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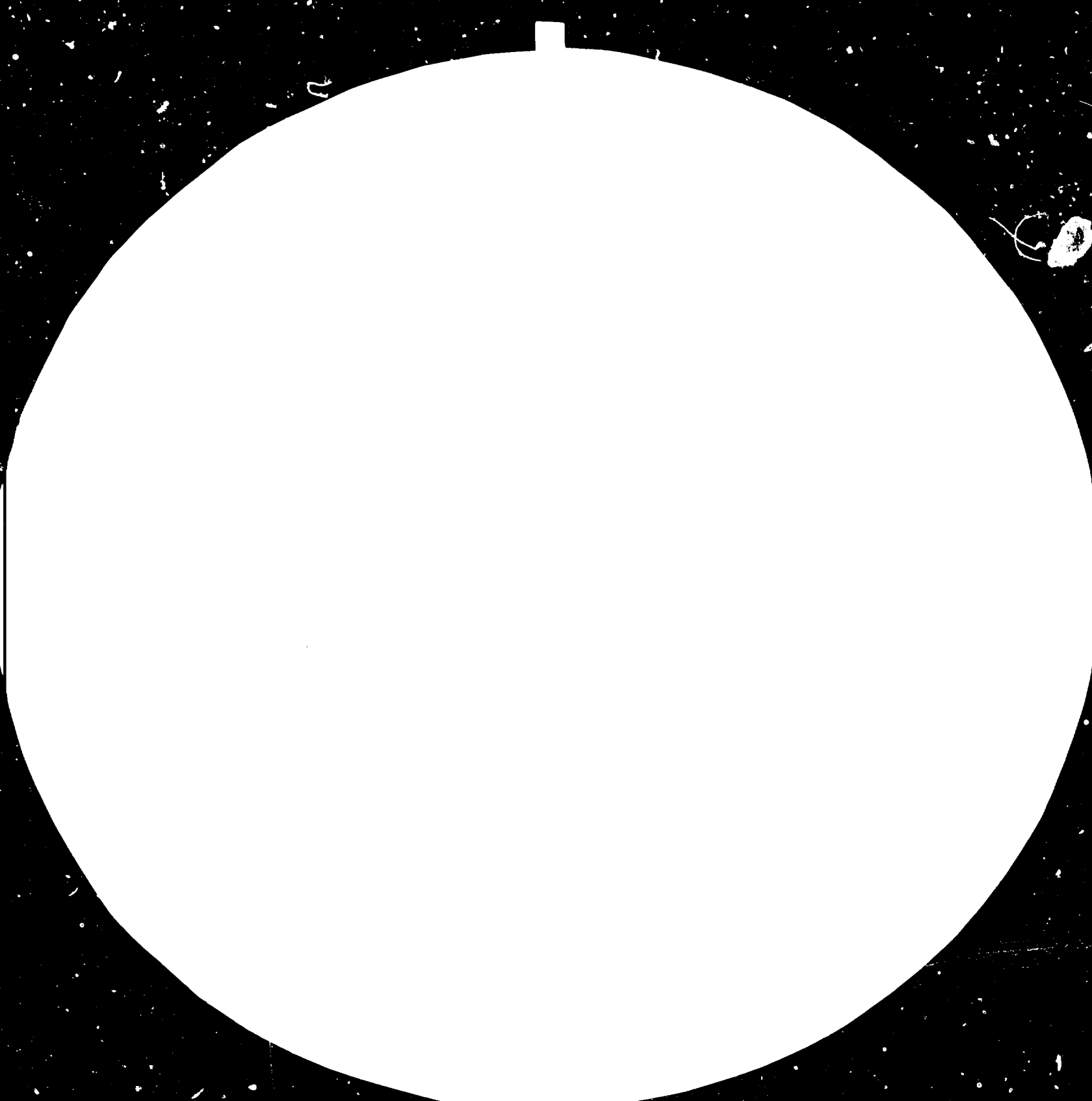

