INTERNATIONAL AGRICULTURAL TRADE AND DEVELOPMENT CENTER

THE PROCESSING SECTOR OF THE SUGAR INDUSTRIES OF CUBA AND FLORIDA

By
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2. Coordinating and facilitating formal and informal educational opportunities for students, faculty, and Floridians in general, on agricultural trade issues and their implications.

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Abstract

The main characteristics of the industrial (processing) sector of the sugar industries in Cuba and Florida are analyzed. In addition to the discussion on industrial parameters and industry efficiency in both places, the section on Cuba includes a description of the current process of economic reforms taking place in its sugar agro-industry.

Key words: Cuba, efficiency, energy, Florida, sugar, UBPC

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PREFACE

Cuba has entered into a process of economic reform which, combined with other factors, may lead to the restoration of diplomatic and commercial relations with the United States. Given the striking similarity between historical agricultural production patterns in Cuba and Florida, and the extensive pattern of agricultural trade between the United States and Cuba prior to 1960, agricultural producers and processors in Cuba, Florida and throughout the United States are likely to face both challenges and opportunities if and when the U.S. embargo is lifted.

In an effort to provide timely research on this important potential policy issue, the International Agricultural Trade and Development Center (IATDC) of the Food and Resource Economics Department, Institute of Food and Agricultural Sciences at the University of Florida has initiated a comprehensive research project to study Cuba's agricultural and fisheries sectors. The project does *not* address the question of whether commercial relations between the United States and Cuba should be resumed. Rather, the research is designed to provide objective and current information on these sectors in Cuba and Florida for Federal and State legislators, government agencies, private firms, consumer groups and others to draw upon for discussion and debate if the issue should arise.

With the support of the John D. and Catherine T. MacArthur Foundation, this research is being conducted via a program of active collaboration between the IATDC and the University of Havana, Center for Research on the International Economy (Centro de Investigaciones de Economía Internacional, or CIEI). The MacArthur Foundation support has been a pivotal element of this research project and is hereby very gratefully acknowledged.

A preliminary and important part of this research was the identification of potential commodities or groups of commodities that would become likely candidates for trade or investment once commercial relations between the two countries are resumed. Five groups were identified:

1. sugar;
2. citrus: grapefruit, lemon, *lima*, orange, and tangerine;
3. vegetables: cabbage, *calabaza* (pumpkin), cucumber, garlic, lettuce, onion, pepper, plantain, and tomato; roots and tubers: *boniato* (sweet potato), *malanga* (taro), potato, and *yuca* (cassava);
4. tropical fruits: avocado, coconut, guava, mango, papaya and pineapple;
5. fisheries and aquaculture.

The next step consisted of conducting a thorough diagnostic of each of these commodity sectors in Florida and Cuba. These diagnostic studies provide the basis for the third phase of the research, preparation of a series of publications which make preliminary assessments of potential competition and complementarity between Cuba and Florida if the embargo is lifted.

Previous research (Alvarez and Peña, 1995) contains the diagnostic of the sugarcane sub-sector of the sugar industries in Cuba and Florida (see also Alvarez, 1992; Peña Castellanos and Alvarez,

1996) in addition to some preliminary work on the competition and complementarity issues (Alvarez and Peña Castellanos, 1996). This paper completes the diagnostic phase of the project for sugar by examining sugar processing sub-sectors in both Cuba and Florida. A future publication will contain some general and specific analyses about the competition and complementarity issues.

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THE PROCESSING SECTOR OF THE SUGAR INDUSTRIES OF CUBA AND FLORIDA

Lázaro Peña Castellanos and Jose Alvarez*

CUBA: SUGAR AGRO-INDUSTRIAL SECTOR

INTRODUCTION

The sugar agro-industry constitutes one of the essential productive sectors of the Cuban economy. During the 1980s, sugar agro-industrial production represented, in terms of value, between nine percent and 12 percent of Cuba's annual Global Social Product, was absorbing between 12 percent and 15 percent of all investments, and provided employment to more than 11 percent of the existing civilian labor force in the country.

In 1987, the processing branch of Cuba's sugar agro-industry possessed 32 percent of the machinery and productive equipment of all the Cuban industries, 35 percent of the energy-related machinery and equipment, and 24 percent of buildings and facilities. At the same time sugarcane was planted on more than 43 percent of the country's total land area under production (CEE, various issues).

The sugar agro-industry also supplied a considerable percentage of the energy requirements of the Cuban economy during the 1980s; for example, the apparent energy consumption of the Cuban economy in 1988 (production + imports - exports), expressed in tons of oil, amounted to 16 million tons, of which almost five million tons were provided by primary biomass energy from sugarcane bagasse (Larson and Torres Martínez, 1995).

The sugar agro-industrial sector's products also generated between 74 percent and 77 percent of the global income generated by Cuban exports in the last ten years (Banco Nacional de Cuba, 1995). Thus, the sugar agro-industry during the last decade was not only a fundamental productive sector of the internal economy, but also constituted the country's basic channel to the international economy.

Sugar agro-industrial production was particularly important in the process of linking the Cuban economy to the Council for Mutual Economic Assistance (CMEA). Sugar was Cuba's principal export commodity to the CMEA countries, representing more than 60 percent of the value of its exports to the region. Sugar was also the main Cuban commodity included in the index applied to the

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Cuba-U.S.S.R. commerce that defined prices of the main Cuban exports based on price variations of Cuba's main imports from the U.S.S.R., mainly oil and its derivatives, raw materials and equipment, which together represented more than 70 percent of Cuba's total imports (Alvarez González and Fernández Mayo, 1992).

The Cuban sugar agro-industry also helped to generate external income in freely convertible currencies during the 1980s. In effect, during that period, part of the oil exchanged for sugar was re-exported (with the consent of CMEA countries, and especially of the U.S.S.R.) which resulted in additional income in convertible currencies for Cuba estimated at US$3 billion per year. Such income, added to the income obtained in those years in freely convertible currencies from direct sugar exports (approximately another US$3 billion), represented 65 percent of Cuba's total income in freely convertible currencies (Banco Nacional de Cuba, 1995).

The activity of the sugar agro-industry was also the basis for the flow of external loans provided to Cuba during the 1980s. These loans included those of a commercial nature, given the influence of the sector in their quantity and the risk guarantee (interest rate), as well as those loans designated for development, mainly coming from CMEA countries, and primarily destined to the advancement of the sector.

The Cuban sugar agro-industry was a growing sector during the decade of the 1980s. However, since the beginning of the 1990s, the sector has been forced to adapt to many abrupt changes. The impact of these changes is demonstrated in the behavior of the industry's main indicators for the period 1988-1996 (Table 1).

The deterioration of sugar production from the beginning of the 1990s is a consequence of three concomitant processes: a) the exhaustion of the extensive growth model applied to Cuba's sugar agro-industry over more than twenty years; b) the impact of the abrupt disappearance of socialism in Eastern European countries and the Soviet Union; and c) the reinforcement of the economic measures of the U.S. against Cuba. The impact of each of these issues is described in the following sections.

The Extensive Growth Model Applied to Sugar Agro-industry

In the decade of the 1980s, the fundamental indicators of the sugar agro-industry showed a relatively favorable behavior. According to the 10-year indicators, sugarcane agricultural production for industrial processing averaged 71 million tons, 28 percent above the yearly mean during the previous decade, and 54 percent above production levels during the 1960s. These were the main reasons for sugar production exceeding seven million tons in almost all the seasons during the 1980s.

There was also an increase in average agricultural yields (metric tons of cane harvested per hectare), and average industrial yields (relationship between sugar produced from sugarcane ground) during the 1980s. Average yields during this period were above 50 metric tons per hectare, while factory yields reached more than 10.5 percent (Alvarez and Peña Castellanos, 1995, p. 81).

While these results were noteworthy, by the end of the 1980s, the extensive growth model that was promoting them was already showing serious signs of exhaustion. This was true in both the agricultural and industrial (processing) sectors.

The main characteristics and development of the extensive growth model applied to the sugarcane agricultural sector in Cuba have already been described in detail (Alvarez and Peña Castellanos, 1995, pp 2-32; and Peña Castellanos and Alvarez, 1996). This paper is devoted to the study of the processing activities of raw sugar production.

The Demise of Socialism in Eastern European Countries and the U.S.S.R. and Its Impact on Cuba's Sugar Agro-industry[1]

At the end of the decade of the 1980s, Cuba conducted around 81 percent of its external commercial relations with CMEA countries. As a result, the crumbling of socialism in Eastern Europe and the U.S.S.R., coupled with the demise of the CMEA, translated into the disappearance of Cuba's main framework for conducting its foreign economic relations and trade.

This had a very significant impact on the sugar agro-industrial sector and indeed the entire economy of Cuba. To mention just one example, it is estimated that, between 1989 and 1992, the value of imports to supply Cuba's sugar agro-industrial sector were reduced by more than 70 percent, which impacted negatively on the development of this sector.

The Reinforcement of Economic Measures of the U.S. Against Cuba

U.S. economic measures against Cuba have been reinforced since the early 1990s. In October 1992, the U.S. Congress approved what was called "The Cuban Democracy Act." This law reiterated the existing prohibition against U.S. firms conducting economic transactions with Cuba, extended it to subsidiaries of U.S. firms located in third countries, and encouraged other governments to do the same.

