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# DIVERSIFICATION OF SUGAR-CANE*

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* The views expressed by the author in this document do not necessarily reflect those of the UNIDO Secretariat. The document has been translated from an unedited original.

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## INTRODUCTION

The production of sugar as a product both for export and internal consumption is an branch of the economy of strategic importance in a growing number of underdeveloped countries.

In the Latin American region sugar-producing countries were receiving, at the beginning of the present decade, approximately $4,000 million from the sale of sugar on different markets, these exports taking third place among internationally marketable products. At the present time the earnings have dropped to a third and the predictions are that they will continue to do so.

For several decades sugar has been a product with high price fluctuations and with a market creating difficult conditions for the exporters. These circumstances have been aggravated by a combination of negative factors which have caused the consumption figures to fall and the prices to stay below the profitability limits for increasingly longer periods of time.

The protectionist policy of the European Economic Community and the American legislation protecting internal products have been the factors that have weighed most heavily over the last few years upon the delicate situation in the sugar market.

To these two factors, sufficient in themselves, one can add the production of JACF which has undergone very dynamic expansion, mainly in the United States, replacing sugar in its chief traditional uses; and together with this go the health campaigns which claim that sugar is one of the agents causing cardio-vascular disease.

The producer countries are facing the reality of an imminent collapse of the international market, deterioration of the exchange value of sugar, and the consequences of it for their economies. Faced by these difficulties, they see diversification of the use of sugar-cane as the most viable alternatives, since it will make it possible to broaden the range of production for other than sugar markets at more favourable prices.

In Cuban conditions the diversification of sugar fits in with a strategy which has been put into practice for more than 25 years, and for which at the present time there are some 40 industrial plants and another 10 at the investment stage, which makes the country one of the most advanced in the use of by-products from a sugar industry and sugar-cane growing. These experiments and their results are reviewed in this paper.

## 1. SUGAR AS A PRODUCT OF INTERNATIONAL MARKETING

The world capacity for the commercial production of sugar of all types is reckoned at some 115 million metric tons, thereby exceeding by 15 million tons the present consumption, which remains at a little more than 100 million tons, while the existing stocks have grown to such an extent that they amount to around 40 per cent of the production, thereby doubling the acceptable levels. The installed capacity exceeds the consumption estimated by FAO for the year 1990, which optimistically places the demand at 110 million tons.

The sugar consumption index has been marked by drastic changes over the last 15 years in the areas of demand, in such a way that while the countries with a developed market economy have declined over this period, the socialist countries have stepped up their consumption by a little more than 50 per cent, and the underdeveloped countries have virtually doubled it.

The production, consumption and stocking level achieved in the present decade are influenced by a combination of factors which have been in effect negative.

The absence of a sugar agreement as an efficient instrument for establishing a relationship between producers and consumers in the search for stable prices has had an impact that, even while affecting the price trends, cannot be regarded as a determining factor.

At the present time, of the total sugar produced only 25 per cent is sold on international markets and barely half of that is subject to the market prices, with the remainder coming under special agreements between countries.

An important factor has been, however, the protectionist policy of the EEC and the United States of America, which have kept internal prices above those of the international market by granting various forms of subsidy, limiting the import quotas and even exporting below the market price. The United States quota policy made it possible to place some 3 million tons on the Latin American market scarcely five years ago, and for the present year, 1987, these exports will be about 700 million tons; this means that the producer countries lose $1,000 million each year.

Similarly, one of the factors that has most likely exercised considerable influence on the world market has been the role of exporter played by the EEC since the middle of the 1970s; it is at the present time placing around 4 million tons with prices that are subsidized.

Some underdeveloped countries have in the mean time been creating situations aimed at protecting the official policies of supporting the creation of new production capacities to ensure self-sufficiency.

A contribution to the dynamic development is made by the new sweeteners of the fructose syrup type; they emerged as commercial products 10 years ago and in the United States today represent a production of 5 million tons (dry base), which covers around 35 per cent of the market; they are produced at about 20 plants which utilize for this purpose from 5 to 10 per cent of the maize produced in the country. By 1990, JMAF should represent about 10 per cent of the total quantity of sweeteners consumed in the world, according to the predictions made by specialist organizations.

