

**Unclassified**

**ENV/JM/MONO(2011)51**

Organisation de Coopération et de Développement Économiques  
Organisation for Economic Co-operation and Development

**25-Oct-2011**

**English - Or. English**

**ENVIRONMENT DIRECTORATE  
JOINT MEETING OF THE CHEMICALS COMMITTEE AND  
THE WORKING PARTY ON CHEMICALS, PESTICIDES AND BIOTECHNOLOGY**

**Cancels & replaces the same document of 21 October 2011**

**CONSENSUS DOCUMENT ON COMPOSITIONAL CONSIDERATIONS FOR NEW VARIETIES OF  
SUGARCANE (*Saccharum ssp. hybrids*): KEY FOOD AND FEED NUTRIENTS, ANTI-NUTRIENTS  
AND TOXICANTS**

**Series on the Safety of Novel Foods and Feeds No. 23**

**JT03309801**

Document complet disponible sur OLIS dans son format d'origine  
Complete document available on OLIS in its original format



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OECD Environment, Health and Safety Publications

Series on the Safety of Novel Foods and Feeds

**No. 23**

**Consensus Document on Compositional Considerations**

**for New Varieties of SUGARCANE**

**(*Saccharum* ssp. hybrids):**

**Key Food and Feed Nutrients, Anti-nutrients and Toxicants**

**Environment Directorate**

**ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT**

**Paris 2011**

*Also published in the Series on the Safety of Novel Foods and Feeds:*

- No. 1, Consensus Document on Key Nutrients and Key Toxicants in Low Erucic Acid Rapeseed (Canola) (2001)
- No. 2, Consensus Document on Compositional Considerations for New Varieties of Soybean: Key Food and Feed Nutrients and Anti-nutrients (2001)
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- No. 19, Consensus Document on Compositional Considerations for New Varieties of Grain Sorghum [*Sorghum bicolor* (L.) Moench]: Key Food and Feed Nutrients and Anti-nutrients (2010)
- No. 20, Consensus Document on Compositional Considerations for New Varieties of Sweet Potato [*Ipomoea batatas* (L.) Lam.]: Key Food and Feed Nutrients, Anti-nutrients, Toxicants and Allergens (2010)
- No. 21, Consensus Document on Compositional Considerations for New Varieties of Papaya (*Carica papaya* L.): Key Food and Feed Nutrients, Anti-Nutrients, Toxicants and Allergens (2010)
- No. 22, Consensus Document on Molecular Characterisation of Plants Derived from Modern Biotechnology (2010)

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## FOREWORD

The OECD's Task Force for the Safety of Novel Foods and Feeds decided at its first session, in 1999, to focus its work on the development of science-based *consensus documents*, which are mutually acceptable among member countries. These consensus documents contain information for use during the regulatory assessment of a particular food/feed product. In the area of food and feed safety, consensus documents are being published on the nutrients, anti-nutrients or toxicants, information of its use as a food/feed and other relevant information.

This consensus document addresses compositional considerations for new varieties of sugarcane (*Saccharum* spp. hybrids) by identifying the key food and feed nutrients, anti-nutrients and toxicants. A general description of these components is provided. As well, there is background material on the production, processing and uses of sugarcane and considerations to be taken into account when assessing new varieties of sugarcane. Constituents to be analysed, related to food use and to feed use, are suggested.

Australia served as the lead country in the preparation for the document, and the draft has been revised on a number of occasions based on the input from other member countries and stakeholders.

The Task Force endorsed this document, which is published under the responsibility of the Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology of the OECD.