In March 1996 the enactment of what is known as the "Helms-Burton Act" legally codified the embargo policy as a U.S. component toward Cuba and third countries that maintain economic relations with Cuba. According to preliminary estimates from Cuban sources, the economic impact of the reinforcement of these measures against Cuba total more than US$1.6 billion per year in terms of the negative impacts on Cuba's import capacity (Alvarez González, 1995, p. 57).

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[1]This topic has been widely covered in the literature. For that reason, it is mentioned only briefly in this introduction. For more information, see Alvarez González and Fernández Mayo (1992), and, in this series of international working papers, consult Alvarez and Peña Castellanos (1995, pp. 28-32), who present a longer treatment for the sugar industry based on the former.

THE INVESTMENT PROCESS IN CUBA'S SUGAR INDUSTRY

The investment process during the 1975-1989 period corresponded with the particular objective of inserting the Cuban economy into the international economy, and with the characteristics of the extensive growth model applied in the sugar agro-industry during those years. In reality, the characteristics that the Cuban sugar industry acquired in this period (number of sugar mills in operation; average grinding capacity; and average industrial yield) were conditioned by the influence of two fundamental factors: a) the necessity of creating an industrial base capable of producing volumes of sugar close to, or higher than, 10 million metric tons annually to satisfy the increasing existing external demand from the CMEA countries, while sustaining the country's economic growth; and b) the development of the extensive growth model applied to sugarcane production, characterized by large areas of land devoted to cane production, but with relatively low agricultural yields.

In the case of the Cuban sugar agro-industry, it was not the processing industry and its advanced technology which imposed its requirements on sugarcane agriculture, as is normally the case in countries producing for the world market. On the contrary, the needs of the processing industry were subordinated to the conditions imposed by agricultural production. This happened after a Cuba-CMEA agreement guaranteed the existence of export markets for sugar production volumes approaching eight million metric tons, and which also facilitated financing levels to achieve a total sugar production volume of 10 million metric tons or more.

In fact, the increase in the amount of land devoted to the growing of sugarcane, as the fundamental means for increasing sugar production, forced the construction and maintenance of grinding capacity in areas close to harvesting areas. This resulted in the existence of a large number of mills in operation -- 156 at present. On the other hand, the relatively low agricultural yields of the cane growing in extensive areas did not stimulate the construction of mills with large grinding capacity. For example, of the Cuban sugar mills in operation, only 53 have a daily grinding capacity above 4,600 tons, while 29 hardly reach 3,000 tons per day (Larson and Torres Martínez, 1995).

The low grinding capacity of most Cuban sugar mills has negative effects on the average cost of production of the entire sector since they do not take advantage of the possibilities of cost reductions through economies of scale. Similarly, the large number of relatively low-volume mills complicates the process of introducing new technologies. For example, the reduced capacity of most of the operating mills makes economically unfeasible the introduction of advanced energy technologies and obstructs or deters the use of automated technologies in the industrial process of raw sugar production. Nevertheless, there were important achievements within the framework of the extensive growth model applied to the Cuban sugar agro-industry during the 1980s in the area of activities related to raw sugar production as well as in the area of derivatives.

At the triumph of the revolution in 1959, there were 161 raw sugar mills in Cuba, most of which were plants with low grinding capacity. There were also 16 refineries (the same number as today), 20 alcohol distilleries, and several bagasse processing plants for the production of boards or paper.

In the early 1960s, the Cuban sugar agro-industry suffered from both external and internal policies. External policies reflected the hostility of the government of the United States which translated into the suspension of the U.S. import quota for Cuban sugar and the abrupt closing of traditional markets for essential inputs.[2] The economic strategy being applied at that time by the Cuban leadership translated into internal policies which included the promotion and diversification of both heavy and light industrial production. This negatively impacted the investment levels devoted to the sugar sector and, therefore, on the productive activities.[3]

In 1965, the sugar agro-industry regained its priority role within the economic strategy of the country. This policy change was motivated by the following factors: a) the need to offset the increase in the country's commercial deficits, mainly with the Soviet Union, which resulted from the rapid increase in imports of products such as oil and its derivatives, machinery and equipment, raw materials, food, and others; b) the lack of competitive exportable products that could substitute for sugar since, at that time, Cuba's primary exports only included sugar, nickel, tobacco, and rum; and c) the necessity to increase external income that would sustain a process of social and economic development.

After the suspension of the U.S. Cuban sugar quota, the Soviet Union began to purchase around three million metric tons of sugar annually from Cuba at world market prices. However, such a volume, at an average price of US$88/metric ton (four cents/lb.), was insufficient to achieve a positive bilateral trade balance, let alone the planned surplus. It is under such circumstances that both sides negotiated a long-term commercial agreement to expand the exportable volumes of Cuban sugar to the Soviet Union up to five million tons at US$125/metric ton (6.11 cents/lb.).

These and other agreements, in addition to requirements for national consumption, dictated output levels of above eight million metric tons of sugar. Therefore, beginning in 1965, the new strategy consisted of increasing sugar output annually with the goal of obtaining a 10 million metric ton harvest in the 1970 campaign. Such a goal, however, was not achieved. For example, the plan for the years 1966 to 1970 included annual production volumes of six, seven, eight, nine and 10 million tons, respectively. Real production, however, reached 4.5, 6.2, 5.2, 4.5, and 8.5 million tons, respectively (Granma, May 21, 1970; MINAZ, various issues). The main reasons for this failure were: a) underestimation of required industrial investment; b) overestimation of the agricultural production potential; and c) problems of an organizational nature (Granma, May 21, 1970).

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[2] It should also be mentioned that, in addition to the early manifestations of the economic embargo, other factors (such as sabotages against the industry and the mass migration of sugar and sugarcane technologists) had a negative impact on the performance of the industry.

[3] In fact, sugar production during those years was as follows: 1960, 5.6 million metric tons; 1961, 6.8 million metric tons; 1962, 4.9 million metric tons; 1963, 3.8 million metric tons; and 1964, 4.4 million metric tons.

The sharp production increase between 1969 and 1970 (almost 50 percent), would negatively impact production in the next two seasons (1971 and 1972). It is not until 1973 that a slow recovery begins to materialize in sugar production.

In 1975, within the framework of the implementation of a new economic strategy and of the System of Direction and Planning of the Economy, a process of enlargement and modernization of the sugar industry was initiated. This process was based, in part, on the financial funds of development aid coming from the CMEA, supported through the commercial and cooperative agreements between Cuba and the CMEA countries.

Between 1975 and 1980, 946 million Cuban pesos were invested in the sugar industry, which represented 17.8 percent of the total funds invested in Cuba's industry during that period (CEE, 1983, pp. 135-36). The priority status of the sugar agro-industry was to be maintained during the next decade, which would result in the industry investments becoming even more significant. During the period 1981-1990, total investment in Cuba's sugar processing sector reached 13.5 billion pesos, which represented 35 percent of total investment in the country. During the same period, the level of total investment directed to the sugar industry reached 2.2 billion pesos, which represented 16.3 percent of the total for all industry.

Comparing the first and second half of the decade of the 1980s, it is obvious that investments in the sugar industry showed two discernable tendencies: an ascending one between 1981 and 1985, and a descending one in the remainder of the decade (Fig. 1). During the 1981-85 period, sugar was the most important industrial branch, receiving 21 percent of a total investment level of 6.6 billion pesos. During the remainder of the decade, sugar was the second most important industrial branch (following the country's electrical energy branch) when it received investments represented 11.6 percent of a total industry investment of 6.9 billion pesos (CEE, 1988).

This investment process expanded the industrial base for raw sugar production significantly, allowing an appreciable decrease in the level of obsolescence that was present in the sector at the beginning of the decade (Table 2), and generating the necessary technological capacity for the design and construction of new Cuban sugar mills. During the 1980s, eight new sugar mills were built with average grinding capacities of 4,600 tons daily. This increased the total number of operating mills to 156. Sixty percent of the equipment for the new mills was produced by the country's mechanical and metal industries (Informe, 1991, p. 19).

Despite its important achievements, the investment process in the sugar industry did not have, however, a significant positive impact on the raw sugar production efficiency indicators. Moreover, average industrial yields showed a decreasing trend during the 1980s in relation to previous decades. Percentage industrial yields were (CEE, various issues):