A new situation has been arising in the international market with the shift in the demand of importers from raw sugar to white sugar. The refined variety, which barely used to attain 25 per cent of the market in 1970, currently occupies about 50 per cent and predictions show that before the end of the present century, virtually all the sugar sold on the international market will be white sugar of various types.

This set of circumstances, which is influential in different ways, has exerted pressure on prices and their cyclic fluctuations, heralding longer periods of depressed prices. The latter have been marked by extreme fluctuations ranging from 1.5 cents per pound in 1968 up to 60 cents in 1974. On the other hand, the average prices of sugar at international level have been considerably below the cost of production, which is reckoned to be about 15 cents.

While all these phenomena occur in the international field, the Latin American region, which contributes a little less than a third of the entire amount of sugar produced - and this means one of its principal sources of foreign currency - shows a new trend in the destination of its produce; it is now going basically for

internal consumption, a little more than 40 per cent being exported to markets different from the traditional ones of 10 years ago when the United States was the main customer, but is now only marginally so and by 1990 will not appear on the lists of sugar importers at all.

This overall view of the production, marketing and pricing of sugar suggests that the international market is facing a fully-fledged crisis, which shows up in a reduction in the volume of marketable sugar; in the low prices prevailing for long periods; in the protectionist policies pursued, which are increasingly damaging, in the existence of production capacities which exceed the demand, and in the dynamic development of new competitive sweeteners which are ousting sugar.

This gloomy prospect for sugar-producing countries could undergo a complete change if diversification strategies suited to the characteristics and conditions of each enterprise and country were adopted and if, using sugar-cane as a raw material with abundant possibilities, we could select among the different alternatives those proving most technically and economically viable.

## 2. BACKGROUND AND PRESENT POSITION OF THE CUBAN SUGAR AGRO-INDUSTRY

Sugar production began in Cuba at the end of the sixteenth century and since that time the course followed historically by Cuban sugar production can be divided into five periods.

The first of these corresponds to the pre-industrial phase which stretched from the end of the sixteenth century until the time when Havana was taken by the English in 1762, and is marked by a rapid increase in the number of sugar mills. From that time up to the middle of the nineteenth century, under the influence of the industrial revolution there were introduced into agriculture and industry the technological changes which mark the second period. At that time there were slightly more than 1,300 rudimentary sugar mills which used to produce approximately half a million tons of sugar. Cuba had by then become the greatest sugar producer in the world.

The third period runs from 1860 up to the end of the War of Independence between Cuba and Spain at the end of the nineteenth century, when the mills suffered greatly as a consequence of this episode in history. The emergence of the pseudo republic during the first three decades of the new century, under the protection and with the backing of American capital, brought about a major industrial concentration and reduced the number of sugar refineries to 166. At this stage there followed a crisis in the industry through the fall in sugar prices, the stagnation in production and the unfavourable type of agriculture, which lasted up to the time of its nationalization in 1960.

The last period starts from the victory of the revolution and can be divided into different stages: the first involves the introduction of revolutionary legislation and the nationalization of private companies; the second relates to the sugar development programme, culminating with the harvest of 1970 when a record production figure was reached; the third stage covers the 70s and is characterized by the creation and consolidation of the technical-material base for supporting development programmes; during this there was further mechanization of cane sugar growing and there were set up, after 50 years, the first sugar refineries, designed and constructed by Cuban engineers; in addition to this there was a major advance in the production of derivatives; and a fourth stage has been going on since 1980 with unification of cane sugar growing with the sugar industry, leading to a higher form of organization - the agro-industrial complexes.

