ECONOMIC ASPECTS OF TECHNOLOGY GENERATION IN THE BRAZILIAN SUGAR-CANE INDUSTRY, AND THE USE OF ITS PRIMARY PRODUCTS AND BY-PRODUCTS

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ABSTRACT - This paper analyses technology generation in the Brazilian sugar-cane industry from 1975 to 1995. We evaluate the impact of technological change on the quality and utilization of sugar-cane by-products. We determine the main agents in the process of technology creation and develop a cataloguing methodology. Finally, we evaluate how technological change influenced the quality and utilization of cane by-products. We found that technological innovation in the Brazilian sugar-cane industry is generated by the State, cooperatives, private industrial enterprises, sugar mills, and alcohol distilleries. The adoption of technological strategies is differentiated among enterprises.

Key words: Sugar-cane industry, technology, by-products.

INTRODUCTION

This paper analyzes the process of technology generation in the Brazilian sugar-cane industry from 1975 to 1995. We examine the impact of technological improvement on the quality and utilization of sugar-cane products and production by-products.

The period under study includes the most significant era of Brazil's National Alcohol Program (PROÁLCOOL). Moreover, between 1975 and 1995, there was a distinct change in governmental policy that impacted the process of technology generation in the sugar-cane industry.

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Early in this period, State intervention was the fundamental force regulating the sugar and alcohol sector. By the end of this period, beginning with the dissolution of the Sugar and Alcohol Institute (IAA) in 1990, there was a relative reduction in the government's interventionist role.

Several papers have already analyzed technology generation and its impacts on the sugar-cane industry (see Belik, 1985; Eid, 1996; Macedo, 1996; Olalde, 1993; Szmrecsányi, 1994, among others). However, no effort has been made to link technology generation in the sugar-cane industry with the concepts of Technology Economy, mainly, Freeman's theory of technological strategies (Freeman, 1974). Some papers have analyzed the by-products generated by the sugar-cane industry and their possible uses (Stalder & Burnquist, 1995; Olalde, 1993; Szmrecsányi, 1994). Nevertheless, we need more information about the impact of technology generation on the quality of these by-products and the evolution of their use.

This paper evaluates the economic effect of technology generation on the quality and use of Brazil's sugar-cane industry's primary output and secondary by-products. However, we do not propose to compare Brazil's sugar-cane industry with other agro-industries.

In first section, we examine the current organization of the Brazilian sugar-cane industry, identifying the agents who determine the sugar-cane industry's dynamic. Second section contains an analysis of the process of technology generation in the industry, showing how the main agents were responsible for technology generation. Third section evaluates the impacts of technology generation on the industry's primary products and by-products. In Final Considerations (fourth section), we summarize the main points noted in this paper.

THE ORGANIZATION OF THE SUGAR-CANE INDUSTRY

Initially, it is necessary to differentiate the sugar-cane industry from the sugar-cane agro-industrial complex.

The sugar-cane agro-industrial complex includes the production and marketing of inputs from cane growers[1] and/or sugar mills and alcohol distilleries and the industrial transformation of these inputs to produce a range of products and by-products destined for the domestic and/or foreign markets. These products and by-products may be produced by a single firm or through an arrangement between individual firms or cooperatives (Figure 1). Together, the agricultural and industrial segments of the sugar-cane complex make up the sugar-cane industry. The main agents acting in that industry are private enterprises, cooperatives, and the State.

[1] Farmers who harvest sugar-cane and sell it to sugar mills or alcohol distilleries.

