

## DESIGNING, PRODUCING AND PROCESSING 'ULTIMATE' VARIETIES OF SUGARCANE

By

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### Abstract

MANY sugar industries, beet and cane, would predict that in the future they will produce a wide range of products, which could include sugar. To realise this prediction, new varieties must be designed, production practices improved and alternative processing techniques developed. Sugarcane breeding and selection has moved far beyond the 'old days' of crossing the best parents and hoping to select the best segregate as a potential new variety. Modern breeding procedures and biotechnology offer greater efficiency. Typically, varieties are selected on the basis of high yield of sugar and characteristics important to agronomic production and pest resistance in each growing region. The typically measured juice quality characteristics of brix and pol along with tonnage, ratooning ability and fibre content can predict yield of sugar per unit area. It is anticipated that the 'ultimate' variety of the future will involve much more detailed analysis than the typically measured characteristics. Once produced, high yielding varieties for various products need to be grown in a sustainable manner that provides maximum production with minimal environmental and economic impact. Processing of these varieties will need to accommodate the specific product(s) being produced whether sugar, energy, some other product or some combination of these. To demonstrate the importance of quality characteristics of future varieties, the Sugar Processing Research Institute has investigated the presence of components that could either enhance or inhibit production of various products from sugarcane. Significant variability among and within species of sugarcane and related genera have been found for starch, polysaccharides, ash, cations, invert sugars and other parameters. This paper includes these data and the potential importance of these parameters in future varieties, its importance in a sustainable production system and its importance in processing needs.

### Introduction

While we often like to use the word 'traditional' when we speak about issues regarding the sugar industry, the fact is sugarcane industries around the world always find themselves as part of a dynamic situation. Papers that deal with sugarcane breeding and the history of breeding traditionally start with discussions about Indonesia and Barbados that once had thriving sugar industries.

Today, tradition is somewhat gone as Indonesia's sugar production is less than half of its total use and Barbados, like much of the Caribbean, is struggling to survive as a sugar industry. Both still have significant breeding efforts, but the tradition of the industry has certainly changed.

Papers dealing with sugar industry production traditionally have listed sugar and molasses as the saleable products produced from an industry. Over the last decade we now find other columns in production tables; these include ethanol, building products from bagasse, electricity produced,

betaine (sugarbeets), acid production, and others. None of these products are new, but they aren't part of what one remembers as the traditional sugar industry.

Production practices and pest control, while often thought of as traditional within each country, have changed, oftentimes drastically, to meet changing pest problems; climatic conditions; environmental regulations; prices for energy, fertiliser and crop protection chemicals; and, sustainability issues. When one considers this dynamic situation, the word 'tradition' becomes less meaningful.

This brings us to the future. What will industries in the near and long-term future be producing? How will the varieties for these products vary? What type of production practices will be required for these newer varieties with increased concerns about sustainability and the environment? How will processing practices change to most efficiently produce these products?

Much is already known about the variability and heritability that exist with yield and sugar content in sugarcane (Richard and Henderson, 1976; Heinz, 1991). Monosaccharides (glucose and fructose), total polysaccharides (gums), starch, colour, and organic acids present in the juice vary with variety, climatic conditions, extraneous matter content, age of cane, location, degradation, and other factors (van der Poel *et al.*, 1998; Clarke and Godshall, 1988; Zhou, 2007).

Heritability of these factors is not as well understood as for major components such as sucrose content. The future of sucrose and its potential use along with other products from the sugarcane plant have been discussed for many years (Paturau, 1969; Purchase, 1995; Godshall, 2009). However, little emphasis has been given to directed breeding of sugarcane for these products.

Sugar Processing Research Institute (SPRI), located in New Orleans, USA, has attempted to answer questions concerning component analysis of sugarcane and how that might impact future breeding of sugarcane varieties.

SPRI is a unique research organisation, representing international sponsors that produce sugar, provide services and technology to the sugar industry, or use sugarcane or sugarbeet products. It conducts research in areas important to quality products coming from these segments of the sugar industry. As such, evaluation of issues important to sugar processing is a mainstay of this research organisation.

Recently, one project of SPRI was to evaluate sugarcane germplasm and sugarcane harvest treatments for potential impact on production of all products.

The objective of this research was to examine the varying levels of components contained in the juice of these varieties and harvest treatments that could then be considered as enhancing or inhibiting the production of potential final products including alcohol and sugar.

