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ALTERNATIVE USES FOR SUGARCANE IN THE CARIBBEAN BASIN

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SUMMARY

For centuries a major agricultural commodity in the Caribbean Basin, sugar planting is an increasingly unprofitable enterprise today. Contributing factors include rising labor costs, rising costs of production operations, a chronically-depressed sugar market, and increased industrial usage of alternative sweeteners such as the high-fructose corn syrups. Diversification of sugarcane plantations into horticultural and cattle commodities is one option given serious consideration. An alternative option is the management of cane as a multi-product biomass commodity featuring fuels, chemical feedstocks, syrup, and high-test molasses, in addition to the traditional sugar and blackstrap molasses products. This option is attractive from a botanical standpoint owing to the special growth attributes of the cane plant. It is also attractive for social and economic reasons, particularly in developing tropical nations having little in the way of fossil energy but long experience with sugarcane.

INTRODUCTION

TODAY, the planting of sugarcane has become unprofitable as a mono-product enterprise (1,2,3). Production costs for labor, machinery, transportation, and a range of energy-related inputs have risen drastically. The cost of cane cleaning, milling, and factory compliance with environmental quality regulations have far exceeded expectation (3,4). Added to this are a chronically-depressed sugar market and permanent shifts in industrial sweetener consumption (2,5,6,7). Diversification from a monolithic sugar commodity to a more flexible, multi-product enterprise is indicated as a realistic approach to survival (2,6,8,9,36). This is important for high-technology industries having large investments in the sugar-

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cane field and factory infrastructure. It is even more important in a social context. The bulk of the world's sugarcane is planted in underdeveloped nations whose historic commitment to sugarcane culture can be neither ignored nor totally abandoned (10, 11).

Puerto Rico's case is perhaps indicative of future developments for other sugar planting countries. Once one of the world's major exporters of sugar and molasses, Puerto Rico's sugarcane industry has succumbed to forces that were never fully understood nor adequately accommodated with adjustments in traditional sugar planting concepts. Since 1970 alone our cane harvest has declined by almost two-thirds (Table 1). The 1983 sugar yield has barely attained 100,000 tons (12), about have the amount needed for domestic sweetener consumption. Equally important is the heavy reliance of PR run distillers on imported molasses, a situation that has worsened materially in the last decade (Table 2).

Among the contributing factors to sugar's decline here were unexpectedly large increases in costs of energy and labor (Tables 3 and 4). Added to these were Puerto Rico's lack of success in mechanizing cane production and harvest operations (13), and the high costs (also unexpected) of factory compliance with environmental protection laws (3,4). Such cost increases have not been compensated with higher sugar values; on the contrary, many U.S. sugar-utilizing industries have turned to lower-cost alternative sweeteners such as corn syrup (Table 5). It can be seen that some of these forces are already affecting sugarcane wherever it is planted as a monolithic sugar crop. Others, such as social evolution of the labor force and environmental awareness, must soon follow. The time has arrived for serious consideration of sugarcane's multiple-product potentials at the international level.

SUGARCANE AS A MULTIPLE-PRODUCT COMMODITY

1. Historic Multiple Uses of Cane

As early as the seventeenth millinium B.C., primitive man recognized *Saccharum* as a multiple-purpose resource (14, 15 chap. 1). Immature tassels of certain clones were used as food. Forerunners of the "noble" or garden canes, having sweet and soft characteristics, were prized for chewing enjoyment. They are believed to have accompanied early man during his migrations from the region of modern-day Indonesia. Sugarcane was also used for supports, fences, and building purposes, a *de facto* recognition of *Saccharum* hardiness, long fibrous stems, and an exceptional growth capability even in the wild state.

Fuel, roofing, and cattle-feed were recognized uses of cane tops since the early days of modern sugar planting. In Puerto Rico, prior to mechanization, the large herds of oxen maintained by sugar centrals were fed dry foliar trash mixed with molasses, usually in the dark early morning hour before field work began (16). Where hand harvesting is still performed it is common practice to sell or give away the green tops to dairy farmers or cattlemen. Volunteer cane on abandoned plantations is still commonly harvested for cattle feed by enterprising individuals.

2. Alternative Industrial Uses

Since 1974, well-publicized attempts have been made to capitalize on the second-product potential of existing commercial canes. Brazil's fuel alcohol program is the outstanding example (17, 18). Bagasse/electricity projects are operational or under development in Hawaii, Florida and the Dominican Republic. Systems modifications for the direct-firing of bagasse have been proposed for study in Puerto Rico (19, 20, 21). In each case the secondary use is based on existing interspecific hybrids that were selected for their sugar attributes. No research was performed in support of the alternative use *per se*, that is, to improve the yield/quality/cost relationships of fermentable solids for ethanol of lignocellulose for electricity. In Brazil, for example, where cane yields barely average 22 tons/acre year, the supply of fermentable solids for ethanol was increased merely by expanding the cane acreage under traditional management.