1951-60	1961-70	1971-80	1981-90
12.85	12.26	11.30	10.80

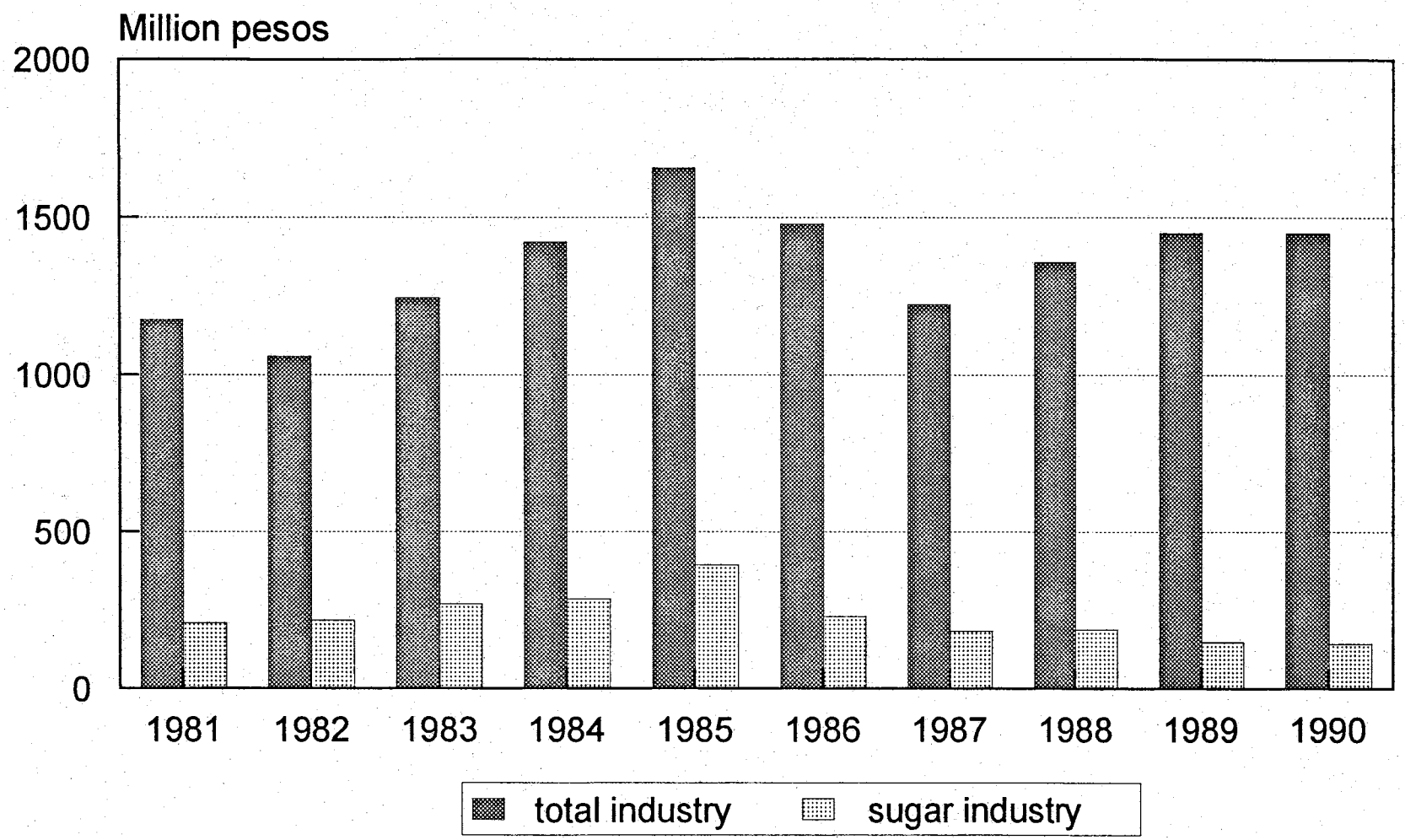

Fig. 1. Investment in Cuba's sugar industry in relation to total industry, 1981-90.

Source: CEE (Various issues).

Several factors influence the levels of industrial yields, most of which are related to agricultural and harvesting activities (Alvarez and Peña Castellanos, 1995, p. 81), while others are related to the industry efficiency, as described in the following section.

THE INDUSTRIAL EFFICIENCY OF CUBA'S SUGAR MILLS

Five-year average industrial yields showed a steadily decreasing trend between 1960 and 1989 in Cuba (Table 3). Over the same period, average percentage sugar recovery decreased between 1960 and 1975, recovered for the next ten years, then decreased again during 1986-89.

In examining the complex problem of the industrial efficiency of Cuba's sugar processing, the emphasis generally focuses on three of the basic processes that comprise the flow of raw sugar production: grinding plant operation, boiler house operation, and the energy and steam production unit. This paper follows the common practice but also incorporates some elements related to the labor force, which influences factory efficiency in the production process.

The Grinding Plant and its Efficiency

The distribution of Cuba's 156 sugar mills, broken down according to their potential daily milling (grinding) capacity, is shown in Table 4. Of Cuba's 156 sugar mills, only 53 (about one-third) have a daily milling capacity equal to, or greater than, 4,600 metric tons. During the second half of the 1980s, these mills ground an average of 57.2 percent of all the cane processed in Cuba. About 19 percent of the sugar mills have a milling capacity below 2,300 metric tons per day, milling an average of 8.2 percent of the cane destined to be converted into sugar during the last half of the 1980s. 16 percent of all mills surpass the daily capacity of 6,900 metric tons and this group handled 34 percent of the milling over the period.

Two parameters must be considered when analyzing the industrial efficiency of the grinding plants: the degree of utilization of the industrial capacity by season, and the operating efficiency of the grinding plant. Table 5 presents data comparing the planned and actual levels of utilization of sugar mill capacity in the 1980s. This table shows that, only in 1981, did the actual utilization exceed 85 percent of total capacity, and surpass the planned figure. It also shows a fluctuating level of actual capacity use between a minimum value of 73.8 percent and a maximum of 86.8 percent. The average utilization of industrial capacity was only slightly more than 80 percent during the 1980s.

To show the operating efficiency of the grinding process, a set of three parameters are presented: polaris losses in bagasse; bagasse polarization at the exit of the tandem; and general recovery at 12.5 percent of fiber. As shown in Figure 2, the losses from pol in bagasse increased during the 1980s, but in smaller percentages than the increase in total losses in sucrose. Two factors influence the increase in the percentage losses from pol in bagasse: the technological quality of the work in the mill, and the quality of the cane milled in terms of the percent of fiber. Figure 2 also shows the stable behavior

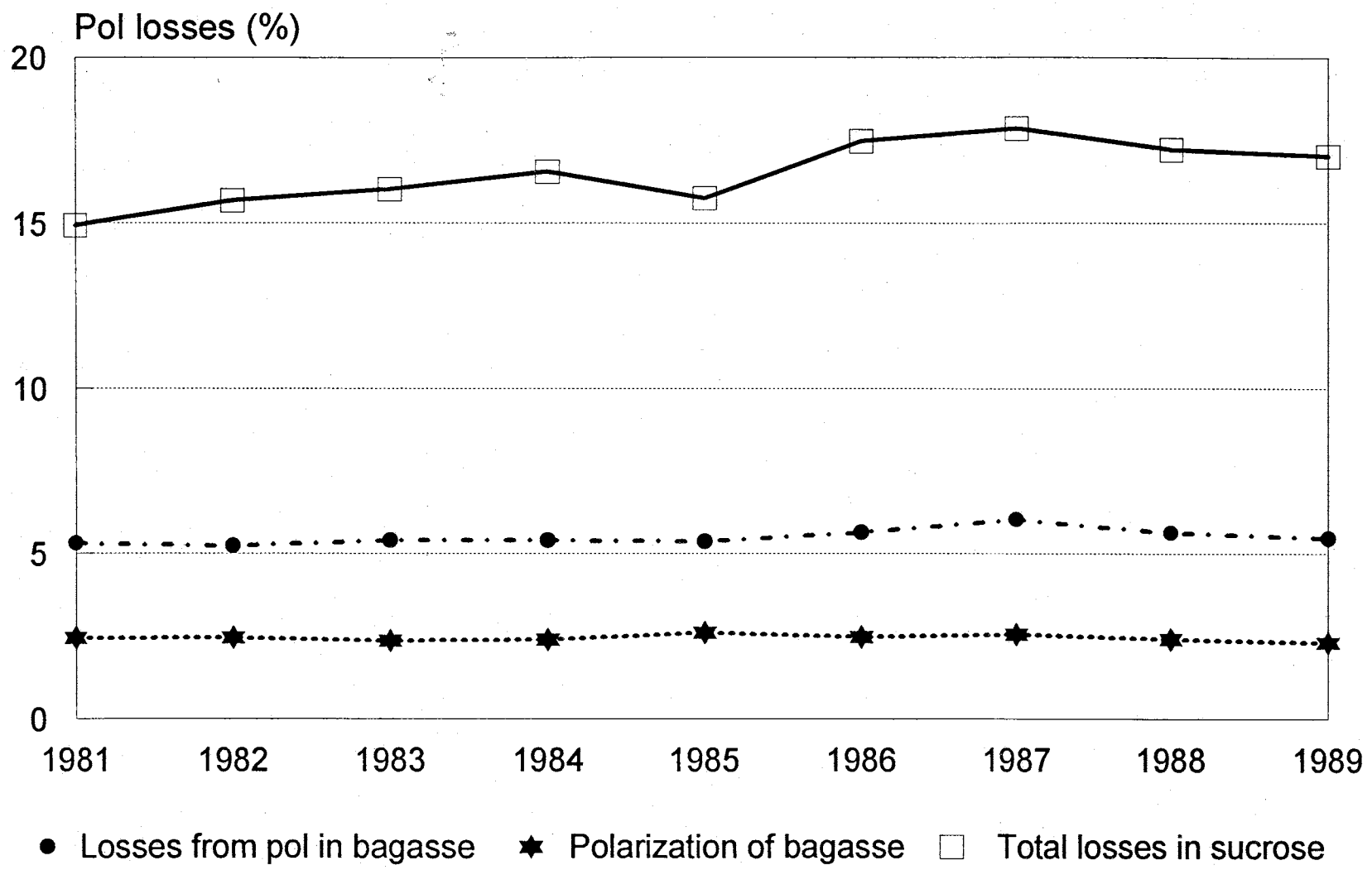

Fig. 2. Milling efficiency in Cuba's sugar mills, expressed as percent losses in pol cane, 1981-89.

Source: Hernandez Rodriguez (1989).

(always at a level below three percent), of the indicator "polarization of bagasse at the exit of the tandem," which reflects relatively efficient work in the mills.