Finally, consideration was given to how varieties with these varying components could then fit into a sustainable production system and be most efficiently processed.

## **Materials and methods**

In the first phase of the research in 2007, in collaboration with the USDA Sugarcane Research Unit (USDA SRU) in Houma, LA, SPRI began studying three sugarcane varieties. Two were commercially grown varieties, HoCP96-540 and Ho95-988, while L79-1002 was a wild type now referred to as 'energy cane'. Each variety was harvested under three conditions: A- total biomass consisting of tops, side leaves and stalks; B- only side leaves and stalks with the tops removed; and C- only stalks with the tops and side leaves removed. Four replications were harvested by hand for each treatment, each of which was a 15-stalk sample. The samples were milled by the USDA SRU laboratory and the juice obtained for a typical analysis. The typical analysis usually performed to determine the value of sugarcane includes brix, sucrose, fibre and total recoverable sugar (TRS).

Duplicate juice samples from variety/treatment samples were then composited and analysed in greater detail at the SPRI laboratory for the parameters of pH, brix, total polysaccharide, starch, ash, sucrose, glucose, fructose, colour, turbidity, and cations (potassium, magnesium, and calcium).

As a second phase to this project, in November 2008, 29 sources of germplasm from five different species of sugarcane, along with a related genus, *Erianthus*, were harvested and analysed.

There were two species, *S. officinarum* and *S. barberi* generally regarded as cultivated species and three generally regarded as wild types, *S. sinense*, *S. spontaneum*, and *S. robustum*.

The stalks were milled by the USDA-SRU in Houma, the juice was put onto ice and immediately transported to the SPRI laboratory for detailed analysis for brix, pH, starch, polysaccharides, ash, colour and turbidity and cations (potassium, magnesium and calcium).

Test procedures, equipment, and references used for the detailed analysis were as follows:

- pH – Orion model # 520A meter.
- Brix – Bellingham and Stanley RFM81 refractometer.
- SPRI Rapid Starch – Reference for juices: Godshall, M.A., Triche, R. and Moore, S. SPRI Proc. Conference on Sugar Processing Research, 2004, 428–441. (which is based on ICUMSA Method GS1-17 (2005). The Determination of Starch in Raw Sugar by the SPRI Rapid Starch Test ICUMSA Methods Book, 2005).
- SPRI long starch method – Reference: Godshall, M.A., Clarke, M.A., and Dooley, C.D. SPRI Proc. Conference on Sugar Processing Research, 1990, 244–264.
- Total polysaccharides – Roberts, E.J. Proc. 1980 Technical Session Cane Sugar Refining Res., 1980, p 130.
- Conductivity ash – YSI 3100 Conductivity Instrument, ICUMSA method GS1/3/4/7/8-13 (1994) The Determination of Conductivity Ash in Raw Sugar, Brown Sugar, Juice, Syrup and Molasses.
- Sucrose, glucose, and fructose – Liquid Chromatography, BioRad HPX-87K column with 0.01M potassium phosphate (0.6 mL/min at 75°C) RI detection (Waters 2410).
- Calcium, magnesium, potassium – Ion Chromatography, Dionex IonPac CS12A column 20 mN H<sub>2</sub>SO<sub>4</sub> at 1 mL/min with Conductivity detection (Dionex ED40)
- Colour and turbidity – ICUMSA Method GS1/3-7 (2002) Determination of the Solution Colour of Raw Sugars, Brown Sugars and Coloured Syrups at pH 7.0

## Experimental results

In the first phase of the project, results of the typical juice analysis performed by the USDA-SRU of the three harvest treatments of three varieties indicated, as expected, that the C treatment (cane free of all extraneous matter) of each variety had the highest sugar content and the lowest fibre content.

The A treatment, consisting of the entire plant, had the lowest level of sugar and highest level of fibre. As expected, the two commercial varieties were not different for comparable harvest treatments, while the wild variety showed significantly lower sugar levels and significantly higher fibre levels.

Results of the detailed juice analysis performed by SPRI of the three harvest treatments of three varieties can be seen in Table 1. The pH ranged from 5.46 to 5.57 with no apparent difference between harvest treatments or varieties.

Varieties Ho95-988 and HoCP96-540 had similar averages in brix content consistent with commercial varieties while L79-1002 had considerably lower brix content.