The broader scope of potential cane products, uses, and applications remains largely ignored by sugar planters (22, 23, 24). Biotechnological and other advances toward more sophisticated uses of sugar and cellulose are being made outside of the sugarcane industry itself (25, 26, 24, 27). It is correct to say that within the international sugarcane community the cane plant remains both underutilized and under-researched.

3. Current Products Development

At maturity, the dry matter content of a typical hybrid sugarcane consists roughly of 30% fermentable solids and 70% lignocellulose. Since the mid-1970's, industrial enterprise has shown mounting interest in lignocellulose as a feedstock for fuels and chemical products. Much attention has been directed toward upgrading the combustion properties of lignocellulose residues by dehydration, size reduction, and compaction in some easily-manageable and salable form (Woodex* pellets, AGRI-FUEL* powder, Koppleman K-FUELS*). Numerous other processes attempt to render more efficient or economical the traditional conversion of lignocellulose to glucose by acidic or enzymic hydrolysis. Certain proprietary methods stress special preparation of the feestock or bypass direct hydrolysis entirely (OMNI process, STAKE Pretreatment Technology, PURDUE process (Tsao/Ladisch Solvent Extraction). Once glucose is "freed" from the lignocellulose structure, it can be used to produce industrial ethanol by conventional fermentation technology. Ethanol in turn is the basic substrate for numerous downstream chemicals.

Little-known work has touched both extremes of the conversion options for sugarcane. For example, there is some question as to whether conventional crushing and grinding is the optimal method for dewatering the cane stalk in a multiple-use scenario. An alternative approach is to split and depith the stem, thereby recovering an easily-extractable soft center, an intact rind with unbroken fibers, and natural waxes from the outer stem surface (28). At the distillery, there has been some success in upgrading stillage for agricultural applications and biological conversion to biogas fuel for electrical power production (29, 30).

Recent analyses of developing-nation requirements of their biomass resources have stressed the need for local charcoal production (31). Traditionally produced from wood, the possibility exists that sugarcane can substitute as the basic lignocellulose feedstock. This is particularly attractive for Central American regions where native forests are already depleted and there is little experience with reforestation technologies (32).

Sugarcane is a potentially attractive feedstock source for virtually any process requiring large quantities of inexpensive lignocellulose. This statement is predicated on the thesis that bagasse can be supplied in a relatively continuous time-course (relative to crop residues, timber residues, municipal refuse). This is not the case today. n Puerto Rico, having experienced a complete turnabout from an economic, cheap-labor industry to a poorly mechanized economic catastrophy, cane residues are increasingly costly, seasonal, and in short supply [1/]. Moreover, current P. R. cane is excessively dirty (3, 4). This is largely a result of substandard mechanization that never adequately replaced the clean harvests formely enjoyed with cheap hand labor (13). There is a decisive role here for the sugarcane breeder. He must help to assure the needed high tonnages that can be cleanly harvested, loaded, and delivered to the dewatering/ processing site.

LIGNOCELLULOSE POTENTIALS

1. Production Potential

As previously noted, the bulk of whole cane dry matter consists not of sugar but of lignocellulose (lignin, cellulose, hemicellulose). The maximum yield of this fraction is seldom realized in sugar-planting operations, but it is considerable nonetheless. Hence, the world's average cane yield is in the order of 23.0 tons/acre year, but up to 160 tons/acre year are theoretically possible. (Table 6)

A major fraction of the unrealized growth potential can be made up through alternative management technologies for existing varieties. Puerto Rico's hybrid PR 980, for example, produces in the order of 25 to 30 tons/acre year as a conventional sugarcane, but averaged 83 tons/acre when managed for total biomass yield (33). A variety selected for its exceptional growth attributes, US 67-22-2, yielded over 100 tons/acre year with essentially the same production inputs (9). To approach the theoretical maximum yields would require revision of production management, selection of varieties having exceptional growth characteristics, and the production of new hybrid sugarcanes in which high tonnage rather than sugar was the breeder's primary concern.

2. Uses and Products

Lignocellulose is indeed a versatile material. As an intact residue, such as bagasse or solar-dried grasses, it can be utilized directly in a range of industrial processes, including:

1/ The P. R. 1983 grinding season averaged only 92 days for four of the five active mills (12).