The indicator "general recovery at 12.5 percent of fiber" is used to measure the efficiency of the milling work in isolation, making abstraction of the cane quality and its fiber percentage. During the 1980s, this indicator maintained an average level above 94 percent.[4]

In summary, in relation to the performance of the grinding plants of Cuban sugar mills during the 1980s, the following can be stated:

(a) The number of sugar mills in operation increased; however, the level of potential grinding remained low, and the utilization of available grinding capacity averaged around 80 percent.

(b) The level of pol losses in bagasse increased in absolute terms but decreased in relation to total losses of sucrose. On the other hand, the degree of polarization in bagasse remained low, while juice extraction in the mills was high.

(c) The milling plants for raw sugar production maintained a relatively satisfactory efficiency level (Hernández Rodríguez, 1989), based on the quantity and quality of the available equipment in the 156 Cuban sugar mills currently in operation.

Efficiency of the Boiler House

Table 6 contains data on pol losses in final molasses during the 1980s. The two basic indicators that reflect the efficiency of the boiler house are: gallons of final molasses produced per metric ton of milled cane, and degree of purity of such molasses. The first indicator should average 5.12 gallons, while the second should not be above 31 percent purity.

Both indicators, as shown in Figure 3, generally increased slightly during the 1980s. The reasons for the relatively deficient behavior of the boiler houses in Cuba's sugar mills are of two types: technological quality of the industrial process, and technological discipline of the labor force.

Problems related to the labor force, its stability and technological discipline, are dealt with in a separate section of this paper. Concerning the technological quality of the work at the boiler houses of the sugar mills, based on available information, the following can be stated:

(a) There exists an appreciable obsolescence in fundamental equipment linked to the work area in the boiler houses, such as boilers and steam machines, tandems, purifiers, centrifugals, etc., which detrimentally impacts the efficiency of the process.

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[4]The figure of 94.5 percent is considered a satisfactory level for a sugar mill with average equipment (Ver Zambrano and López Sánchez, 1978, p. 74).

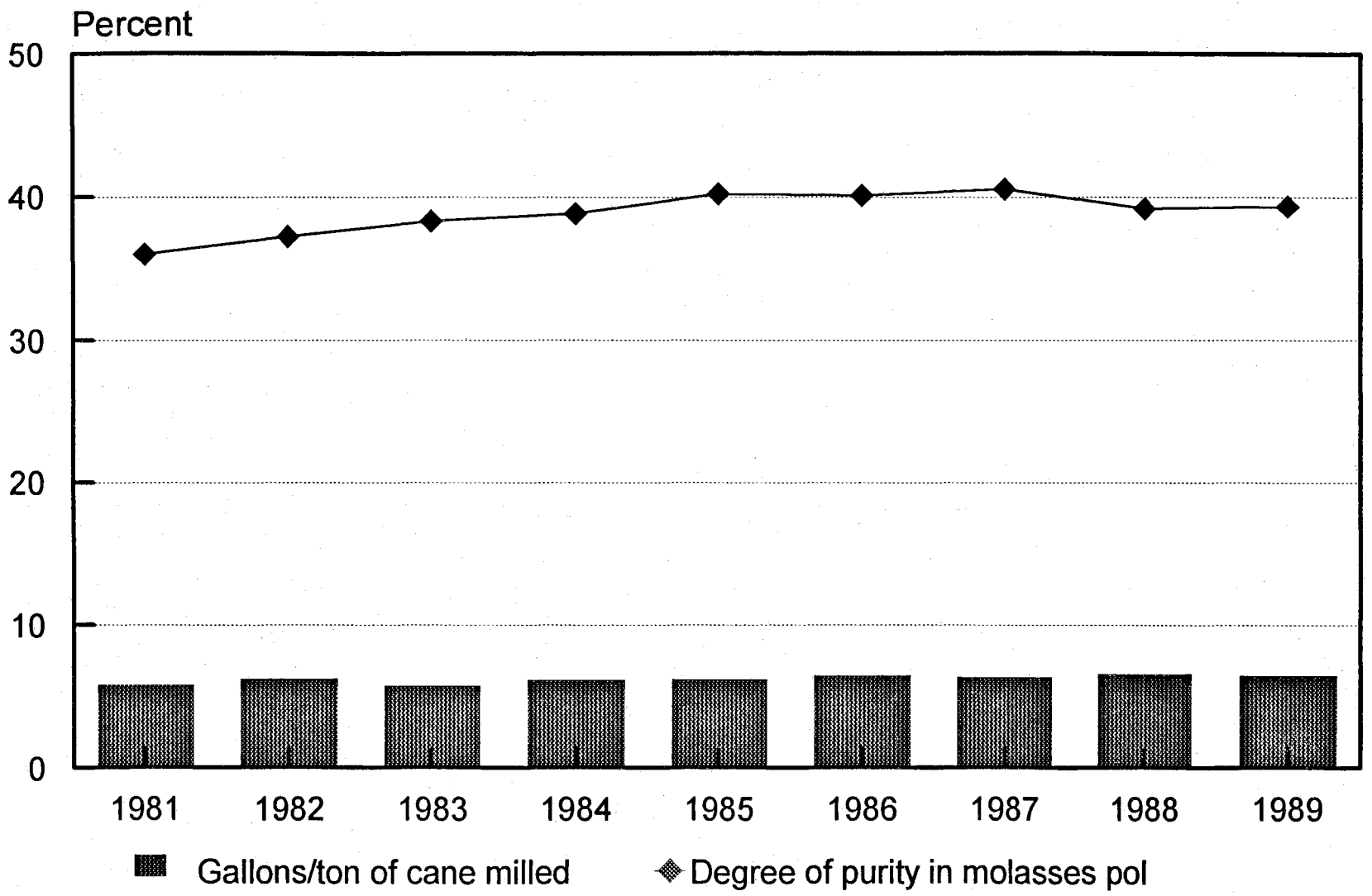

Fig. 3. Efficiency of boiler houses in Cuba's sugar mills, 1981-89.

Source: Hernandez Rodriguez (1989).

(b) The degree of automation of the production process for raw sugar, including the control of its parameters, is very low. The efficiency of the different operations, therefore, is highly dependent upon the technological ability and discipline of the operators.

(c) Another factor that has been affecting the work in the boiler houses is the quality of the sugarcane and its maturity, which, according to estimates made by several specialists, could have influenced the quality of the cane juices and in the composition of the so-called "non-sugars" (Hernández Rodríguez, 1989, p. 11).

(d) The insufficient emphasis on repair and maintenance of the mill equipment in the period designated as preparation for the *zafra* is another consideration. Furthermore, the extended sugarcane harvestings increase the need for capital repairs, which have already been excessively deferred.

(e) Finally, the combined effects of the above mentioned factors, accumulated over time, further contribute to the deterioration of boiler house efficiency, which is, without a doubt, the most technologically complex of the factors involved in the raw sugar production process.

Fuel, Steam and Electricity: Antecedents

Bagasse represents approximately 25 percent of the total weight of the milled sugarcane; for that reason, the availability of bagasse after milling is theoretically sufficient to cover more than 120 percent of the fuel needs in an efficiently balanced mill from an energy standpoint. Therefore, only an insufficiently balanced sugar mill consumes petroleum fuel directly, when bagasse is not available, or indirectly when it consumes electricity from the national electrical system (*Sistema Electroenergético Nacional*, or SEN).

During the 1980s, there was an emphasis on the reduction of the direct consumption levels of oil by the processing industry (excluding the analysis of the consumption in the agricultural and transportation areas). By the second half of the decade it was reduced to low, technologically-acceptable levels; however, this was not the case in the indirect consumption of oil.

Production and Consumption of Electricity

In 1959, the installed capacity to produce electricity in Cuba's sugar mills amounted to 311.3 Mega watts (MW). Electrical energy consumption at the mills was 378.8 Giga watt hours (GWh) (where one GWh is equivalent to 274 tons of oil). This was below the electrical generating capacity of the mills themselves which was 391.6 GWh (Torres Martínez et al., 1993). Since that time, these three indicators have increased at different rates. In the last 30 years, the installed capacity in sugar mills to produce electricity has more than doubled, while energy generation and consumption have increased by factors of 3.7 and 5.7, respectively.

The increase in the consumption of electrical energy relative to the energy generated by the mills themselves, has brought about growing deficits of electricity. The deficits have been supplied by the

SEN. In 1990, the energy deficit in sugar mills grew to 800 GWh, which brought about an indirect additional consumption of approximately 260,000 tons of oil.

The inability of the sugar mills to supply their own electric energy requirements is due largely to technological problems. For example, the majority of the Cuban sugar mills still use a relatively inefficient process composed of steam turbines and turbogenerators. The steam turbines operate with low-pressure boilers (between 10.5 - 28 kg/cm^2), which produce between 350 and 500 kg of steam per metric ton of milled cane, and the low capacity turbogenerators only generate between 15 and 25 kWh of electricity per metric ton of milled cane. These combined energy levels are not sufficient to satisfy the mill's self-consumption.

Table 7 contains statistics on the energy-related characteristics of Cuban sugar mills. The data apply to a grinding of 72 million tons of sugarcane in a *zafra* of eight million metric tons of sugar.

At present, very few sugar mills operate with newer high-pressure steam turbines (above 40 kg/cm^2). These units are capable of generating between 70 and 120 kWh per metric ton of cane, which allows the delivery of a surplus of electricity to the SEN of between 50 to 100 kWh per metric ton of cane milled.