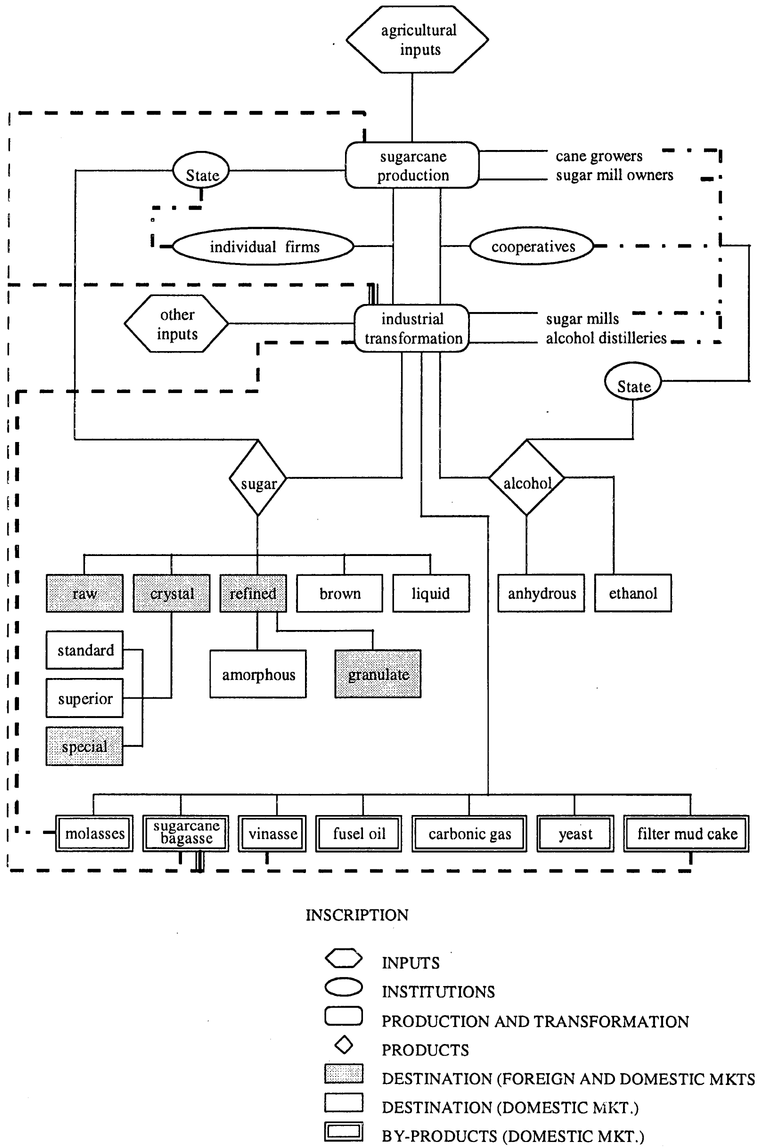

Figure 1 - The Sugar cane Complex

Private enterprises working in the sugar-cane industry consist mainly of input suppliers, cane growers, sugar mills, and alcohol distilleries. Most processed cane comes from sugar mills and alcohol distilleries, which use their both their own land and leased property. According to data from the 87/88 and 88/89 harvest (Statistical Annual of Brazil, 1990), approximately 35.9% of the sugar-cane processed by mills came from cane growers and 64.1% was produced by the sugar mills and alcohol distilleries themselves. According to Carvalho (1996), in 1994/95, about 38.3% of the cane processed by the sugar mills came from cane growers and 61.7% was produced by sugar mill owners.

Cooperatives have had an important influence on the sugar-cane industry's performance. According to the Cooperative of Sugar-cane, Sugar, and Alcohol Producers of São Paulo State (COPERSUCAR), *"in Brazil ... sugar is manufactured by sugar mills that are located mainly in São Paulo, Pernambuco, Alagoas, and Rio de Janeiro States. Of the more than 200 sugar mills located in those States ... around 80% are affiliated with cooperatives"* (COPERSUCAR, 1989a, p.14). Today, COPERSUCAR is the largest cooperative in the Brazilian sugar and alcohol sector.

Some government controls on the sugar-cane industry were present prior to 1933, when the Sugar and Alcohol Institute (IAA) was created; but from 1933 to 1990 (when the IAA was disbanded), the State employed several forms of direct intervention to increase its control of the sugar and alcohol sector. The IAA acted by motivating, directing, and controlling sugar and alcohol production in all Brazil. Starting with the inception of PROÁLCOOL (National Alcohol Program, also called PNA) in 1975, the State acted to create demand in the sugar-cane market (Moreira 1989, p.107):

> *" Before PNA, the State based its intervention on the control of supply and on the neutralization of sugar price fluctuations originating in foreign markets. Starting with that program, the State enlarged its presence by 'creating' demand for combustible alcohol. This was accomplished by establishing percentiles of alcohol to be mixed with gasoline and maintaining alcohol prices somewhat below gasoline prices."*

After IAA was dissolved[2], State intervention in the sugar-cane industries diminished. Nevertheless, this reduction was only relative as all the attributes of the IAA were transferred to the Regional Development Bureau (SDR) by Decree number 99,288, enacted on June 6, 1990.). SDR is subordinated to the Presidency of Republic (Lima, 1992). Olalde (1993) reports that the government continued to determine production share and made harvest planning decisions through SDR's Sugar and Alcohol Office after IAA was disbanded; but sugar export decision making was transferred to the private sector. This was the main policy change that occurred in the sugar and alcohol sector during the first part of 90s. Today, the State's role in sugar and alcohol sector regulation has become the responsibility of the Bureau of Industry, Trade, and Tourism ("MINISTÉRIO cria certificado para impedir fraudes de usineiros," 1997).