The sugar agro-industry employs 400,000 workers and is composed of 156 agro-industrial complexes, 16 sugar refineries, of which seven are for direct white sugar, and about 40 plants for derivatives, more than 150 animal fodder plants, an infrastructure of more than 1.7 million hectares of land, 45,000 tractors, 4,300 sugar-cane combines, 800 centres for shipping and cleaning the sugar-cane, 7,700 km of railway, 1,000 locomotives, seven modern harbour installations with a daily export capacity of 75,000 tons of bulk unrefined sugar, and 12 plants for machine making.

The technical development of the production of sugar and its derivatives is backed up by four specialized research institutes, eight stations for the development of varieties, two design institutes, and various technological faculties and institutes relating to sugar.

The sugar agro-industry is the principal creator of exportable commodities and during the last five-year period the products of the sugar industry have been about 80 per cent of the country's total exports and about 20 per cent of the overall social product; Cuba is the greatest world exporter of sugar and covers about a quarter of all international sales and more than 10 per cent of its exports go to the free world market. The Cuban sugar economy is one of the most efficient among the sugar producing countries, principally in the industrial field, where yields higher than 11 per cent are gained and the sugar recovery is of the order of 85 per cent; all of this is accompanied by harvest mechanization levels of more than 60 per cent, which normally bring about a decline in industrial efficiency, but in Cuban conditions this has not been significant.

The production of raw sugar in Cuba is self-sufficient from the standpoint of energy, and a programme is under way for the conversion of the industry into a net energy producer. The last sugar-cane harvest provided the national network with approximately 10 per cent of the electricity generated in the country during the harvesting.

Cuban sugar production has been absorbing the new trends on the international markets in the shift in demand from raw to refined sugar and is now at the stage of introducing more advanced production techniques for white sugar that have been established internationally. The growing of sugar-cane covers more than 1.7 million hectares with an average yield of 55 t/ha. The sugar production per hectare-year attained is of the order of 6.4 t, above the world average of 4.4.

Cuba's agro-industrial sugar activity is progressing under conditions of relative efficiency and a technological level that is fairly high; this makes it possible to take advantage of major reserves available chiefly in the agricultural area.

## 3. EVOLUTION OF THE SUGAR DERIVATIVE INDUSTRY AND THE PRESENT SITUATION

### The development of derivatives

The use of sugar-cane by-products at international level is relatively recent in the present century; their initial uses were the consumption of bagasse as fuel and molasses in animal feeds and in alcohol production.

The beginning of expansion of the derivatives, with the setting up of large industrial plants, began in the 1940s; that decade saw the deployment of significant technological efforts in the pulp and paper, fermentation and board industry, and it was at the end of the 1950s and beginning of the 1960s that the large-scale industrial application of the by-products began at international level.

The sugar derivative plants are spread over 20 countries and those that have attained the greatest development are for: pulp and paper, alcohol, board, animal fodder, furfural, yeast, lysine, monosodium glutamate and citric acid.

In Cuban experience the development of the derivatives, from the standpoint of raw materials, degree of processing and technological complexity, is characterized by four generations, the limits and scope of which are not exact and are fixed by convention.

The first generation relates to direct use of the by-products or derivatives with a low level of processing, in which minimum transformation of the original raw materials occurs; examples are the direct consumption of molasses by cattle, production of molasses-urea-fine bagasse (bagacillo), predigested fine bagasse and so on.

The second generation relates to production that uses the by-products and intermediate products of the sugar processing; it is characterized by technologies of low and medium complexity and results in derivatives with their own characteristics. Examples of this are the production of board, protein molasses, furfural, alcohol, pulp and enzymes.

The third generation covers products obtained through the chemical and/or biochemical transformation of second-generation derivatives and sugar; it leads to new products with properties that are different from the original raw material and is based on medium and high complexity technologies. Examples are: paper, CMC, ethylene, artificial fibres, yeast for human consumption, furanic derivatives, lignisulphonate organic acids, surfactants, and so on.

The fourth generation belongs to products obtained from the by-products, derivatives and sugar, resulting in precursors or intermediate products from other processes in which they are used as raw material. They are based on chemical and/or biochemical technologies of high complexity; examples are phytosterols, AD, ADD, amino acids, and grafted cellulose as a support for immobilized enzymes.