Feasibility studies are being conducted at present with the objective of assessing the possibilities for transforming the technology of the current energy models in Cuba's sugar industry. It is in this area where the greatest number of possibilities exist for the increase in efficiency of industrial processing of sugar.

Preliminary studies have demonstrated, for example, the possibility of generating electric energy equivalent to 30 million barrels of oil per *zafra* from bagasse and agricultural residues of sugarcane using technology of high-pressure steam turbines fed with biomass in a system of cogeneration, extraction, and condensation. That figure is more than half of the average annual imports of oil of the Cuban economy during the decade of the 1980s (Torres Martínez et al., 1993).

The Labor Force in Cuba's Sugar Agro-industry

During the 1980s, the number of workers in the sugar agro-industry increased from an average of 350,000 in the period 1980-85 to nearly 380,000 workers in 1988. The breakdown between the agricultural and industrial (processing) sectors appears in Table 8.

In order to stimulate labor force stability, the workers of the sugar agro-industry received special treatment in terms of their salaries during the 1980s in relation to their counterparts in other areas of the economy. These special benefits included an increase of 15 percent in salary and a payment based upon duration of employment of up to an additional 15 percent of their salaries, as well as premiums for night work, etc. These increases resulted in an average monthly salary in the sector of 141 pesos per month in 1980, 195 pesos per month on average during 1981-85, and 203 pesos per month on average from 1986-90 (MINAZ, 1990, p. 208).

At the beginning of the 1990s, however, two negative trends in the organization and utilization of the sugar labor force were observed: a) the instability of the employed labor force; and b) the unfulfilled demand of the sector's labor force. For example, it was estimated that, in 1993, the calculated labor force needed in the productive sector (total number of workers in the sugar agro-industrial complexes, CAI) was approximately 267,000 workers, only 85 percent of which was achieved (MINAZ, 1994, p. 15).

In relation to the specific industrial activities, in the same year of 1993, only 86.6 percent of the approved payroll of 76,000 workers in the CAIs was covered, mainly by an unstable and relatively inexperienced labor force, whose turnover was above 15 percent. In fact, in 1993, 30 percent of all the labor force employed in the sugar industry had only between one to four years of experience (MINAZ, 1993).

Since 1994, this situation has improved as the result of the adoption of a series of organizational policies within the framework of the new economic program currently enforced in the country. For example, in the agricultural area, the profound transformations introduced in the system of organization and management of sugarcane agriculture through the Basic Units of Cooperative Production (Unidades Basicas Produccion Cooperativas, or UBPCs), have allowed an important decrease in the necessary labor force in the area. At the same time, these policies have increased their remuneration and provided incentives which have helped to improve the labor force stability (Alvarez and Peña Castellanos, 1995, pp. 32-36).

Also, a new set of salary norms (decentralized control of the salary fund) has been gradually introduced since 1994. These norms tend to grant a greater autonomy to the administrations of the CAIs in the use of the salary fund and of the labor force, which has allowed ostensibly the improvement of the organization of employment and its remuneration, as well as the labor and technological disciplines in every activity of the industry.

At the same time, a number of measures to improve the workers' incentives, have been taken. For example, in 1996, a new form of stimulus was created for the workers employed in sectors generating freely convertible currency through the creation of funds in convertible currencies. The quantity of funds available is directly related to the sector's recovery and performance, since it is part of the items encompassed in the external financial plans contracted by MINAZ with foreign capital.

Although the specific procedures for incrementing the workers' real earnings are still in the process of being improved (and made consistent with other sectors of the economy with similar financial arrangements), without a doubt, the access to a market with consumer products of better quality that such programs have facilitated for the workers of the agro-industrial sector, has been an important factor in the achievement of a more stable labor force.

THE PROCESS OF ECONOMIC REFORM IN THE SUGAR SECTOR

The economic reform in the sugar agro-industry started with a series of reforms generally targeting the agricultural sector. The basic problem faced by the Cuban leadership at the beginning of the 1990s was how to react to and maintain productivity under severe restrictions of resources. The initial response to that challenge was the structuring and implementing of a new form of management and enterprise organization that would lead to a more efficient use of the scarce resources. This section discusses two of the most important reforms, with emphasis on the second one.

The Basic Units of Cooperative Production (UBPCs): A New Form of Management and Organization of Agricultural Activities

Law-Decree No. 142 of 20 September 1993 established the UBPCs in pursuit of the following goals: (a) to achieve a closer relationship between man and the land; (b) to channel the cooperative efforts of the workers and their families in the improvement of the living conditions of the collective, including self-sufficiency; (c) to closely and rigorously relate workers' earnings to the production achieved; and (d) to develop the autonomy of management of the collective on their resources with the objective of achieving self-sufficiency in the productive process (MINAZ, 1993, p. 3).

Once the establishment of UBPCs in sugarcane agriculture was approved, an accelerated process of change took place in the sector. By the end of 1993, practically all state lands devoted to sugarcane production had been reorganized under this new form of management and direction, and more than 98 percent of the cane agricultural workers had become cooperative members.

The Opening of the Agro-industrial Sector to Foreign Capital

A second important aspect of the economic reform was the opening of the agro-industrial sector to foreign capital investment. In reality, since 1982, when Law-Decree No. 50 was enacted, there already existed a legal framework for the establishment of economic ties between the Cuban government and foreign capital. However, it was not until 1990 that it was expanded in scope. In September 1995, the National Assembly approved Law No. 77, which authorizes and governs all activities related to the action of foreign capital in the Cuban economy.

In the particular case of the sugar agro-industrial sector, the concrete arrangements with respect to foreign capital only allowed the establishment of investment agreements for financing the production and commercialization of sugarcane derivatives. In 1994, facing the scarcity of available resources and the difficult situation of the sugar sector, such restrictions were eliminated and the sector in general was opened to foreign associations. There is insufficient data available to provide

a thorough synthesis of that process for the sugar agro-industry but there is some information available.[5]

The agro-industrial sector clearly is of interest to foreign investors. It is known that Cuban governmental institutions have been involved in agreements of diverse nature with firms from Great Britain, The Netherlands, Spain, and others, that imply economic commitments in the agricultural and/or industrial branches of this sector.

Until the time of publication of this paper, the most important form of foreign capital participation in the sugar agro-industrial sector has been through financing plans for sugar production at regional levels. Such financing arrangements are granted annually, though it is feasible to negotiate five-year agreements. These plans are intended to ensure the necessary agricultural and industrial inputs that the regional sugar production requires under the agreement.

For example, for the 1995-96 campaign, nine of the 13 sugarcane-producing provinces received agricultural credits from foreign companies for agricultural production requirements in an amount totaling more than US$130 million (Nodal, 1996; Financiamiento, 1996). In addition, another more than US$160 million was devoted to supply the more important necessities of industry, transportation, and other *zafra* activities.

The agreements established with foreign capital under this plan presuppose that the principal, interest and a portion of the profit will be paid in physical sugar, based upon increases in production obtained above the average production level reached in recent *zafras* and fluctuations of sugar prices in the world market. According to the Cuban leadership, such financing agreements for sugar production have been arranged under very harsh credit conditions for the Cuban economy, but they are, however, necessary because of the scarcity of resources and the current situation of the sugar agro-industrial sector (Lage, 1995).

MAIN INDICATORS OF THE 1995-96 SUGAR CAMPAIGN

The three-year trend of continued deterioration in sugar production levels was reversed during the 1995-96 campaign, when sugar production was close to the 4.5 million metric ton volume that had been forecast. With respect to the 1994-95 *zafra*, not only did sugar production increase by more than 33 percent (from 3.3 million metric tons), but agricultural yields also improved by 4.3 metric tons per hectare, and industrial yields by almost one percentage point.

Moreover, the campaign took place at a relatively minor increase in cost per metric ton in relation to imported inputs, which allowed a reduction in the cost in freely convertible currencies from 160 to 120 dollars per metric ton (Lage, 1996). Negative aspects, however, included three main elements:

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[5] For additional detail on the topic of foreign investment in Cuba's agricultural sector, see Ross and Fernandez Mayo 1997.

(a) The projected estimates of available cane for grinding did not correspond with the actual volumes in all provinces, which affected the quality of the cane sent to the mill, and the general fulfillment of the production plans in several provinces.

(b) The sugarcane crop was affected by adverse climatological conditions which, in turn, forced an extended harvest (several provinces had to extend the harvest until the summer), and increased the overall cost of the *zafra*.

(c) Several problems of industrial nature were experienced, which caused the harvest time lost due to breakdowns and interruptions (although inferior to the previous year) to reach a high level of 11.48 percent (Varela, 1996).

THE PROSPECTS FOR THE SUGAR AGRO-INDUSTRIAL SECTOR

The prospects for the future of Cuba's sugar agro-industry are determined by a large number of internal and external factors, whose influence varies according to the time frame within which they are estimated: short-, medium-, or long-run. This section concentrates in the short- and medium-run perspectives.

During the period 1986-90 Cuba maintained an average level of exports of 6.89 million tons of sugar. On average, approximately four million tons were sent to the former Soviet Union each year during this period. In a perspective of five to eight years, external demand does not appear to be a limiting factor for the exportation of a volume of Cuban sugar similar to that. In that regard, one must take into account the following factors:

(a) World sugar consumption increased at an annual rate of about two percent from the beginning of the 1980s until 1993. In 1993-94, consumption declined abruptly. The fall was due, in part, to reductions in sugar consumption in the countries of Eastern Europe and in the former Soviet Union (Lord, 1995).