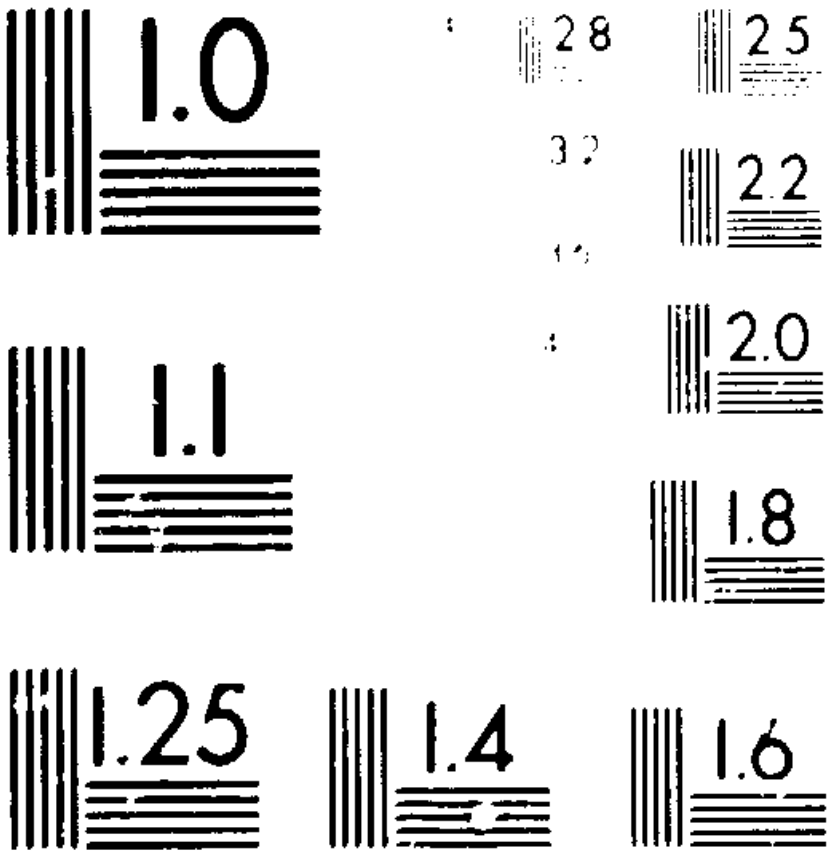

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CANE SUGAR INDUSTRY BY-PRODUCTS UTILIZATION*

A general review with particular
reference to Africa

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I. INTRODUCTION

Sugar is produced today in some 110 countries. Additionally, several countries are producing sugar cane, but with no recorded production of sugar (e.g. Burundi). In Africa alone, sugar is produced in 32 countries with a total production of 6 to 6.5 million tonnes of cane sugar and some 350,000 tonnes of beet sugar, with some fluctuations from year to year. These figures indicate the extent to which the sugar industry is important for the overall economy of African countries. The average annual consumption is approximately 15 kg per caput and this is far less than in Europe (42 kg), North America (41.5 kg) or South America (44 kg) but still more than in Asia (8.8 kg). The average annual consumption for the world is about 20-21 kg.

The free market prices of sugar have fluctuated between US$ 60 per tonne in 1968/69, US$ 660 in 1974 (with some daily spot prices reaching more than US$ 1,000) and the present price close to US$ 200-250 per tonne. The low prices may be welcomed by importers however, they may create difficulties for the exporters if they have to sell sugar below its production cost and reduced foreign exchange income. The repercussions of these fluctuations would be even worse without special bilateral import/export arrangements between a number of countries which reduce these fluctuations to a certain extent. The International Sugar Agreement was in fact, aimed at stabilizing the prices within certain limits however, the existence alone of the Agreement has not eliminated all the problems.

Another aspect of price fluctuations is that many decisions for the expansion of sugar production were made at the time when the prices were high and some countries expected to benefit from this situation by increasing their production and exports. Others, faced with increased import costs (coincidental with the first "oil crisis") decided to increase domestic production and thus reduce imports. Not all of these decisions were fully justified and it appears that some have contributed to the present situation. All this however, would have a different dimension if only Asia would increase consumption from the present average of less than 9 kg to the world average of 20 kg, not to mention the average of Europe, North and South America (more than 40 kg).