Though peripheral firms control a slight portion of the Brazilian sugar-cane industry's production, capital concentration in the industry (expressed by industrial and land capital concentrations) have caused technical and economic concentration in that sector (Ramos, 1983 and 1991). Brazil's sugar-cane industry can be considered a competitive oligopoly (Moreira, 1989). In this industry, price competition is minimal because State intervention determines production share and commodity prices, yet many producers have been impacted by economic fluctuations.

We can characterize the various enterprises working in this competitive oligopoly by considering the technological strategies they have adopted. In the next section, we will examine the technological strategies employed by sugar mills and alcohol distilleries.

GENERATION OF TECHNOLOGY

In second section, we discuss Freeman's theoretical classification of the various technological strategies that have been employed by businesses. We then analyze the behavior of private enterprises, cooperatives, and governmental agencies operating in the sugar-cane

[2] By 151's Medida Provisória (a kind of Brazilian act) from march 15th, 1990.

sector applying Freeman's classifications to determinate the sector dynamic.

Freeman's Classification of Technological Strategies

Christopher Freeman analyzed different technological strategies as they have been adopted by various business enterprises (Freeman, 1974; Freeman *et al.*, 1982). According to Freeman, these technological strategies can be offensive, defensive, imitative, dependent, opportunist, or traditional.

The offensive strategy is characteristically research and development (R&D) intensive and tends toward a high level of applied research.. A firm whose objectives are technical and market leadership and the production and sale of new products would adopt an offensive technological strategy.

The defensive strategy also leads to intensive investment in R&D, but this investment is made to avoid a significant technological lag developing between the firm itself and other firms. The enterprise is responding to the marketplace, attempting to keep up with the product innovations other companies. A company employing the Freeman's defensive strategy makes technical and legal adjustments as demanded by the appearance of new products.

Using an imitative strategy, a firm competes with other, better equipped firms by reducing its costs. This firm gives special attention to the information available and carefully selects items to fit its technological capabilities. The firm needs to give attention to the institutional and legal aspects of technical licensing and know-how appropriation.

The dependent strategy is employed by a firm that doesn't conduct R&D activities. In this case, the firm establishes an economically and institutionally dependent relationship with other firms.

The firm that uses the opportunist strategy searches to compete in a limited number of specific markets. It doesn't conduct R&D, and it depends basically on individual or group intuition to analyze market fluctuations.

Lastly, firms that employ Freeman's traditional strategy also don't possess R&D capabilities. Those enterprises work in markets which have developed a nearly perfect competitive structure. These markets are atomized, and competition doesn't generally stimulate innovation.

The Technological Development in the Sugar-Cane Industry From 1975 to 1995

According to Macedo (1996), technological development in the sugar-cane industry went through three phases from 1975 to 1995: from 1975 to 1981/82, industry focused on increasing productivity; from 1981/82 to 1985, it sought to increase efficiency in the conversion of sucrose to the final product and to reduce costs; during the current phase, beginning in 1985, the industry is attempting to manage both agricultural and manufacturing production on a global scale.

COPERSUCAR, PLANALSUCAR (until it ended), some mixed and solely industrial companies (IPT and Dedini, among others), and some independent sugar mills have made important contributions assisting in the generation of new technology.

The most modern firms in the sugar-cane industry are affiliated in COPERSUCAR. These firms are a good example of firms that employ a strategy similar to Freeman's Offensive Strategy (1974). They characteristically invest in intensive R&D biased toward applied research.

Examining the studies conducted by Lima (1988a and 1988b), Lima & Melo (1989), Olalde (1993), and Eid (1996), we observe that the other enterprises in the sugar-cane industry, those not affiliated with COPERSUCAR, apply Freeman's other strategies when developing their business plan. Some large sugar mills located in the State of São Paulo, unaffiliated with COPERSUCAR, have adopted a business strategy similar to the defensive strategy classified by Freeman (also intensive in R&D, but more averse to risk taking). Quite a few sugar mills and alcohol distilleries located in the Brazilian Northeast, the State of Minas Gerais, and the State of Rio de Janeiro have adopted a business strategy similar to either Freeman's dependent strategy or his opportunist strategy (a search for success in specific specialty markets).