It is precisely the Russian Federation, along with other nations that were part of the former U.S.S.R., which were the principal markets for Cuban sugar exports. It is anticipated that such markets will gradually recover and will be able to absorb annual volumes close to three million tons of Cuban sugar, at terms advantageous for both trading partners, and within a barter framework.

(b) World sugar exports during 1981-95 maintained an annual average level of 30 million tons, with very little relation to price levels and to the increase in consumption. It can be assumed that, in the short-run, the sugar volume in the world market will be maintained in the range of 27-32 million tons.

This suggests, on one hand, the existence of a more or less stable demand for Cuban sugar in the Russian markets, Asian countries, Canada, African countries, and countries in the Middle East,

fundamentally. On the other hand, if the volumes of world imports of sugar remain stable, it is unlikely that Cuba can expect high rates of increase in the demand for its sugar.

The restrictive factor of the Cuban sugar agro-industry in the short-run does not appear to be, therefore, external demand. (At the present time, given the level of deterioration of its sugar industry, Cuba can not satisfy the existing demand.) Rather, it is the scarcity of resources of the sector that motivates it to increase its productive efficiency to become competitive under the conditions of world market prices. Even though it is certain that very few countries can truly be competitive at world sugar market prices, one cannot overlook that such price is to be considered a reference price, especially under conditions of acute scarcity of resources.

During the period 1980-94 monthly prices in the world sugar market averaged 10.71 cents/pound, which places the average price of a metric ton of sugar for this long period at US$236 (Alvarez and Peña Castellanos, 1995). During the years 1986-90, years in which the sector still had a relatively adequate availability of resources, total production expenses for one metric ton of Cuban sugar was estimated to be 448 pesos (MINAZ, various issues); that is, about 90 percent above the world market price, according to the official Cuban exchange rate of 1 peso = 1 US dollar.

It has not been possible to accurately calculate, with the available data, the average total cost of a metric ton of raw Cuban sugar in convertible currency. However, as stated earlier (Lage 1996), estimates appear to be ranging between US$120 and US$160 (between 51percent and 68 percent of the world market average price per ton) over the last few years (Lage, 1996).

Based upon this information, it becomes evident that increasing the productive and economic efficiency of the Cuban sugar agro-industrial sector is a necessity. Furthermore, it is important to remember that the barter agreements between Cuba and the Russian Federation, which is the most important Cuban sugar market, take place based on prices in the world sugar market, which forces the sugar sector to become more and more competitive.

The greatest potential for the sugar agro-industry to increase its efficiency would appear to be by increasing its agricultural yields, which have always been below the potential levels given the edaphic and climatic conditions of the country (Alvarez and Peña Castellanos, 1995, pp. 3-6). Increasing agricultural yields is, at the same time, the necessary condition to specify the parameters that will be used in the restructuring of the sugar agro-industry, according to demand conditions and the resources of the sector.

In fact, the extensive growth model applied to the sugar industry created potential for production volumes above 10 million metric tons of sugar annually for Cuba, assuming national agricultural yields close to 66 metric tons per hectare and industrial yields of 10 percent. However, it does not appear prudent to assume the existence of export markets above six million metric tons (once previously unfulfilled commitments have been delivered). Adding this six million metric ton potential export figure to an internal consumption volume of one million metric tons generates a total production level of seven million metric tons. Based on this figure, if agricultural yields are increased sufficiently, then

it is feasible to reduce the agricultural area devoted to sugarcane production. A simple estimation, for example, suggests that it might be possible to decrease the amount of land allocated to sugarcane production by more than 20 percent.

Such a reduction of the agricultural area compels, at the same time, a restructuring of the industrial processing capacity of the sector. At present, there exist 156 sugar mills in Cuba that milled an annual average volume of around 71 million tons of cane annually between 1986 and 1990. This represented an under-utilization of the average daily milling capacity of more than 15 percent, assuming *zafras* of 150 days and an average use of the industrial capacity of 85 percent (MINAZ, various issues).

Therefore, under these assumptions, the daily grinding capacity of the country potentially could be reduced by 15 percent without affecting the total quantity of necessary grinding for *zafras* of 7.5 million tons. In fact, of the total mills existing in Cuba, 16 percent have a daily milling capacity below 2,300 tons (the average is about 4,200 tons) and, whose economic efficiency, in the majority of cases, is questionable (Larson and Torres Martínez, 1995).

The process of restructuring of the sugar agro-industrial sector, as already stated, would be closely tied to its technological reconversion, especially in terms of energy-generating capability. Such a restructuring would generate multiplier effects throughout the entire economy of the country, and would produce very beneficial effects on its balance of trade and payments.

Finally, looking briefly at a long-run perspective, the Cuban sugar agro-industry is facing the same challenges that are faced by all sugar industries of the world; that is, relative reduction of sugar demand, competition from natural and artificial sugar substitutes, influences of technological changes in the sector, alternative energy balance, the necessity to diversify the sector's production, and many others. Such aspects can not be overlooked during the process of reincorporating Cuba's sugar agro-industry into the present and future structure of the global economy. It is for that reason that the redesigning of the Cuban sugar agro-industrial sector must be approached as a dynamic and ongoing process.

Table 1. Main indicators of Cuba's sugar agro-industry, 1988-1996.

Year	Production		Yield	
	Raw Sugar	Cane	Processing	Agriculture
	Million Metric Tons		Percent[a]	MT/HA
1988	7.42	67.5	10.85	51.7
1989	8.12	73.9	10.83	54.5
1990	8.04	74.4	10.65	52.0
1991	7.62	71.0	10.59	49.1
1992	7.01	65.4	10.57	44.7
1993	4.30	42.9	9.85	35.3
1994	4.00	43.0	9.26	33.5
1995	3.33	33.2	9.92	28.2
1996	4.45	41.4	10.73	32.5

[a] Expressed in metric tons of sugar produced per metric ton of cane milled.

Source: Compiled from Ministry of Sugar Industry data, 1994, 1995, 1996.

Table 2. Level of obsolescence of Cuba's sugar industry in relation to total equipment needs, 1970 and 1990.

Item	1970	1990
	Percentage of Obsolete Equipment	
Steam machines	100	95
Steam boilers	69	47
Turbogenerators	63	31
Clarifying pans	60	32
Tandems	88	31
TOTAL	74	19

Source: MINAZ (1991, p. 31).

Table 3. Indicators of industrial efficiency in Cuba's raw sugar production, 1951-55 through 1986-89.

Period	Recovery	Industrial Yield
	Percentage	
1951-55	85.43	12.72
1956-60	86.00	12.73
1961-65	85.28	12.49
1966-70	83.67	11.56
1971-75	81.88	11.42
1976-80	84.39	11.18
1981-85	84.23	11.00
1986-89	82.61	10.74

Source: Hernández Rodríguez (1989, p. 9)

Table 4. Distribution of potential daily milling capacity of Cuba's sugar mills, and average participation, 1985-89.

Average Daily Milling Capacity	Mills	Average Participation
Metric Tons/Day	#	Percentage
Up to 2,229	29	42.8
2,300-4,599	74	34.6
4,600-6,899	28	22.9
6,900-9,199	14	15.9
9,200-11,499	7	10.7
11,500-More	4	7.7

Source: Larson and Torres Martínez (1995).

Table 5. Level of utilization of Cuba's sugar mill processing capacity, 1981-89.

Daily Milling Capacity			Milled Cane Per Days Worked	Processing Capacity	
Year	Potential	Actual		Plan	Actual[a]
	(1)	(2)	(3)	(2/1)	(3/1)
	Million Metric Tons			Percentage	
1981	563.8	470.4	489.1	83.4	86.8
1982	582.0	502.4	429.6	86.3	73.8
1983	596.2	515.3	471.1	86.4	79.0
1984	613.4	528.3	495.2	86.1	80.7
1985	623.9	539.0	497.8	86.4	79.8
1986	629.5	540.1	473.3	85.8	75.2
1987	638.6	547.2	535.1	85.7	83.8
1988	638.9	548.1	527.8	85.8	82.6
1989	639.9	548.3	511.2	85.7	79.9

[a] Computed by subtracting the planned lost time from the potential daily quota or norm.

Source: CEE (Various issues).

Table 6. Polaris losses in Cuba's final molasses, 1980-90.

Year	Polaris Losses
	Percentage
1980	9.15
1981	8.21
1982	8.95
1983	9.10
1984	9.71
1985	8.92
1986	10.23
1987	10.09
1988	9.98
1989	9.92
1990	9.91

Source: Hernández Rodríguez (1989, Annex 4).

Table 7. Energy-related characteristics of Cuban sugar mills.

Steam Boiler Pressure	Mills	Milled Cane	Gross Electricity Generation	
kg/cm^2	#	Percentage	kwh/tcm[a]	Percentage
Up to 14	79	40.4	11.0	23.3
18	23	19.6	24.0	24.6
10 and 18	41	24.7	16.5	21.4
10 and 28	3	3.6	27.4	5.2
18 and 28	1	1.2	26.9	1.5
28 and over	9	10.5	44.0	24.0
TOTAL	156	100.0	19.2[b]	100.0

[a] Gross electricity generated (kilowatt hours) by the mill per metric ton of cane milled.
[b] Weighted Average
Source: Torres Martínez et al. (1993).

Table 8. Total number of workers employed in Cuba's sugar industry activities, 1980-88.