Evolution of the Cuban industry

The initial production of derivatives that attained the greatest development in Cuba related to alcohol and rum, which appeared at the end of the last century. The 1930s saw the beginning of the production of baker's yeast by a small plant and several initiatives were developed in animal fodder containing bagasse and molasses. In the 1950s plants were set up for the production of crude wax and in 1955 a dextran plant was started up. 1957 saw the beginning of pulp and paper production, while installations for manufacturing fibre board began operation in 1959.

At the time of the victory of the revolution there were 17 alcohol distilleries in the country, 16 of which are still in operation at the present time. In 1965 the first plant to produce Torula fodder yeast from blackstrap molasses started production.

In the middle of the 1970s and beginning of the 1980s there was considerable expansion of the sugar derivative industry with the installation of nine Torula yeast plants, three bagasse board factories, two pulp and paper plants, and more than 150 small animal fodder plants; a new alcohol distillery with the production of Torula yeast from must was set up and began refining crude sugar-cane wax.

Present situation

There are some 40 sugar derivative plants and more than 150 facilities in the country for the production of animal fodder based on different by-products. These capacities make Cuba a sugar producing country with the broadest range of derivative products. For the production of Torula yeast with a 45 per cent protein content for animal fodder there are 10 plants with an installed capacity of 100,000 tons per year. This capacity is the highest in existence for production from blackstrap molasses; it was set up in the country in 1965 when the first unit of the "Ciro Redondo" Refinery was installed. Later on, in the 1970s, nine plants were purchased and set up with a capacity of 40 t/d each. These plants operate efficiently and their products are basically intended as poultry and hog fodder as well as for export to the socialist camp.

New developments in the use of Torula yeast have been geared to the production of a protein concentrate from intermediate molasses as hog fodder - protein molasses - of which approximately 70,000 tons are being produced at present. Similarly, technologies have been developed for reducing the nucleic acids in yeasts and making them suitable for direct human consumption. A new plant with a capacity of 8,000 tons will be started up at the end of 1987.

The alcohol industry has 16 plants with a capacity of 150 million litres per year, which is intended for domestic fuel, the production of beverages, the pharmaceutical and cosmetic industry and for export. The investment programme under way provides for the modernization and installation of new distilleries designed and constructed in the country, with the possibility of recovering saccharomyces yeast and carbon anhydride. The use of juices from filtered sludge for the fermentation of alcohol has been introduced. Similarly, work is in progress on the use of dregs from the distilleries as animal fodder. New technologies have been developed to speed up the maturing of tafia and the production of light rums for internal consumption, five such plants being in operation.

There are five pulp and paper factories with an installed capacity of some 17,000 tons. Three of these - Damují, Técnica Cubana and PROCUBA - were set up in the 1950s, while Cuba-9, a pilot plant of semi-commercial capacity, began operating in 1983 and the Uruguay Combine, the largest of the plants existing, was started up in 1984. The main product of these plants is printing and writing paper and it is only Cuba-9 which manufactures newsprint for experimental purposes. The technologies for different types of paper with a high bagasse fibre content predominate in Cuba, a country which has the support of research and development teams with broad experience and experimental facilities of international standard.

There are in operation seven plants for producing bagasse board with an installed capacity of 240,000 $m^3$ per year. The first three plants were built in the 1950s and one of them - the Amancio Rodríguez - has technology suitable for manufacturing fibre board. At the end of the 1970s another three plants were set up with modern technology for continuous processing and single-plate presses. This set of facilities makes Cuba a country with a high installed capacity as well as one with the greatest diversity of technology and equipment. Production involves a high level of quality, in accordance with international standards; the board constitutes a commodity for which there is ample demand and it is used throughout the country for making furniture, in the construction industry and also for export. Work is being done to design new types of board with a low content of free formaldehyde, phenols with high resistance to humidity and cement board resistant to weather.