According to Belik (1985) and Macedo (1996), COPERSUCAR's technological research efforts have been important and have impacted several areas in the sugar-cane industry. In the area of genetic improvement, there is the improvement of São Paulo's sugar-cane varieties. Normally it takes from ten to twelve years to produce a new tradable variety of sugar-cane; COPERSUCAR produces around 600,000 individual plants in one year. In the management of agricultural production, COPERSUCAR has employed new technology to map soil types and has used satellite imaging to identify cane varieties, climatic variations, topography, fertilization patterns, spacing, etc. COPERSUCAR has reduced harvest costs with the introduction of the "rodotrem," a more efficient cane transport vehicle which uses more (five) sugar-cane containers for cane transport, and the creation of overflow stations. In agricultural management, we now reuse *vinasse*, we have developed a residue mixer and applied it to crops, and we have developed and now employ the rotary push piler. In agricultural work organization, we now harvest seven sugar-cane lines (streets) simultaneously, thereby decreasing crop losses and reducing the number of field impurities carried together with harvested cane. In industrial activity, COPERSUCAR has improved techniques used to extract sugar-cane juice, to treat and ferment the juice, to produce distillates, and to generate energy using sugar-cane *bagasse*. The technology developed by COPERSUCAR's Technological Center (CTC) is responsible for a reduction in the median cost of alcohol by around 30%, agricultural costs by 22.2%, and industrial costs by 8.1% (Lopes, 1996).

The technological efforts of COPERSUCAR have put its affiliated sugar mills and alcohol distilleries a step ahead of others in the industry. Because enterprises affiliated with COPERSUCAR are all located in the State of São Paulo, it has contributed to regional differentiation in the sugar-cane industry. Nevertheless, Eid (1996) emphasizes that heterogeneity exists among COPERSUCAR affiliated enterprises. Within the cooperative, we find the most modern sugar mills, which use new technologies and new administration techniques, working together with some much less modern mills. It is necessary to take "... *into consideration that we observe modern sugar mills using new technologies among sugar mills affiliated to COPERSUCAR along with other, less modern mills that use the traditional technology*" (Eid, 1996, p.34).

In the middle of the 80's, COPERSUCAR spent the equivalent of US$ 7 million a year in research (0.8% of its gross revenue) and employed about 120 technicians, 30% with either a Masters Degree or a Ph.D. (Belik, 1985). The cooperative has 10,000 m^2 of laboratory space and 3,000 ha. of experimental areas.

However, starting in 1990, COPERSUCAR began to rein in expenditures for technological activities. Facing diminishing profits in the sugar and alcohol sector, COPERSUCAR fired 54% its employees working on technological programs and closed five of its nine experimental stations (Olalde, 1993). Though COPERSUCAR cut expenses, it continues to be a very important force in the generation of sugar and alcohol sector technology, especially as PLANALSUCAR no longer exists.

In 1971, the Sugar and Alcohol Institute (IAA) began the National Sugar-cane Improvement Program (PLANALSUCAR). PLANALSUCAR was intended to improve the quality of the raw material used by the sugar-cane industry and to rationalize cane production. As opposed to COPERSUCAR, PLANALSUCAR influenced the whole country. In Brazil's Northeast, technological improvements developed by PLANALSUCAR caused a sugar-cane production increase of between 8% and 25% per cultivated hectare (Carvalho & Caron, 1982).

Referring to Benakouche's study, Belik (1985, p.110) says *"... that COPERSUCAR and PANALSUCAR had a division of tasks in the Center-South region; where the former worried about economics, the latter was preoccupied with the non-economic domain"*. The non-economic domain was that portion of technological research that was non-convertible into monetary revenue (Benakouche, 1981).

After the IAA was disbanded in 1990, PLANALSUCAR suffered an institutional crisis that was partially solved when its technicians and infrastructure were incorporated into the Federal Universities located near PLANALSUCAR offices. However, over last seven years, the locus of sugar-cane research has been indefinite; and a specific budgetary endowment for these research activities still doesn't exist. Moreover, many of the researchers once employed by PLANALSUCAR are now part of the university system, either as professors or as post-graduate students, and have adapted to their new activities (Olalde, 1993).