Sector	1980	1981	1982	1983	1984	1985	1986	1987	1988
----------1,000 Workers ----------									
Agriculture	261	258	259	240	211	202	218	225	235
Processing	92	95	101	111	133	138	136	138	142
TOTAL	353	353	359	351	344	340	354	363	377

Source: CEE (Various issues)

FLORIDA: SUGAR PROCESSING SECTOR

The Processing Area: Number, Location, and Daily Grinding Capacity of Raw Sugar Mills

The processing sector of the Florida sugar industry is located within the growing area; i.e., around the southern shore of Lake Okeechobee, primarily in Palm Beach County. There are seven raw sugar mills with grinding capacities ranging from 11,000 to 25,000 tons of cane per day, for a total daily grinding capacity of 123,300 tons and an average grinding capacity of 17,000 tons per day (Table 9).

The degree of vertical integration in the industry is very high. For example, mill ownership includes one cooperative, one independent, a company with two mills, and another company with three mills (Lord, 1995, p. 9). Together they control the majority of the sugarcane land since there are very few independent growers. The few independent growers negotiate contracts for the harvesting and delivery of their cane to any of those mills.

Total Raw Sugar Production, 1986-96

Florida's total raw sugar production during the 1986-96 period ranged from 1.413 million tons in 1989-90 to a record production of 1.833 million tons in the 1991-92 season. Average raw sugar production during that time period amounted to 1.635 million tons, with an average recovery rate of 11.88 percent, which yielded an average of 3.97 tons of sugar per acre (Table 10).

A production breakdown by mill, including cane ground, and sugar and molasses produced for the 1993-94 through the 1995-96 seasons is shown in Table 11. Total cane ground has approached 16 million tons per season. Raw sugar production has been around 1.7 million tons per year. Production of molasses has approached and surpassed the 95 million gallon figure.

Costs of Processing

Total processing costs per pound of sugar produced in Florida during the 1991-92 season amounted to $0.064, which was the lowest in the cane sugar processing areas of the United States. The corresponding figures for other areas were $0.141 for Hawaii, $0.074 for Louisiana, $0.084 for Texas, and $0.082 for the U. S. average (Lord, 1995, p. 59). Sugarcane production costs were discussed in our previous paper (Alvarez and Peña Castellanos, 1995, pp. 40-41, 43, 90).

According to Landell Mills Commodities Studies, the U.S. cost of sugar produced from sugarcane ranked 31st out of 62 cane sugar-producing countries or regions during the 1987-88 through the 1991-92 seasons (Lord, 1995, p. 14). Obviously, Florida's ranking would be much better if considered separately.

Marketing Channels

Florida sugar mostly is marketed through the Florida Sugar Marketing and Terminal Association, established by five of the seven raw sugar processors in 1978 and with storage and port facilities in the Port of Palm Beach. Some raw sugar is also marketed through long-term contracts with sugar refineries located outside the state of Florida (Buzzanell et al., 1992, p. 18), mainly on the eastern seaboard and Gulf coast.

Only approximately 300,000 tons of raw sugar were being refined in Florida annually until a few years ago. In recent years the situation has changed fairly significantly. One more refinery has been added and one more is being built in the processing area. These two additions constitute a value-added operation to the sugar processing sector of the industry.

THE INDUSTRY PERFORMANCE, 1995-96

The latest data published by the Gilmore Sugar Manual (Sugar Publications, 1996) provide necessary figures to evaluate the industrial performance of the Florida sugar industry (Table 12). The almost insignificant differences in performance measures among the mills are the result of the relatively high degree of homogeneity of the cane-growing region but also of the high levels of modern technology employed throughout the industry.

General Figures

During the 1995-96 season, the harvesting and milling operations were underway from late October until sometime in the month of March. Depending on cane availability and processing capacity, the harvest lasted between 104 and 147 days, for an average of 132 days, or less than 19 weeks.

The seven mills ground about 15.7 million tons of cane, for an average of 2.243 million tons per mill. Using the 132 day average length of harvest, the average processing volume per mill per day is about 17,000 tons. This figure is very close to the average daily milling capacity of the industry shown in Table 9, providing a good measure of the industry efficiency.

Sucrose and Fibre in Cane

Percent sucrose in cane ranged from 11.77 to 12.86, for an average of 12.22 percent. The percent of fiber in the harvested cane ranged from 9.71 to 11.31, for an industry average of 10.45 percent.

Bagasse and Energy

Bagasse is one of the major sub-products of the sugarcane milling process. It has multiple uses. The most important use for bagasse is to burn it in the mill boilers which produce all the steam necessary to operate Florida sugar factories.

In addition to burning bagasse to supply energy for operating the processing mills, bagasse fuels are used to produce electrical power in a separate plant operated by one of the sugar companies which is then sold to the public electric company. Millions of gallons of commercial fuel oil are saved annually because of the bagasse (Florida Sugar Cane League, 1983).

The analyses of bagasse include its percentage of sucrose, fibre and moisture. The percent sucrose ranged from 1.68 to 2.94, for an average of 2.37 percent. Percent fibre figures varied from 43.29 to 46.28, yielding an average of 45.0 percent. Lastly, percent moisture in bagasse ranged from between 49.91 and 53.70, for an average of 51.79 percent (Table 12).

Five of the seven mills produce fuel oil, while the remaining two produce gas. Gallons of fuel oil per ton of cane ranged from 0.013 to 0.4612 (both rounded to two decimal places in the table), for an average of around 0.213, and a total of close of two million gallons produced from the 11.735 million tons of cane milled by the five mills. The results translate into an average of 0.17 gallons of fuel oil per ton of cane ground.

The other two mills generated 1.12 and 0.31 MCF of natural gas per ton of cane ground, for a total of 3,455,650 MCF from the 3.967 million tons of cane ground.

Crusher Juice

Crusher juice is measured in terms of percent brix, sucrose, and purity. Brix ranged from 17.33 to 18.66, for an average of 17.95. Sucrose percentages varied from 14.53 to 15.89, yielding an industry average of 15.21 percent. Finally, purity figures ranged from 82.98 to 86.36, for an average of 84.73 percent.

Normal Juice

Normal juice is measured with the same parameters as crusher juice. Brix ranged from 16.81 to 18.10, for an average of 17.40. Sucrose percentages varied from 13.69 to 15.02, yielding an industry average of 14.40 percent. Finally, purity figures ranged from 80.60 to 84.36, for an average of 82.67 percent.

In addition to those three measures, normal juice has other characteristics. The percentage of purity in the syrup ranged from 83.75 to 85.69, yielding an average of 84.93 percent for the industry. Normal juice extraction went from 79.59 to 83.64, for an average of 81.09 percent. Sucrose extraction, measured in terms of percent sucrose in cane, ranged from 94.69 to 96.97, for an average

of 95.50 percent. The range for maceration (percent cane) figures was wider ranging from 15.01 to 30.14, for an average of 23.12 percent. Finally, recovery, expressed in terms of percent sucrose in juice, went from 86.92 to 91.33, for an industry average of 89.71 percent.

Other Sugar Measures

Sugar yield, expressed as percent of cane with 96^0 test sugar, ranged from 10.25 to 11.59, for an average of 10.96 percent. Total sugar production, of course, depends on milling capacity. It reached 1,737,100 tons during the 1995-96 season.

Polarization ranged from 98.55 to 99.00, for an average of 98.78, while percent mud in pol went from 0.99 to 4.84, yielding an average of 2.23 percent for the industry.

Final Molasses

The quality of molasses is also expressed in terms of brix, sucrose, and purity. Brix figures ranged from 84.40 to 89.73, for an average of 87.30. Sucrose levels went from 25.99 to 37.00, for an average of 30.43 percent, while purity ranged from 29.96 to 35.32, for an average of 32.85 percent. In addition, gallons of molasses produced from each ton of cane varied from 4.92 to 6.05, for an industry average of 5.36 gallons.

The last section of the table (sucrose account) is a summary of previous data and is self-explanatory.

REASONS FOR PERFORMANCE: IMPACT OF NEW TECHNOLOGIES

A few years ago, Alvarez and Polopolus (1991, pp. 9-25) published an article on the impact of new technologies on sugarcane production and processing in the United States for the period 1970-89. Since the literature on specific technological developments in the Florida industry is extremely limited, the above referenced article has been summarized to explain some of the reasons for the advancements in U.S. sugarcane production and processing.

The Production Sector

Data for the period 1973 to 1988 reflect a clear trend toward consolidation in the sugarcane production (agricultural) segment of the industry. The number of sugarcane farms decreased by more than 45 percent over the period, while the harvested acreage per farm increased by 764 acres.

While such a trend is an important indicator of structural change in the U.S. industry, it is not necessarily an indicator of a change in technology or efficiency. The trend toward fewer and larger farms would represent more efficient operations if significant increases in output, due to yield improvement and not acreage expansion, were achieved. The regression results seemed to indicate that, in general, that was not the case. However, after analyzing the particular cases of Hawaii

(declining acreage), Louisiana (declining acreage) and Florida (increasing acreage), the authors' statistical analyses showed stable yields in Louisiana and Florida, and increasing yields in Hawaii. Stable yields in Florida is a clear sign that new cultivar releases had resulted in more sugarcane production because most of the industry expansion has taken place on marginal lands. In addition, the analysis showed that technological changes had taken place with the increase in mechanical harvesting and the development of new cultivars with higher sucrose content and increased resistance to rust and smut.