- . WOODEX PROCESS (Fuel Pellets, Chemicals)
- . OMNI PROCESS (Glucose from Cellulose)
- . AGRI-FUEL (Fuel Powder, For Oil Blends)
- . ABA INTERNATIONAL (Boiler Fuels)
- . PETRO-SYN CORP. (Fuel Pellets)
- . AMERICAN SYNFUELS CORP. (Alcohol Fuels)
- . ANDER-CANE PROCESS (Fiber, Pith, Wax)
- . HOPPLEMAN PROCESS (K-Fuels, Biogas)
- . STAKE TECHNOLOGY, LTD. (Fuels, Chemicals)

From a chemical engineering standpoint, more sophisticated uses can be made of lignocellulose separated into its principal components. Some of these are listed in Table 7. This tabulation is perhaps over-condensed; for example, ethanol alone is an industrial feedstock from which ethylene and subsequently dozens of downstream products are obtained.

CANE PRIORITIES; ADVANCED VS DEVELOPING COUNTRIES

Where the alternative cane products are fuels, two popular sets of goals become involved and confusion over priorities can follow. For example, on the U. S. mainland, alcohol fuels produced from the entire cane industry would have little impact on the national motor fuel requirement (34). On the other hand, for U.S. sugar planters and processors the opportunity to sell alcohol as a second cane product could have major impact.

Puerto Rico's situation is intermediate between that of the U. S. and underdeveloped tropical nations. A Puerto Rican cane industry oriented to utility fuel as a third product, after sugar and molasses, could produce anywhere from 11 to 27 per cent of insular energy needs (34, 35). This is a significant impact. The parallel effect on the local cane industry should be decisive - a complete turnabout from an economically failing enterprise to a highly lucrative one. However, it is sometimes argued that the energy impact is too small to justify reorientation of the P.R. cane industry. The opportunities thus afforded for a domestic molasses supply and economic revitalization of sugarcane are ignored. This argument fails to visualize the productivity of reoriented field operations, particularly management and varietal changes combined with breeding for multiple-product hybrids.

When extended to developing tropical nations, where most of the world's cane is grown, the analysis of priorities would heavily favor continued cane planting with the greatest possible diversification into multiple products. Because reliance on fossil energy is low by developed-nation standards, there is greater likelihood for sugarcane to contribute significantly to total energy needs. Similarly, the same category of underdeveloped countries is generally devoid of fossil energy resources. Where such resources do exist their development would require technology imports from foreign countries. Finally, the continuation of historic and cultural ties with sugarcane is preferable to alternative agricultural crops for which prior experience and technical resources are lacking. Diversification is most logically directed to sugarcane's multiple products, particularly to cellulose as a domestic feedstock substitute for imported oil.

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TABLE 1

CANE HARVEST DECLINE; 1970-82

Year	Tons Cane 1/ (Thousands)
1970	3,799
1973	2,749
1976	3,032
1979	2,280
1982	1,579
1983	1,298

1/ Junta Azucarera de Puerto Rico

TABLE 2

MOLASSES USE AND IMPORTS BY PR RUM INDUSTRY; 1972-1977

Year	Gallons x 10^6	
	Total Use	% Imported
1972	33.7	45.7
1973	29.8	40.9
1974	27.8	53.6
1975	25.9	47.4
1976	34.9	68.4
1977	38.8	78.8
1978	39.4	88.0

TABLE 3

OIL COST FOR PR 1970-81

Year	Cost ($US/BARREL)
1970	2.90
1974	9.00
1977	11.80
1979	14.90
1980	25.50
1981	32.50

TABLE 4

HOURLY WAGES IN PR CANE

Year	Ave. ($/hour)
1939	0.16
1957	0.35
1968	0.69
1977	2.10
1981	3.20
1983	3.50

TABLE 5

RELATIVE SWEETENER COSTS
(Coke Fountain Syrup)

Sweetener	Cost ($) 1/
Refined Sucrose	0.30
Corn Syrup	0.17

1/ Wall St. Journ., March, 83

TABLE 6

SUGARCANE PRODUCTION POTENTIAL

Parameter	Tons/Acre Yr.
World Average	22.6
Puerto Rico Ave. (1980)	26.6
PR Energy Cane Ave.	83.0
Estimated Theoretical	112-160

TABLE 7

USES AND PRODUCTS OF LIGNOCELLULOSE

Cellulose	Lignin	Hemicellulose
Cattle Feed	Vanillin	Glucose
Glucose	Insulation	Sweetener [2/]
Butadiene	Stabilizer	(Xylitol)
Sweeteners[1/]	Act. Carbon	Acetic Acid
S.C. Protein	Adhesives	(Vit. C)
Ethanol	Binders	Furfural

1/ Fructose, Sorbitol 2/ Xylitol