Besides COPERSUCAR and PLANALSUCAR, some independent enterprises in the sugar-cane industry have also been worked to develop new technology. Eid (1996) draws our attention to two large sugar mills that are not affiliated to COPERSUCAR: Usina da Barra and Usina Santa Elisa, both in the State of São Paulo. They have introduced new technologies, organizational innovations, and new concepts for the reuse of industrial processing residues. For example, Usina da Barra still possesses an entomological laboratory that conducts important research into biological control of the sugar-cane stem borer (*Diatraea Saccharalis*).

Small firms in the sugar-cane industry haven't had to develop technology but have incorporated improved inputs produced and sold by larger enterprises (Olalde, 1993). These small firms have adopted Freeman's dependent and/or opportunist technological

Specifically, most industrial R&D activities in the sugar-cane agro-industrial complex are attempts " ... *to improve the components of existing equipment and effect technological modernization, starting with the transfer and adaptation of foreign technology*" (Olalde, 1993, p.66). Technological adaptation most commonly occurs through the application of learning-by-using (LBU) techniques; although, cases of learning-by-doing[3] (LBD) are also employed by COPERSUCAR's Technological Center, by Brazilian industry, exemplified by the Dedini and Zanini enterprises (Negri, 1981), and in São Paulo's Institute of Technological Researches (IPT). This Institute has contributed important alcohol fermentation research; and, more recently, it developed an eco-plastic derived from sugar-cane.

At PROÁLCOOL's inception in 1975, the automobile industry, rousing from laconic fear, agreed to develop a modern, original technology for alcohol powered vehicles. Several research centers linked with Brazilian universities made important contributions to the effort, but the alcohol engine they developed is still economically less attractive than the gasoline engine .

For quite some time, institutional arrangements haven't stimulated

[3] The general idea of *learning* is linked to the technological learning process, whose improvement originated from the diffusion process. According to Rosenberg (1982), in the case of LBU the derived result of learning is achieved through use, that it is pursued consciously, and that new knowledge leads to an improvement of production methods and product use. In the case of LBD the result is derived from learning through a productive process often caused by bottlenecks that exist in that process. LBD develops new skills in production stages.

large research investment in the sugar-cane and alcohol industry. However, the technology generation which has occurred in the sector has all been directed toward the development of new techniques for production and administration and the market introduction of new, more competitive products. Sugar-cane's economic importance is directly linked to its products, by-products, and the multiplicity of its social and economic functions (Szmrecsányi, 1979).

IMPACTS OF TECHNOLOGICAL GENERATION ON THE USE OF PRIMARY PRODUCTS AND BY-PRODUCTS CREATED BY THE SUGAR-CANE INDUSTRY

This section examines the improvement in production, utilization, and quality of the sugar-cane industry's products and by-products due to technological effort. We then use a selected sample to examine how sugar mills and alcohol distilleries broadened the economic use of their manufacturing operation's by-products.

The Sugar-Cane Industry's Primary Products and By-Products and Their Uses

Figure 1 displays the sugar-cane industry's primary products and by-products. Most of these products are destined for the domestic market. Only raw sugar, granulated special sugar and refined crystal sugar can be shipped to either the domestic or foreign market, determined by the economic situation in those markets.

Sugar and alcohol are the primary products of sugar-cane industry and can be produced separately or together[4]. The proportion of primary products produced in relation to by-products generated, depends on industrial plant in use and the *"... soil conditions, climate, and efficiency of the methods and machinery adopted"* (Renault, 1978, p.54).

Brazilian sugar-cane industry produces five traditional kinds of sugar:

[4] See Canto(1986) and Stalder & Burnquist(1995) about productivity obtained according to the method used.

raw sugar, crystal sugar, refined sugar, brown sugar and liquid sugar[5] .

The industry is currently developing a non-caloric sugar. It is similar to common sugar and is made from sugar-cane. It sweetens foods and drinks but is not metabolized by the stomach, doesn't produce calories and caries, and doesn't lead to glucose accumulation in the blood ("NOVO açúcar beneficia diabéticos e obesos," 1997).

Non-caloric sugar was created by Yong K. Park and Gláucia Maria Pastore, researchers at the Department of Food Sciences at the University of Campinas (UNICAMP). Its production technology is based on the creation of the fructosyl-transferase enzyme using a fungus called *Aspergillus niger*, found in the soil of sugar-cane crops.

This new product will be market tested in 1998. Today, non-caloric sugar production is beginning in Usina da Barra (São Paulo State), one of the most modern sugar mills in Brazil ("NOVO açúcar beneficia diabéticos e obesos," 1997). This new sugar will probably be very important in the competition between sugar and synthetic sweetening products.