Although in the economy of Africa as a whole, the sugar production may not be the sector of primary importance, except for some countries (e.g. Mauritius), the total value of sugar produced still represents more than US$ 2,000 million, if taking the average price of US$ 300 per tonne. The real value for consumers, with all taxes, duties, packaging, distribution and other costs, is much higher of course.

II. SUGAR INDUSTRY BY-PRODUCTS

With an average yield of 10 percent (in practice it is between 5 and 13-14 percent) the quantity of processed cane in Africa is probably more than 60 million tonnes, with some 20 million tonnes of bagasse and some 2 million tonnes of molasses (exact statistics are not available) as by-products obtained annually. Most of the bagasse is used as a fuel in sugar mills, however, with rational energy utilization, particularly in large plants, it may be possible to save up to 15 percent of bagasse which could be used for other purposes. This would represent some 3 million tonnes however, 2 million tonnes may be considered to be more realistic but still requiring some effort. To this, one can add some 9 million tonnes of cane tops and 2 million tonnes of filter mud, both being hardly utilized except by leaving in the field or spreading round as a fertilizer (filter mud).

Although sugar is the main product from the sugar industry, there has been some discussion whether it is more feasible to produce sugar or fuel alcohol. This question has been raised particularly by those countries which are sugar producers and large petrol importers, at the time of low sugar and high petrol prices. If alcohol, which otherwise may be exported for US$ 200-300 per tonne, is used locally (at least partly) as fuel or chemical feedstock, it may save US$ 350 per tonne of petrol which it replaces. With the present free market price of sugar (US$ 254 per tonne in February 1983) it appears that the value of alcohol as a petrol replacement which can be produced from the same raw material (sugar cane) has a value close to US$350 (or US$ 400 with various expenses). By directing a portion of sugar cane and beet towards alcohol production (as a fuel replacement), the sugar surplus would be reduced and its price kept at a reasonably economical level for the majority of sugar exporting countries. This calculation may change of course, if the price of oil (fuel, petrol) is changed, as it happened only recently.

The high price of sugar, as we recall it during the 1972-1975 period, had an interesting effect on the development of the sweetener industry based on starch, particularly High Fructose Syrup (HFS) which has become a sugar competitor to some extent. The expansion of HFS production has somehow, slowed down lately, but in the case of high sugar prices it will, no doubt, further expand. A new market has been opened when both the Coca-Cola Company and the Pepsi Company approved the replacement of 50 percent of sucrose with 55 percent of HFS on a world wide basis in their fountain syrup.

The above examples, may indicate how the sugar production or over-production and price fluctuations may create situations with considerable impact on the industry, both positive and negative. It would be advisable to keep this in mind when looking into the possible utilization of by-products. At one time, one of the largest sugar producing countries was not interested in looking into the problem of rational energy utilization in sugar mills, and thus to increase the surplus bagasse. But suddenly, after the oil prices increased and the sugar price decreased, the situation changed and much interest was shown for the Latin American Workshop on Rational Energy Utilization in Cane Sugar Industry which UNIDO organized jointly with OLADE and GEPLACEA in 1980. This no doubt indicates that sugar industry by-products may play an important role in the overall economy of the sugar industry, particularly in developing countries. The beet sugar industry has probably less problems of this nature; beet pulp is traditionally used for animal feed (its digestibility is much higher than that of bagasse); the beet sugar industry is primarily located in developed countries, having other industrial sub-sectors sufficiently developed to use most or all molasses; it has a good infrastructure and transport facilities, etc. In the case of cane sugar production in developing countries, the situation is quite different. Old cane sugar mills were designed and built in such a way that all bagasse was used as fuel, any surplus bagasse would create a problem because there were no facilities to use it for any other purpose. Something similar occurred with molasses which was mainly exported, partly used locally and in some places even thrown away into the river. This situation has gradually changed and there is more and more interest to obtain surplus bagasse and to use it locally, together with molasses, as much as possible.

The list of products which could be produced from bagasse and molasses is quite large, particularly if considering also some products which could be produced by other industries from intermediate products obtained from bagasse and molasses, such as furfural and alcohol.

It is not the intention of this paper to elaborate industrial utilization of the cane sugar industry by-products in detail. There is quite comprehensive technical literature on this subject, those interested may refer both to the available books and to a number of technical papers and articles published regularly in various periodicals or presented at different meetings. Some possibilities however, may be of particular interest and are therefore, worth mentioning.