**Table 1**—Detailed analysis conducted by SPRI for three varieties and three harvest treatments for pH, brix, total polysaccharides, starch, ash, colour, turbidity invert sugars and cations.

Sample	pH	Brix	Total polysaccharides	Starch	Ash	Colour	Turbidity
			ppm on solids				
HoCP96-540-A	5.46	19.2	6958	2038	3.27	27 172	94 274
Ho95-988-A	5.48	21.0	4954	1984	2.39	18 823	71 626
L79-1002-A	5.52	14.3	12 950	5514	10.05	55 201	110 465
HoCP96-540-B	5.52	20.4	6078	2372	2.56	16 223	77 206
Ho95-988-B	5.48	20.2	5306	2064	2.69	14 512	72 933
L79-1002-B	5.57	13.5	12 830	5769	10.33	36 694	101 856
HoCP96-540-C	5.47	20.5	3873	2265	2.10	9656	49 531
Ho95-988-C	5.46	20.4	3919	1620	2.18	11 559	53 952
L79-1002-C	5.52	13.4	11 286	6833	10.38	21 949	78 827

Sample	Sucrose	Fructose	Glucose	Potassium	Magnesium	Calcium
	ppm on solids					
HoCP96-540-A	71.6	8.89	6.54	1.325	0.135	0.180
Ho95-988-A	83.9	8.27	3.27	0.730	0.088	0.106
L79-1002-A	60.1	10.2	6.40	3.375	0.144	0.305
HoCP96-540-B	81.1	8.31	3.83	0.805	0.092	0.094
Ho95-988-B	83.8	8.39	3.44	0.805	0.092	0.110
L79-1002-B	65.5	10.01	5.60	3.210	0.123	0.262
HoCP96-540-C	82.7	1.62	Not detected	0.650	0.068	0.065
Ho95-988-C	80.1	3.26	3.03	0.665	0.070	0.082
L79-1002-C	55.5	10.76	8.09	3.905	0.111	0.234

For each variety, treatment C had the lowest level of total polysaccharides with the wild type sugarcane variety L79-1002 having the highest total polysaccharide content. For the starch analysis, there was little difference among harvest treatments, although L79-1002 had much higher starch levels than the two commercial varieties. Differences in ash content were similar to that of total polysaccharides, with the wild type variety considerably higher than the two commercial types.

Juice colour in each harvest treatment was highest for variety L79-1002 as compared to the two commercial varieties. Harvest treatment A (tops, side leaves, and stalk) had the highest colour followed by treatment B. Treatment C, stalks with no leaves or tops, had substantially lower colour regardless of variety. Turbidity followed the same trend as colour.

Varieties HoCP96-540 and Ho95-988 showed comparable sucrose content for harvest treatments B and C, while Ho95-988 was slightly higher in treatment A. Variety L79-1002 had much lower sucrose levels in all three treatments. Variety L79-1002 also reported the highest invert sugar levels of the three varieties, with little difference between the two commercial varieties. Fructose levels were considerably lower in treatment C as compared to treatments A and B for the

commercial varieties, but did not vary in the wild variety. Glucose levels dropped by half from treatments A through C for HoCP96-540, while there was less difference in Ho95-988 and L79-1002.

Cation content varied widely between the three varieties with L79-1002 having the highest levels of potassium, magnesium and calcium as compared to the two commercial varieties. Overall, levels of potassium were higher than levels of the other cations measured.

In the second phase of the project, averages of the analysis of clones of the five different species of sugarcane along with a related genus are shown in Table 2 for the parameters of brix, pH, starch, polysaccharides, ash, colour, turbidity and cations. Large variations in most of the parameters were found between the averages of the different species as well as when comparing clones within the same species. It is very obvious that *Erianthus* along with clones of the wild species *S. spontaneum* and *S. robustum* were in a much higher range than the cultivated species *S. officinarum*. *S. barberi* and *S. sinense* for several parameters such as polysaccharides, ash content, colour, and to some degree starch and turbidity. Brix was highest for the cultivated species and lowest in the wild clones and *Erianthus*.

**Table 2**—Detailed analysis conducted by SPRI of 29 cultivars among various genera and species of *Saccharum* for pH, brix, total polysaccharides, starch, ash, colour, turbidity invert sugars and cations.