Brazil's sugar-cane industry produces two types of alcohol from sugar-cane, anhydrous alcohol and ethanol. Alcohol is mainly produced for the domestic market. Ethanol can be used as a complete substitute for gasoline. Its advantages in relation to gasoline are that it causes less air pollution and is obtained from a renewable source. However, the automobile industry has not yet developed technology that improves the efficiency of alcohol as a fuel (that increases fuel economy) similar to those technological improvements that have been made for the gasoline engine.

By-products are generated during the industrial production of sugar and/or alcohol (see: figure 1). However, after an economic crisis hit the sugar-cane industry in 1985, those by-products began to receive attention as a possible source of income. Since that time, sugar mills and alcohol distilleries have made an effort to put their production by-products to better use in order to cut costs and increase revenue.

Molasses, also known as poor honey or saturated honey, is a non crystallizable residue created during the production of sugar. It can be

[5] We base on Renault (1978) and CEMIG (1990) in order to make that technical description about products and by-products made by sugar cane industry.

used as animal feed and is a good raw material for alcohol production in secondary distilleries. A purified type of molasses can also be used for human consumption.

Sugar-cane bagasse is a residue left after sugar-cane juice extraction. It consists of cellulosic material, ashes, residual sugar, mineral salts, other soluble materials, and water. Sugar-cane bagasse is used as animal feed, as fuel in the industrial transformation of sugar-cane, as fertilizer, in the generation of electric energy, and in the production of pulp.

According to COPERSUCAR (1989b), the sugar-cane bagasse market in the State of São Paulo is calculated to be around 1.7 million tons a year and is sold at 45% of the price of equivalent energy yielding combustible oil. According to COPERSUCAR, sugar mills and alcohol distilleries affiliated with COPERSUCAR produce around 80% of electric energy that they use. Sugar-cane bagasse is used to generate 8 mw of electric energy throughout the State of São Paulo and 14.9mw in the Brazilian Northeast. However, two major obstacles restrict to the use of bagasse for energy generation: the low prices paid for bagasse, and the large investment needed to make the high pressure boilers used to trap the gas yielded by sugar-cane bagasse transformation (Olalde, 1993).

Vinasse is a residue of sugar-cane juice distillation. It can be used to fertilize sugar-cane crops if one observes certain technical procedures. The production of one liter of alcohol yields from 12 to 15 liters of vinasse. Vinasse is rich in potassium and contains other nutrients such as: nitrogen, sulfur, calcium and magnesium. *"The application of 150 m^3 of the residue (per hectare) substitutes for 412 kg of potassium or 690 kg of potassium chloride and generates a benefit of US$ 83"* (COPERSUCAR, 1989b, p.43). According to Szmrecsányi (1994), although vinasse can be used with success as a fertilizer, its use cannot be excessive and or haphazard due to potential soil and aquifer salinity problems.

Bio-gas can be produced using vinasse. This gas can be used as a substitute for diesel fuel in sugar mill and alcohol distillery equipment. Some enterprises are installing bio-digestors to make the gas. However, this use of vinasse requires more study because some of the acidic, polluting residue of bio-digestion is still is discharged into environment.

Fusel oil is a light alcohol, obtained as a secondary product in the fermentation process and separated out in the distillation process. It can be used in the chemical industry, particularly the paint and solvent industry and the perfume industry.

Carbonic gas (CO_2) has little economic value. Most sugar mills ferment using open vats making it makes impossible to catch that gas. CO_2 can be used to produce dry ice and to make soft drinks and other beverages.

Yeast comes from alcoholic fermentation and can be used as cattle feed. It is still difficult to market yeast as a cattle feed because it's to production costs make it overly expensive relative to soy bran feed (Olalde, 1993). Filter mud cake comes from sugar-cane juice treatment and can be used as a fertilizer.

Thermo-plastic resins, derived by bacterial cultures fed with sucrose, have a potential market, especially for environmentally conscious industries. A new biodegradable plastic, poli-hidroxi-butirato (PHB), can contribute to reduce the accumulation of conventional plastic garbage. PBH disappears in approximately one year; petroleum based plastics disappear in 20 to 40 years. (Nothenberg, 1995). In Brazil, IPT, COPERSUCAR, and University of São Paulo (USP) are jointly conducting research into this new plastic. At this time, PHB has a higher production cost than conventional plastic and is only marketable to businesses that have a strong concern for the environment.