II/1 Bagasse utilization

As already indicated, with a proper heat economy it is possible to have surplus bagasse particularly in large and modern sugar mills. The bagasse, consisting of some 43-52 percent fibre, 46-52 percent moisture and 2-6 percent soluble solids, may be used in several ways. Its average gross calorific value is 9790 kj/kg or net calorifc value of 8033 kj/kg which is less than green wood (with 30 percent moisture). However, if air dried to some 15 percent moisture it is practically equivalent to air dried wood with the same moisture content. Since cane sugar mills are already using bagasse for fuel and the steam produced is used in the mills for evaporation of the sugar juice, for electricity generation and sometimes for running milling tandems, the first logical consideration is to burn all bagasse and to use the surplus steam either as such or for electricity generation. Steam, as such, may be used very effectively in any kind of plant attached to the sugar mill, such as alcohol distillery. Additional electricity may be transmitted to the public network, which is done in some places and is under consideration in others, although not always without problems. Some of the problems are; an inadequate distribution and connecting network; availability during certain periods only (a regular supply is not guaranteed) etc.

Another possibility is to use bagasse for animal feed. Low digestibility of bagasse, if used directly for cattle (mixed with pith, urea and molasses), has led to some development aimed both to increasing its digestibility (from 17% to more than 50%) and enrichment with protein. There are methods with simple alkaline treatment, alkaline and heat treatment, followed up

with the fermentation process, in order to increase the protein content etc. Some suppliers of plants and machinery for animal feed industry, offer complete lines for the production of pellets and which include milling of bagasse, mixing with sodium hydroxide, adding of molasses and making pellets which could easily be stored and are given directly for feeding. Any other additives and components may be added to the mixture without any difficulty.

In addition to animal feed, bagasse can be used as a source of energy, besides steam and electricity generation, in the production of charcoal, briquettes, methane gas, producer gas or methanol. As a fibrous material, it can be used for pulp and paper, paper board, fibre-board, furfural, xylitol, plastics (based on lignin), poultry litter, soil conditioning, bagasse concrete, etc. Under the prevailing conditions in most developing countries, it is obvious that the production of only some of these products may come into consideration, probably two or three. In a recent study prepared for a large sugar producing country in Africa, it was indicated that the use of bagasse in that particular country should be considered primarily for electricity generation, animal feed and charcoal production. The size of the market, availability of surplus bagasse, industrial infrastructure and specific needs for individual products, are determining factors.

The value of bagasse, as a source of energy, fibre, chemicals or animal feed, in money terms depends basically on the value of the material it replaces (such as fuel oil), less the additional costs of handling, possible drying, transport and storage. Due to its bulky nature (low density), rather high moisture content and need for depithing in some cases, these costs may be quite large, giving very little room for pricing bagasse as it comes out of a sugar mill. It still has its merit to look into its possible use, primarily due to its value as a ready available replacement of other materials some of which have to be imported either in a raw or a processed form.

It is interesting to note that the problem of bagasse utilization has a certain similarity with the utilization of wheat straw, rice straw, corn (maize) stoke and some other fibrous/cellulosic materials. Some developed and non-cane sugar producing countries have looked into this seriously and there has been considerable research and development activity going on lately. A very interesting illustration of this, is the Computer Conference

on Bio-conversion of Ligno-cellulosics for Fuel, Fodder and Food to be run for a period of 5 to 6 months as of the middle of 1983. Some 450 scientists from more than 40 countries (including 20 developing), have been invited to participate. This type of conference is very innovative, reasonably cheap (20 - 25 US$ per hour of on-line connect time), does not involve travel and enables a large number of persons to maintain contacts, exchange their views and have their presentation in a standard and uniform format.