In animal feeds, sugar-cane by-products and derivatives are tending to be used more and more. During the last harvest the amount of fodder used for bovines constituted 34 per cent of the total consumption and this figure has been growing at an annual rate of more than 10 per cent over the last five years. More than 10 types of fodder are being produced currently and another 10 are at different research and development stages.

The development of sugar products and by-products as fodder has permitted the steady and very fast growth of food sources for bovines and they are beginning to be significant also in hog fodder.

The evermore important role played by by-products in animal food has called for the development of silage, storage, drying and other methods of preservation as well as a tendency to site food consumption centres close to where the supply is, thereby making it possible to extend the practice of stabling for long periods. The developments envisaged will require a great deal of participation by engineers and construction of domestic equipment.

Prospects for development suggest that by 1995 the derivatives of the sugar agro-industry will account for 45-50 per cent of total amount of fodder intended for bovines and hogs. The ratio of tons of animal fodder to tons of sugar produced has gone up from 0.3 t/t in 1981 to 0.6 t/t in 1987, and according to prediction will reach 1.0 t/t in 1990. It is estimated that this ratio could potentially rise to about 3 tons of fodder to a ton of sugar produced.

Cuba has facilities and plants for a series of derivatives, the production of which is unique: among them are predigested fine bagasse, protein molasses, wax, dextran and straw/molasses mixtures in different forms. This means that the country possesses the greatest diversity of production and the most varied knowledge of the way in which to utilize the by-products, even though other countries are better versed in some of the special technologies.

The development programme for the derivatives provides for the setting up of several plants to broaden the diversification of the Cuban sugar industry, basically geared to the creation of a national fodder base and the production of items for export.

Over the present five-year period 1986-1990 investments are being made in plants producing lysine, furfural, citric acid, wax, dextran, enzymes, surfactants, protein molasses and by-product fodders. The bulk of these facilities will be constructed with domestic technology and design and with incorporation of equipment built in accordance with the capacity available in the country.

## 4. STRATEGIC ASPECTS OF DEVELOPMENT OF DERIVATIVES

The low prices of sugar and its decline as an export product for the international market compels us to look for alternatives by which to compensate for the losses caused by this situation as well as to develop new products for export that make foreign trade more flexible. Over the last few decades there have been many initiatives in the region for the use of by-products and to employ them to broaden the range of possibilities for the sugar economy; most countries have set up the production of derivatives and are planning new investments. Of all the efforts made, those of Brazil are the most important in terms of their extent and impact on alcohol as a fuel and this has been done in accordance with the country's conditions and features.

Among the plants cultivated for trade, sugar-cane possesses the greatest qualities both as regards its photosynthetic uptake of solar energy, and its

capacity for producing green matter composed of sugars, starches, protein and lignocellulose compounds, all of these raw materials for a broad range of economically important products.

One hectare-year of sugar-cane with an average yield is able to produce 100 metric tons of green matter, more than double that of the majority of other plants; in terms of total energy, more than 1,000 metric tons of oil equivalent, and when considered as metabolizable energy this is 75,000 megacalories, or several times more than any other crop under the same conditions.

It should be borne in mind that the values applied correspond to the commercial varieties in use; these figures may even be greater when dealing with the varieties expressly developed for the production of derivatives with the possibility of attaining a higher content of green matter, fibre or simple sugars within shorter times. Genetically, this is feasible and can be done with the present cross-breeding techniques with greater stress on the species of saccharum and similar genera.

The possibility of obtaining large amounts of surplus bagasse as a result of improving the energy efficiency of the refineries, which, added to the concentrated agricultural residues at the storage and cleaning centres, ensure a cellulose residue potential that could guarantee the development of many forms of derivative production, chiefly those associated with animal feeding, without necessarily competing with the production of electricity.

The development of derivatives should lead to the greatest possible diversity of production with the greatest aggregate value, on the basis of technological criteria and flexible forms of production employing different intermediate products from the sugar processing and saccharose as raw material, according to the conditions of the demand and the price of the product on the international market.