Genus/species	pH	Brix	Starch	Total polysaccharides	Ash
			ppm on solids		%
<i>S. officinarum</i>	5.23	17.6	432	1348	6.21
<i>S. barberi</i>	5.32	15.9	727	1739	7.98
<i>S. sinense</i>	5.40	16.1	374	1898	8.55
<i>S. spontaneum</i>	5.33	9.4	2019	5081	30.52
<i>S. robustum</i>	5.30	10.8	743	4795	17.04
<i>Erianthus</i>	5.30	4.6	2112	21 293	23.93

Genus/species	Colour	Turbidity	% Potassium	% Magnesium	% Calcium
	ICUMSA Colour Units		ppm on solids		
<i>S. officinarum</i>	13 970	44 118	2.20	0.10	0.05
<i>S. barberi</i>	12 369	54 545	2.85	0.16	0.13
<i>S. sinense</i>	16 037	71 640	2.61	0.21	0.14
<i>S. spontaneum</i>	39 356	97 228	11.64	0.36	0.32
<i>S. robustum</i>	48 773	98 952	5.83	0.42	0.30
<i>Erianthus</i>	138 909	226 107	6.12	0.90	0.95

Of concern is the variation in parameters such as starch content. Domesticated species generally were less than 750, while *S. spontaneum* was 2019 and *Erianthus* was 2112 ppm on solids. Total polysaccharide analysis showed similar variation, although *Erianthus* was higher than all other tested material by a factor of at least 4. Ash content had essentially the same variability with *S. spontaneum* and *Erianthus* being substantially higher. Also of great concern were the average levels of colour for the species.

Averages for the cultivated species were less than 20 000 ICUMSA units, with the wild species higher by a factor of at least 2. *Erianthus* was much higher by a factor of 8 as compared to the cultivated species average. Turbidity showed less distinct differences, although wild species were generally higher than cultivated species and *Erianthus* was considerably higher than all other clones. Results of potassium analysis showed that domesticated species had much lower levels than wild species. The same trend was true for magnesium and calcium although differences were smaller.

To illustrate the amount of variation that existed within species, the individual clones tested of *S. officinarum* and *S. spontaneum* are shown in Table 3 for ash, starch, polysaccharides, potassium, colour and turbidity. As noted in the earlier discussion based on averages, there are considerable differences among the two species in all of these parameters. For ash content and polysaccharides, no clone of *S. spontaneum* was as low as those of *S. officinarum*. However, for starch, potassium, colour and turbidity, even though the averages between species were very different, there were individual clones of *S. spontaneum* that were as low or nearly as low as those of *S. officinarum*.

**Table 3**—Detailed analysis conducted by SPRI of various cultivars among *S. officinarum* and *S. spontaneum* for total polysaccharides, starch, ash, colour, turbidity and potassium.

Clone	Ash %	Starch	Total polysaccharides	Potassium	Colour	Turbidity
			ppm on solids			
<i>S. officinarum</i>						
Badilla	3.89	182	1138	1.29	16 084	34 212
Fiji 1	4.73	315	1258	1.64	11 263	47 106
Muntok Java	12.85	464	1733	4.82	19 983	54 239
Green German	4.90	776	1632	1.71	14 044	50 524
Oi Deng	4.68	421	977	1.55	8476	34 509
Average	6.21	432	1348	2.20	13 970	44 118
<i>S. spontaneum</i>						
MPTH97-218	23.72	1491	2859	9.12	24 469	75 031
MPTH97-107	56.08	1530	8345	21.71	106 071	83 055
MPTH97-216	29.69	1643	5330	11.65	34 649	74 963
MPTH97-003	37.92	5345	9312	14.40	42 312	109 112
Tainan	35.13	2001	5245	14.75	55 096	109 489
Guangzi 87-21	16.50	724	2836	6.14	12 235	89 888
US 56-15-8	24.01	980	2790	8.56	31 651	106 280
SES 234B	31.92	3204	6729	10.75	10 003	132 033
SES 147B	19.69	1256	2286	7.66	37 721	95 200
Average	30.52	2019	5081	11.64	39 356	97 228

## Discussion

Based on the data from the first phase of the project for colour, turbidity, glucose and fructose, it is obvious that leaves and tops contributed negatively to the value of the cane. Based on all of the data, it is also obvious the impact that the wild germplasm has on overall quality with lower sugar content and higher levels of non-sugars and contaminants.