Declining costs of production are another sign of technological changes taking place at the farm level. Average variable costs per acre showed a dramatic decline in current dollars between 1982 and 1989. In 1989, per acre costs were more that 12 percent lower than in 1982. The general average fixed production cost trend for sugarcane had been downward since 1986 on both a per acre and per ton basis. The reasons behind those declines included more efficient production practices, such as pest controls, increased use of mechanical harvesters, laser land leveling, and application of ripeners early in the harvest season. Also, increased average farm size of operations have permitted some economies of scale. Overall management may have improved also as the result of the use of computers. An example of new technology/management system involves the application of radar technology for tracking weather conditions and harvesting equipment and crews, to help improve harvesting and cane deliveries.

The Processing Sector

Total number of mills had decreased from 75 in 1970 to 41 in 1989. Total daily milling capacity, however, remained relatively stable during that period of time, a fact that reflects increasing capacities in the remaining mills. Given this relatively stagle milling capacity, increasing total sugar production and/or sugar recovery would be an indication of technological change in the industry. The statistical analyses demonstrated that to be the case in both instances. Furthermore, both average variable and fixed costs declined during the study period as both sugar yield and juice quality improved. The technological changes at the processing level included automation being applied at boiler and centrifugal stations, and at some evaporation and sugar boiling stations. (At present, they are applied throughout the mill in almost all mills.) Other technological advances at the mill included computerization and the use of bagasse to reduce (or completely eliminate) the usage of petroleum.

In summary, technological changes occurred in both the production and processing sectors of the cane sugar industry of the United States during the period under study. The industry has demonstrated both its willingness and ability to change even under a protective political environment. It is anticipated that the U.S. sugarcane industry is prepared to face the economic realities of what promises to be a very competitive 21st century.

Table 9. Raw sugar mills in Florida, by company ownership and daily grinding capacity, 1995-96.

Sugar Mill	Company	Capacity
		Tons/Day
Atlantic	Atlantic Sugar Association	12,000
Bryant	U. S. Sugar Corporation	18,000
Clewiston	U. S. Sugar Corporation	25,000[a]
Glades Sugar House	Sugarcane Growers Coop. of Florida	21,000
Okeelanta	Okeelanta Corp.	22,800
Osceola	Osceola Farms Co.	13,500
Talisman	Talisman Sugar Corp.	11,000
TOTAL		123,300
AVERAGE		17,614

[a] Capacity figure not available but milled 23,784 tons per day. A 25,000 ton capacity is assumed.

Source: Sugar Publications (1996).

Table 10. Florida's area harvested, sugarcane yield, total sugarcane and sugar production, recovery rate, and sugar yield per acre, 1985-86 through 1995-96.

Crop Year	Area Harvest	Cane Yield	Cane Production	Sugar Production	Recovery Rate	Sugar Yield
	1,000 Acres	Tons per Acre	1,000 Tons	1,000 Raw Tons	Percent	Tons per Acre
1985-86	383.4	32.9	12,615	1,413	11.20	3.69
1986-87	390.0	33.1	12,916	1,476	11.43	3.78
1987-88	402.0	32.3	12,990	1,517	11.68	3.77
1988-89	404.0	31.6	12,766	1,566	12.27	3.88
1989-90	405.0	31.4	12,717	1,399	11.00	3.45
1990-91	419.0	35.5	14,874	1,806	12.14	4.31
1991-92	428.0	34.9	14,937	1,833	12.27	4.28
1992-93	426.0	33.2	14,143	1,710	12.09	4.01
1993-94	425.0	34.1	14,512	1,770	12.20	4.16
1994-95	423.0	33.6	14,216	1,725	12.13	4.08
1995-96[a]	417.0	34.6	14,445	1,772	12.27	4.25
AVERAGE				1,635	11.88	3.97

[a] Estimate.

Source: Economic Research Service (December 1996, p. 53)

Table 11. Total tons of cane ground, and raw sugar and molasses production by Florida sugar mills, 1993-94, 1994-95, and 1995-96.

Raw Sugar Mill	1993-94			1994-95				1995-96	
	Cane Ground	96° Sugar	Molasses 80° Brix	Cane Ground	96° Sugar	Molasses 80° Brix	Cane Ground	96° Sugar	Molasses 80° Brix
	1,000 Gross Tons	1,000 Tons	1,000 Gallons	1,000 Gross Tons	1,000 Tons	1,000 Gallons	1,000 Gross Tons	1,000 Tons	1,000 Gallons
Atlantic Sugar Assoc.	1.391	147.2	9.317	1.464	163.0	9.15	1.171	126.0	7.6
Bryant (U.S. Sugar)	2.357	274.5	13.856	2.488	277.0	14.28	2.540	282.0	14.7
Clewiston (U.S. Sugar)	3.131	364.1	19.592	3.228	363.7	19.89	3.396	393.7	20.1
Glades Sugar House	2.789	308.8	18.271	2.673	278.5	16.40	2.758	292.5	18.2[a]
Okeelanta	2.944	324.8	16.030	2.771	286.9	17.26	2.734	309.2	16.4[a]
Osceola	1.874	207.2	10.236	1.705	185.7	10.24	1.895	208.8	10.4
Talisman	1.322	123.7	7.971	1.293	130.4	8.51	1.219	124.9	6.4
TOTAL	15.808	1750.3	95.273	15.622	1685.2	95.73	15.703	1737.1	93.8

[a] 79.5° Brix.

Sources: The Sugar Journal (1995, p. 20; 1996, p. 24).

Table 12. Summary of manufacturing performance in Florida's raw sugar mills, 1995-96.

	Atlantic	Glades	Okeelanta	Osceola	Talisman	Clewiston	Bryant
Start crop season	10/27	11/1	10/27	10/27	10/25	10/31	10/31
End crop season	2/8	3/18	3/3	3/21	2/24	3/21	3/22
Number crop days	104	138	129	147	123	142	143
Cane milled (million tons)	1.171	2.748	2.734	1.895	1.219	3.396	2.539
Cane milled/day (1,000 tons)	11.26	19.96	21.26	12.89	9.969	23.78	17.76
Capacity of mill/day (1,000 tons)	12	21	22.8	13.5	11.0	--	18.00
Cane:							
% Sucrose	11.94	11.81	12.58	12.17	11.77	12.86	12.39
% Fibre	10.55	9.71	11.00	11.31	9.99	9.81	10.77
Bagasse:							
% Sucrose	1.96	1.68	2.41	2.23	2.55	2.94	2.83
% Fibre	45.02	45.73	44.94	43.29	43.81	45.96	46.28
% Moisture	52.35	51.86	51.75	53.70	52.85	50.12	49.91
Crusher Juice:							
% Brix	17.54	17.51	18.61	17.79	17.33	18.66	18.18
% Sucrose	14.80	14.53	15.87	15.36	14.63	15.89	15.38
% Purity	84.35	82.98	85.30	86.36	84.42	85.13	84.60

Normal Juice:							
% Brix	17.01	16.98	18.05	17.25	16.81	18.10	17.63
% Sucrose	14.08	13.69	14.99	14.65	13.82	15.02	14.58
Item	Atlantic	Glades	Okeelanta	Osceola	Talisman	Clewiston	Bryant
Normal Juice:							
% Purity	82.79	80.60	83.02	84.36	82.21	83.01	82.69
Syrup - % Purity	83.83	83.75	85.69	85.28	84.90	85.43	85.62
Normal juice - Extraction	81.49	83.64	80.05	79.59	80.91	81.44	80.51
Sucrose Extr. -% Sucrose in cane	96.15	96.97	95.30	95.20	95.07	95.12	94.69
Maceration - % Cane	26.72	30.14	22.85	28.04	19.67	15.01	19.39
Recovery - % Sucrose in juice	86.92	89.25	90.54	91.33	87.97	90.97	90.97
Yield - 96% Test - % cane	10.81	10.64	11.31	11.02	10.25	11.59	11.12
96% Test Sugar (1,000 tons)	126.5	292.50	309.17	208.85	124.92	393.73	282.43
Polarization	98.66	98.57	98.89	98.55	99.00	98.98	98.79
Mud % Pol	0.99	2.03	1.47	1.25	4.84	2.70	2.35
Final molasses: Brix Sucrose Purity	 84.40 33.44 31.68	 88.69 31.29 35.32	 87.40 29.53 33.79	 86.26 28.74 33.32	 89.73 37.00 35.07	 87.84 27.04 30.79	 86.75 25.99 29.96
Gallons (per ton of cane)	6.05	5.70	5.25	4.92	5.32	5.19	5.07
Lime (lbs/ton of cane)	1.05	1.34	1.98	1.44	0.69	1.15	0.89
Fuel Oil (gallons/per ton of cane)	0.46	1.12[a]	0.07	0.36	0.31[a]	0.16	0.01

Sucrose Account:							
% Cane							
In bagasse	0.46	0.36	0.59	0.58	0.58	0.63	0.66
In final molasses	0.97	1.09	0.94	0.86	1.03	0.86	0.82
In mud	0.04	0.08	0.08	0.06	---	0.14	0.10
Undetermined	0.09	0.05	0.11	0.08	0.31	0.11	0.14
Mill	Atlantic	Glades	Okeelanta	Osceola	Talisman	Clewiston	Bryant
Total Losses	1.56	1.59	1.72	1.59	1.92	1.74	1.72
In sugar of 96° test	10.375	10.217	10.86	10.58	9.84	11.13	10.68
GRAND TOTAL	11.937	11.805	12.58	12.17	11.76	12.86	12.39

[a] Gas - MCF per ton of cane.

Source: Sugar Publications (1996, pp. 74, 77, 79, 84, 86, 91, 94).

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