The strategic criteria to be taken into account are:

1. Selection of alternatives by which to utilize to the maximum extent cane sugar and its by-products

It is here a matter of selecting the production alternatives permitting the highest revaluation possible of cane sugar and the by-products as raw materials. Furthermore, there should be consideration of the alternatives for using varieties with characteristics geared to the production of derivatives which have a high fibre content or attain their maximum growth or simple sugar content within a shorter period of time than the traditional varieties.

2. Integrated technological schemes for the alternative and/or simultaneous production of sugar and sugar derivatives

The production of derivatives should begin to take shape along with the technological schemes that are interconnected from the standpoint of processing and energy consumption. This will make it possible to use the poorest juices from different stages of milling and filtering for fermentation processes, to use the intermediate molasses, to utilize bagasse with partial sugar extraction, and other possible combinations.

These schemes should be conceived in the form of closed technological cycles in such a way as to make use of all the residues for conversion into useful products at the same time as recycling the water inside the plants and avoiding environmental contamination.

3. Improvement in the energy efficiency of the sugar industry

An essential condition for economic development of derivatives is to have electricity at the lowest possible cost and at the same time to have surplus bagasse.

Both objectives are compatible with the energy properties of sugar-cane as a raw material and in terms of the potential of the refineries for improving their energy efficiency by means of moderate investments based on known technologies.

4. Flexible scaled economy determined by the availability of raw materials and/or local demand

In a large number of alternatives, chiefly those concerning animal feeds, the scaled economies should match the available amounts of raw materials on the site in such a way as to simplify transportation and handling and to avoid the cost involved in such operations. Similarly, the scales should be influenced by local demand.

These considerations do not clash with the needs of large-scaled economies which are required by certain forms of production using high complexity technologies, such as pulp and paper, bagasse board and so on.

5. Priority development for animal fodder production

On account of the characteristics of cane sugar as a raw material, this development involves special conditions in order to meet the requirements of animal diet, used directly or employing harvest residues and industrial by-products. It is an advantage in this alternative that in most cases the investments are not high and the facilities required are not complex.

To these features one has to add the fact that the crops of sugar and installations for producing it are spread over different agricultural areas, where the cattle are usually of different types or where such can be encouraged.

This combination of factors plus the fact that most countries, with the exception of those possessing prairies or natural pastures, are compelled to seek national solutions to the problem of feeding their cattle, mean that the products involved in animal fodder should have the highest priority.

6. Production of export stocks or stocks for replacing imports

In view of the need to find new products to replace the sugar markets that are disappearing, derivatives should be used to encourage the replacement of imports and the build-up of exportable stocks by the setting up of plants for this purpose.

7. Diversification of derivatives and encouragement of new generations connected with feeding, pharmaceutical production and agriculture

Among the strategic priorities for sugar derivatives there should be included diversification of production by the introduction of production of derivatives of the third and fourth generation, based on advance technologies which can meet the requirements of such economic sectors as animal fodder, the pharmaceutical industry and chemical products for agriculture.

These alternatives will gradually be developed as the production of first and second derivative generations is expanded and a broader range of production with high economic value and exportable stocks is assured.

8. Investments with the fullest integration of engineering, designing and machine construction on a national basis

Cuba possesses a scientific-technological-industrial infrastructure with a relative degree of development that can serve as a support in the development of derivatives in such a way that the new facilities will for the most part have a high degree of national integration.

If employed on the broadest scale, this capacity will make it possible to decrease investment costs and to make developments most suited to Cuban conditions, as a result of which the implementation and start-up schedules will be more favourable.

As opposed to other sugar-producing countries, Cuba's principal export is secure on the socialist markets and the country has a strategic outlet for its development on the basis of its most abundant natural resource - cane sugar, a raw material which can be converted into a virtually unlimited number of derivatives demanding a modern economy.

Most of the Latin American countries and among them the sugar producers are engaged in the reconversion of their industrial economies in response to the opening up of new markets and to regional integration. This paper is meant to be a contribution to those endeavours by which to build the foundations for creation of stronger and less dependent economies.