Of value from the data from the second phase is the fact that even within species, there was considerable variation among the clones tested. Whether this is a representative number of clones from each species is unknown and in fact, doubtful. However, it does demonstrate that this variation could allow for selection among the clones for use in breeding energy value canes as well as for routine basic breeding for varieties intended for sugar production or other products.

Based on the knowledge that the level of variability demonstrated in this project may exist among parameters discussed in *Saccharum* and related genera, thoughts should then be directed toward the most efficient breeding of sugarcane for whatever is the desired final product. Knowing that many of the parameters discussed here can have an effect by either enhancing or inhibiting the formation of sugar, ethanol, steam, electricity, and other by-products means that breeders should

begin to take into account the detailed characteristics of elite parents used in their breeding programs. No breeder wants to add another list of parameters to his/her selection criteria, but failing to do so could have severe consequences. Very recently, one sugarcane industry experienced this problem after releasing an outstanding variety for agronomic characteristics only to find out later that some characteristic within the plant did not allow for efficient production of very low colour sugar from this variety. A detailed analysis of this variety before release may have been able to diagnose this problem. It may be that detailed analytical testing could have even prevented the cross from ever having been made or perhaps one of the parents which provided the genes for this characteristic from being used.

As industries continue to look at breeding for products other than sugar, this kind of detailed analysis could become even more important. While it is widely known that factors such as ash content have a negative impact on fermentation, industries are still learning the full impact of starch and polysaccharides on fermentation. These parameters may add fermentable solids, but they can also cause issues in the fermentation process especially related to the activity of the yeast. Cellulosic conversion offers another challenge as to what characteristics would serve as inhibitors or enhancers to efficient energy conversion. Some of the parameters studied here could be considered saleable products and/or precursors to saleable products. Efficient breeding could lead to varieties that are more desirable for each of these potential products.

Biotechnology and gene transformation could perform a very important role in altering the components of sugarcane for more efficient production of final products. Equally important is the potential for sugarcane genome sequencing. Also important is the development of markers associated with these juice characteristics. These technologies could allow for the identification of the genetic basis for these compositional characteristics.

When considering the use of varieties, knowledge of these detailed analyses could lead to more sustainable production practices. Growers often fertilise sugarcane to produce the highest yield of sugarcane believing that this will lead to the highest yield of sugar, as it often does. However, variation in cations among the germplasm studied here would suggest that not all cane is alike. Whether there are different absorption rates by species is not understood but further studies could lead to more efficient utilisation of varieties, especially when considering sustainable production practices where one attempts to utilise minimal inputs to arrive at maximum yield. Water utilisation and the significance of clean ground water for the future could be impacted through a better understanding of the role of the parameters discussed in this paper. The impact of some of these parameters on pest management should also receive consideration.

Processing of varieties has always used the 'average' approach where an industry sets its objectives, and varieties are expected to fall into that range or else the variety is not released to that industry. These parameters are generally based on efficient production of sugar, which of course is still the highest value product that most industries can produce. However, as industries examine the production of other products, these 'average' levels of various parameters may need to be reconsidered. As alternative products are planned, different separation technologies may need to be considered in order to efficiently produce these materials.

During this current period of unusually high world prices of sugar, is anybody really interested in producing products other than sugar? Perhaps the level of interest or desire is not as great as when sugar prices were low and industries were struggling to survive. However, a good strategist would argue that now is the time to think about these issues, out of a position of strength and high sugar prices rather than one of weakness and low sugar prices!

Future work with detailed analysis should include more detailed fibre analysis for cellulose, hemicellulose, and lignin content for their contribution to the value of the sugarcane plant. Also a more in-depth chromatographic analysis for cations, anions, oligosaccharides, sugars, and organic

acids should be considered. Additionally, the same issues should be investigated in sugarbeets as well as sugarcane.