In the next section, we examine how sugar-cane industry by-products have actually been used over the last decade.

The Use of By-Products Created by the Sugar-Cane Industry

From April to June of 1997, we conducted research into the activities of[6] 93 sugar mills and alcohol distilleries located in the Brazilian states of São Paulo, Minas Gerais, Paraná, Rio de Janeiro, Pernambuco, and Alagoas. In table 1, we list the uses these mills and distilleries have found for the by-products generated by their processing of the 1985/86 and 1995/96 cane harvests.

In general, there was an relative increase in the use of by-products

[6] See Shikida (1997, p. 134 to 152) about the methodology of that research and other results.

generated in the sugar-cane industry over that 10 year period, primarily in the State of São Paulo. However, the mills and distilleries located in other several states still discard a relatively elevated percentile of their production by-products.

The large concentration new technology employed by the sugar-cane industry in the State of São Paulo is one explanation for industry in that state's more efficient use of the by-products it generates.

CO_2 is the by-product put to little use in all researched states. Yeast is used less in the states of Minas Gerais and Paraná, and fusel oil has little use in the state of Alagoas. Molasses is the "other by-product" listed in Table 1, and it is used in only the State of São Paulo.

Table 1 - Use of by-products - 1985/86's and 1995/96's harvests - (values in %).

Items and specifications		SP		MG		PR		RJ		PE		AL	
		85/6	95/6	85/6	95/6	85/6	95/6	85/6	95/6	85/6	95/6	85/6	95/6
Uses of Sugar-cane bagasse	1 - Sale	11.4	11.4	-	-	-	-	-	-	21.4	14.3	11.1	11.1
	2 - Intensive use in production	27.3	25.0	77.8	77.8	30.8	76.9	100	100	50.0	50.0	55.6	55.6
	3 - Partially used in production	4.5	2.3	-	-	23.1	7.7	-	-	-	-	11.1	-
	4 - Researches	-	-	-	-	-	-	-	-	-	-	-	-
	5 - Discarded	2.3	2.3	-	-	30.8	-	-	-	-	-	11.1	11.1
	Combination 1 and 2 (see up)	20.5	22.7	11.1	11.1	-	-	-	-	14.3	28.6	-	11.1
	Combination 1 and 3 (see up)	22.7	27.3	-	-	7.7	7.7	-	-	7.1	7.1	-	-
	Combination 3 and 4 (see up)	-	-	-	-	7.7	7.7	-	-	-	-	-	-
	No answer	11.4	9.1	11.1	11.1	-	-	-	-	7.1	-	11.1	11.1
Uses of Vinasse	2 - Intensive use in production	72.7	86.4	66.7	66.7	23.1	69.2	50.0	75.0	42.9	78.6	33.3	66.7
	3 - Partially used in production	11.4	6.8	-	-	53.8	7.7	-	-	28.6	-	33.3	11.1
	4 - Researches	-	-	-	-	-	7.7	-	-	14.3	-	-	-
	5 - Discarded	2.3	-	11.1	11.1	23.1	15.4	50.0	25.0	-	-	11.1	11.1
	No answer	13.6	6.8	22.2	22.2	-	-	-	-	14.3	21.4	22.2	11.1
Uses of Fusel Oil	1 - Sale	81.8	84.1	88.9	88.9	53.8	61.5	50.0	50.0	42.9	35.7	22.2	22.2
	2 - Intensive use in production	-	-	-	-	-	-	-	-	14.3	14.3	-	-
	3 - Partially used in production	-	-	-	-	-	-	25.0	25.0	7.1	7.1	-	-
	4 - Researches	-	-	-	-	-	30.8	-	-	-	-	-	-
	5 - Discarded	2.3	2.3	-	-	46.2	7.7	25.0	-	7.1	7.1	11.1	11.1
	Combination 1 and 2 (see up)	-	-	-	-	-	-	-	-	-	7.1	-	-
	Combination 1 and 3 (see up)	-	2.3	-	-	-	-	-	-	-	-	-	-
	No answer	15.9	11.4	11.1	11.1	-	-	-	25.0	28.6	28.6	66.7	66.7
Uses of CO_2	2 - Intensive use in production	2.3	4.5	-	11.1	-	7.7	-	-	-	-	-	-
	3 - Partially used in production	-	-	-	-	-	-	-	-	-	7.1	-	-
	4 - Researches	-	-	-	-	-	-	-	-	7.1	7.1	-	-
	5 - Discarded	72.7	68.2	55.6	55.6	84.6	69.2	75.0	75.0	57.1	42.9	33.3	33.3
	No answer	25.0	27.3	44.4	33.3	15.4	23.1	25.0	25.0	35.7	42.9	66.7	66.7
Uses of Yeast	1 - Sale	18.2	22.7	-	-	-	-	-	-	21.4	28.6	-	-
	2 - Intensive use in the production	13.6	11.4	22.2	33.3	7.7	7.7	75.0	75.0	14.3	28.6	11.1	22.2
	3 - Partially used in production	2.3	4.5	-	-	-	7.7	25.0	25.0	7.1	7.1	11.1	22.2
	4 - Researches	4.5	2.3	-	-	23.1	15.4	-	-	7.1	-	11.1	-
	5 - Discarded	38.6	31.8	22.2	33.3	53.8	53.8	-	-	14.3	21.4	22.2	11.1
	Combination 1 and 2 (see up)	-	2.3	11.1	-	-	-	-	-	-	-	-	-
	Combination 1 and 3 (see up)	2.3	-	-	-	-	-	-	-	-	-	-	-
	Combination 3 and 4 (see up)	-	4.5	-	-	-	-	-	-	-	-	-	-
	No answer	20.5	20.5	44.4	33.3	15.4	15.4	-	-	35.7	14.3	44.4	44.4
Uses of Filter Mud Cake	1 - Sale	2.3	2.3	-	-	7.7	7.7	-	-	7.1	7.1	-	-
	2 - Intensive use in production	54.5	72.7	77.8	66.7	23.1	76.9	75.0	75.0	50.0	64.3	33.3	44.4
	3 - Partially used in production	11.4	6.8	-	-	30.8	-	-	-	-	-	11.1	-
	4 - Researches	-	-	-	-	7.7	-	-	-	7.1	-	-	-
	5 - Discarded	11.4	6.8	-	-	23.1	15.4	25.0	25.0	-	-	-	-
	Combination 1 and 2 (see up)	-	-	-	-	-	-	-	-	7.1	7.1	-	-
	Combination 1 and 3 (see up)	-	-	-	-	-	-	-	-	7.1	7.1	-	-
	No answer	20.5	11.4	22.2	33.3	7.7	-	-	-	21.4	14.3	55.6	55.6
Other by-products	2 - Intensive use in production	-	2.3	-	-	-	-	-	-	-	-	-	-
	4 - Researches	2.3	-	-	-	-	-	-	-	-	-	-	-
	Combination sale and 2 (see up)	2.3	6.8	-	-	-	-	-	-	-	-	-	-
	Didn't produce other by-product	95.5	90.9	100	100	100	100	100	100	100	100	100	100