II/2 Molasses utilization

Compared with bagasse, molasses represents a completely different by-product in many respects, it is available both from the beet and cane sugar industry and it may be used for many quite different purposes. It may be considered almost as a commodity item, it is exported and imported and has its price on the international market. In principle, the price fluctuations for molasses follow approximately the one for sugar, and are known to have been in the range between US$ 40 and US$ 140 per tonne. This wide range should be of no surprise, because its value is in its sugar content in the form of sucrose (30 - 40%), dextrose (4 - 9%), levulose (5 - 12%) and other reducing substances (1 - 5%) which have not crystallized and have not been separated during the standard sugar production process. The world production of molasses is in the range of 30 - 34 million tonnes. In the case of cane, the yield is about 2.2 - 3.7% of the processed cane (average 2.7%).

There is quite a number of possible uses of molasses and they represent a complex list of products and technologies, particularly if adding those products which are based on intermediates (semi-products) produced from molasses. The following are some possible uses of molasses:

direct use

- fertilizer
- animal feed in liquid or dry form in animal feed mixtures

fermentation by

- yeast
  - ethyl alcohol
  - glycerol
  - bakers' yeast
  - fodder yeast

- bacteria
  - butanol/acetone
  - butyric acid
  - lactic acid
  - propionic acid
  - acetic acid
- moulds
  - itaconic acid
  - citric acid
  - fumaric acid

To this, one can add dextran, monosodium glutamate (MSG), amino acid lysine, xanthan gum, aconitic acid, etc.

If taking ethyl alcohol as an example, there are by-products from its production, such as carbon dioxide, fusel oil and slop (vinasse) as well as products which could be produced from ethyl alcohol as a raw material by:

dehydration via ethylene
- polyethylene
- polystyrene
- ethylene glycol
- polyethers
- vinyl chloride

oxidation or dehydrogenetion, via
- acetone or acetaldehyde
  - diacetone alcohol
  - diphenylol propane
  - chloral
  - butyl alcohol
  - cellulose acetate
  - other acetate
  - acetamide, etc.

Most of these products are only of theoretical interest for many developing countries. The majority of them have no local market for these products and would not be able to produce them and to find their uses on an economically viable scale. Some products however, should be of interest particularly animal feed, alcohol, bakers' yeast, alcoholic beverages (such as rum), acetic acid, and some others.

III. Other by-products

Although the quantities of filter mud are relatively large (2 - 4% on cane, wet basis), it has not proven to have much commercial value, although there are several other possibilities (wax, animal feed, activated carbon, foaming agent, filter aids, compost), it is used mostly as a fertilizer by spreading it over cane fields. The main problem appears to be the economic viability of processing filter mud in spite of the fact that it contains (expressed as % dry matter) 5 - 14% wax and lipids, 15 - 30% fibre, 5 - 15% sugar, 5 - 15% protein and 9 - 20% ash.

Bagasse ash, from boiler furnaces, has found little use as well, it is mostly spread in the field for mineral recovery of the soil. Cane leaves, tops and pith have some possibility, primarily in animal feed mixtures however, most countries are using them to a limited extent only. Some possibility also exists in glass manufacture.

IV. TCDC possibilities

The utilization and industrial processing of sugar industry by-products offers a broad scope for co-operation among developing countries. A number of products mentioned above are already produced in various countries and, in principle, there should be no special problem in exchanging their experience with others. This has already been discussed at various meetings on rational energy utilization in the cane sugar industry, on the implication of technology choice in the African sugar industry, on the manufacture of chemicals by fermentation, on pulp and paper technology, on fermentation alcohol for use as fuel and chemical feedstock in developing countries, on appropriate industrial technology for sugar, etc. These are some of the meetings organized by UNIDO in the past. Mention may be given to the Brasilian experience with alcohol production and its utilization as car fuel, the Cuban experience with paper and boards production from bagasse, the use of bagasse and molasses for animal feeding, the experience of Mauritius in electricity production for the public network from surplus bagasse, the production of rum from cane molasses in several Caribbean countries, etc. Until now, it appears that a good will for co-operation and exchange of experience exists, with a few exceptions and those interested may express their interest one way or another. The exceptions are sometimes related to the specific and not readily available know-how (such as deep

fermentation for citric acid or production of mono-sodium glutamate, l-lysine, etc.), saturation of the international market in some products and resistance to further expansion of the production capacities, etc. As far as UNIDO is concerned, technical assistance has been provided to a number of countries in this field and it is expected that it will be provided in future as well.