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## CONCEVOIR, PRODUIRE ET TRAITER LES VARIETES DE CANNE A SUCRE DU FUTUR

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**MOTS-CLÉS: Variétés De Canne à Sucre, Amélioration Variétale,  
Composition de la Canne, Analyse Chromatographique,  
Produits Alternatifs.**

### Résumé

DE NOMBREUSES industries sucrières, de betterave ou de canne, font la prédiction qu'elles produiraient dans le futur une vaste gamme de produits, incluant le sucre. Pour réaliser cette prédiction, de nouvelles variétés doivent être conçues, passant par une amélioration des pratiques culturales et un développement des techniques de process. La sélection et l'amélioration variétale ont progressé bien au delà des méthodes anciennes de croisement des parents avec l'espoir de sélectionner la meilleure ségrégation qui aboutissant à une nouvelle variété potentielle. Les procédures modernes de création associée à la biotechnologie offre une plus grande efficacité. De façon typique, les variétés sont sélectionnées sur la base d'un haut rendement en sucre et des caractéristiques agronomiques pour la production et la résistance aux ravageurs dans chacune des zones de production. Les habituelles caractéristiques de qualité mesurées du jus - Brix et Pol - ainsi que le tonnage, le comportement en repousse et le taux de fibre, peuvent prédire le rendement en sucre par unité de surface. Il est appréhendé que l'ultime variété du futur implique davantage d'analyses détaillées que les habituelles caractéristiques mesurées. Une fois créées, les variétés à haut rendement en produits variés devront être cultivées de façon durable tout en procurant le maximum de production avec un impact environnemental et économique minimum. Le traitement de ces variétés imposera d'adapter le ou les produits spécifiques en cours d'élaboration que ce soit pour le sucre, l'énergie, d'autres produits ou des combinaisons de ceux-ci. Pour démontrer l'importance des caractéristiques de qualité des futures variétés L'institut de Recherche du Process Sucrier a investigué la présence de composés qui pourraient soit augmenter ou inhiber la production de produits variés issus de la canne à sucre. Des variabilités significatives parmi les espèces de canne à sucre et des genres proches ont été trouvées pour l'amidon, les polysaccharides, les cendres, les cations, les sucres inversés et d'autres paramètres. Cet article présente ces données et l'importance potentielle de ces paramètres dans les futures variétés, leur importance dans un système de production durable et son importance dans les besoins de process technologique.

## DISEÑO, PRODUCCIÓN Y PROCESAMIENTO DE VARIEDADES 'SUPREMAS' DE CAÑA DE AZÚCAR

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**PALABRAS CLAVE: Variedades de Caña de Azúcar, Mejoramiento de Caña de Azúcar, Composición de la Caña de Azúcar, Análisis Cromatográfico, Productos Alternativos.**

### Resumen

MUCHAS industrias azucareras, de remolacha y caña, podrían predecir que en el futuro producirán una amplia variedad de productos, entre ellos azúcar. Para realizar esta predicción, se debe diseñar nuevas variedades de caña, mejorar las prácticas de producción y desarrollar nuevas técnicas de procesamiento. El mejoramiento y la selección de la caña de azúcar han evolucionado mucho desde los 'viejos tiempos' en que se hacían cruces de los mejores progenitores y se esperaba seleccionar los mejores segregantes como potenciales nuevas variedades. Los procedimientos modernos de mejoramiento y la biotecnología ofrecen una mayor eficiencia. Generalmente, las variedades se seleccionan con base en alta productividad de azúcar y algunas características agronómicas importantes para la producción, además de la resistencia a plagas en cada región. Las características del jugo comúnmente medidas de Brix y pol, además del tonelaje, habilidad de soqueo y contenido de azúcar, permiten predecir el rendimiento de azúcar por unidad de área. Se prevé que la variedad 'suprema' del futuro implicará un análisis mucho más detallado de las características que se miden de rutina. Una vez producidas, las variedades de alto rendimiento para varios productos, necesitan ser cultivadas de una forma sostenible que proporcione la máxima producción con un mínimo impacto ambiental y económico. El procesamiento de estas variedades deberá acomodarse a los diferentes productos que se obtendrán ya sean azúcar, energía, otros productos o combinación de estos. Para demostrar la importancia de las características de calidad de las variedades del futuro, el Instituto de Investigación del Procesamiento de Azúcar ha investigado la presencia de componentes que podrían mejorar o inhibir la obtención de varios productos de la caña de azúcar. Se ha encontrado variabilidad significativa tanto ínter, como intraespecífica en caña de azúcar y géneros relacionados, en cuanto a contenidos de almidón, polisacáridos, cenizas, cationes, azúcares invertidos y otros parámetros. Este trabajo incluye estos datos y la importancia potencial de estos parámetros en variedades futuras, su importancia en un sistema de producción sostenible y en las necesidades de procesamiento.