Steam	35.0 tonnes	Acetic acid	550kg
Water	70.0 tonnes	Hydrolysate residue (bone dry)	6.75 tonnes
Power	875 kWh		
		(This residue has 63% moisture and a net calorific value of 5 442 kJ/kg)	
Labour (3 shifts of 8 hrs)	216 man-hours daily		
Maintenance	10% of production cost	Secondary steam (125°C saturated)	7.5tonnes
Overheads	10% of production cost		
Depreciation	10% yearly of capital cost		

Table 4: Cost structure of rum production and marketing (in Mauritius)

			US$ per liter of rum(40°GL)
1	MANUFACTURE		
	(i)	Molasses (US$ 25/tonne, 230 litres alcohol at 100°GL equivalent, after dilution, to 575 litres rum at 40°GL)	0.04
	(ii)	Other costs	0.04
	(iii)	Profits	0.10
2.	BOTTLER		
	(iv)	Cost to bottler	0.18
	(v)	Bottling costs (glass bottle, cap, labour, etc.)	0.20
	(vi)	Excise duty (paid to government)	1.40
	(vii)	Profits	0.45
3.	RETAILER		
	(viii)	Cost to retailer	2.23
	(ix)	Profits	0.55
4.	PUBLIC		
	(x)	Retail price to public	US$ 2.78 per litre

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6. CONCLUSIONS

Although schematic and fragmentary, the preceding survey of the current uses of the main byproducts of the sugarcane industry does indicate a few priority choices, generally applicable to for conditions obtaining in Third World countries.

i. Surplus bagasse should be used to produce electricity for the grid;
ii. If the electricity supply is already adequate, then surplus bagasse could be used for the qua production of cement particle board for the local market;
iii. Filter muds should be utilized as low grade fertilizers in the cane fields;
iv. Molasses should be transformed into rum and potable alcohol, according to the local and elsie export market requirements; sibi no vloeib beau
v. Any surplus molasses left over could be used either locally for animal feed, or exported as such, depending on the ruling market prices and distance of transport;
vi. If there is an excessive use of wood as fuel for cooking which leads to rapid deforestation, a drive should be made to produce industrial ethanol to be used in efficient pressure stoves.

It should be stressed, as a general conclusion, that the large-scale utilization of byproducts of the sugarcane industry, if efficiently implemented, has the dual and important advantage of generating reasonable profits, not only for the sugar producers themselves but also for the national economy at large, as exemplified by cheap electricity, imports replacement, the efficient use of local fuels and forest preservation.

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