Source: Shikida (1997).

Note: we didn't observe any case of vinasse and CO_2 sales. The combination indicates two forms of use. For example, combination 1 and 2 implies that the by-product was both sold and used intensively in production.

FINAL CONSIDERATIONS

This paper analyzed the process of technology generation in the Brazilian sugar-cane industry from 1975 to 1995. We examined how technological improvement has impacted the quality and utilization of the products and by-products produced by that industry.

Sugar-cane industry technology has been generated by the State (through the now extinct PLANALSUCAR), cooperatives, sugar mills, alcohol distilleries, and by other private industrial enterprises. It was found that COPERSUCAR members have adopted a good example of Freeman's (1974) offensive business strategy, characteristically intensive in R&D with an elevated level of applied research. The other sugar mills and alcohol distilleries vary in their use of the other business strategies catalogued by Freeman. Some large, unaffiliated sugar mills located in the State of São Paulo have adopted a research approach similar to Freeman's defensive strategy; they also stress R&D but are more averse to risk taking. On other hand, a significant number of sugar mills and alcohol distilleries located in the states of the Brazilian Northeast, Minas Gerais, and Rio de Janeiro employ an approach to business planning similar to Freeman's dependent and opportunist strategies. They have established institutionally and economically dependent relationships (dependent strategy) with other firms or have directed their efforts toward specific markets (opportunist strategy).

Beginning in 1986, the technologies developed and the economic difficulties encountered by the sugar-cane industry have led to better use of the industry's by-products. Sugar-cane industries located in the State of São Paulo have made the best use of their by-products; possibly, due to the these industries focus on technology generation and their union in COPERSUCAR. Nevertheless, a substantial portion of their manufacturing by-products are still discarded.

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