**TABLE OF CONTENTS**

FOREWORD.....7

PREAMBLE.....10

THE ROLE OF COMPARATIVE APPROACH AS PART OF A SAFETY ASSESSMENT .....11

SECTION I - BACKGROUND .....12

    A. Introduction.....12

    B. Production.....12

    C. Harvesting and processing .....13

        1. *Harvesting* .....13

        2. *Processing* .....14

    D. Uses.....19

    E. Appropriate comparators for testing new varieties .....20

    F. Breeding characteristics screened by developers .....21

SECTION II - NUTRIENTS .....22

    A. Sugar .....22

    B. Sugarcane juice .....22

    C. Molasses.....22

    D. Bagasse.....23

    E. Whole cane.....23

SECTION III - OTHER CONSTITUENTS .....32

    A. Sugarcane allergens.....32

    B. Anti-nutrients and toxicants .....32

SECTION IV- SUGGESTED CONSTITUENTS TO BE ANALYSED RELATED TO FOOD USE .....34

    A. Key products consumed by humans.....34

    B. Suggested analyses for food use .....34

SECTION V - SUGGESTED CONSTITUENTS TO BE ANALYSED RELATED TO FEED USE .....36

    A. Key products consumed by animals.....36

    B. Suggested analyses for feed use.....37

SECTION VI - REFERENCES.....38



**Tables**

Table 1.	Main sugarcane producing countries .....	13
Table 2.	Composition of sugarcane juice .....	24
Table 3.	Amino acid composition of sugarcane juice .....	25
Table 4.	Composition of final molasses .....	26
Table 5.	Mineral composition of final molasses.....	27
Table 6.	Composition of bagasse.....	28
Table 7.	Mineral composition of bagasse.....	29
Table 8.	Composition of sugarcane tops .....	30
Table 9.	Composition of mature whole sugarcane .....	31
Table 10.	Suggested constituents to be analysed for food use .....	35
Table 11.	Suggested constituents to be analysed for animal feed .....	37

**Figures**

Figure 1.	Sugarcane industrial processing .....	17
Figure 2.	Sugarcane artisanal processing.....	18

## PREAMBLE

Food and feed products of modern biotechnology are being commercialised and marketed in OECD member countries and elsewhere. The need has been identified for detailed technical work aimed at establishing appropriate approaches to the safety assessment of these products.

At a Workshop held in Aussois, France (OECD, 1997), it was recognised that a consistent approach to the establishment of substantial equivalence might be improved through consensus on the appropriate components (*e.g.* key nutrients, key toxicants and anti-nutritional compounds) on a crop-by-crop basis, which should be considered in the comparison. It is recognised that the components may differ from crop to crop. The Task Force therefore decided to develop Consensus Documents on phenotypic characteristics and compositional data. These data are used to identify similarities and differences following a comparative approach as part of a food and feed safety assessment. They should be useful to the development of guidelines, both national and international and to encourage information sharing among OECD member countries.

These documents are a compilation of currently available information that is important in food and feed safety assessment. They provide a technical tool for regulatory officials as a general guide and reference source, and also for industry and other interested parties and will complement those of the Working Group on Harmonisation of Regulatory Oversight in Biotechnology. They are mutually acceptable to, but not legally binding on, OECD member countries. They are not intended to be a comprehensive description of all issues considered to be necessary for a safety assessment, but a base set for an individual product that supports the comparative approach. In assessing an individual product, additional components may be required depending on the specific case in question.

In order to ensure that scientific and technical developments are taken into account, member countries have agreed that these Consensus Documents will be reviewed periodically and updated as necessary. Users of these documents are invited to provide the OECD with new scientific and technical information, and to make proposals for additional areas to be considered. Comments and suggestions can be sent to:

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## THE ROLE OF COMPARATIVE APPROACH AS PART OF A SAFETY ASSESSMENT

In 1990, a joint consultation of the Food and Agriculture Organisation of the United Nations (FAO) and the World Health Organisation (WHO) established that the comparison of a final product with one having an acceptable standard of safety provides an important element of safety assessment (WHO, 1991).

In 1993 the Organisation for Economic Co-operation and Development (OECD) further elaborated this concept and advocated the approach to safety assessment based on substantial equivalence as being the most practical approach to addressing the safety of foods and food components derived through modern biotechnology (as well as other methods of modifying a host genome including tissue culture methods and chemical or radiation induced mutation). In 2000 the Task Force concluded in its report to the G8 that the concept of substantial equivalence will need to be kept under review (OECD, 2000).

The Joint FAO/WHO Expert Consultation on Foods Derived from Biotechnology in 2000 concluded that the safety assessment of genetically modified foods requires an integrated and stepwise, case-by-case approach, which can be aided by a structured series of questions. A comparative approach focusing on the determination of similarities and differences between the genetically modified food and its conventional counterpart aids in the identification of potential safety and nutritional issues and is considered the most appropriate strategy for the safety and nutritional assessment of genetically modified foods. The concept of substantial equivalence was developed as a practical approach to the safety assessment of genetically modified foods. It should be seen as a key step in the safety assessment process although it is not a safety assessment in itself; it does not characterise hazard, rather it is used to structure the safety assessment of a genetically modified food relative to a conventional counterpart. The Consultation concluded that the application of the concept of substantial equivalence contributes to a robust safety assessment framework.

A previous Joint FAO/WHO Expert Consultation on Biotechnology and Food Safety (1996) elaborated on compositional comparison as an important element in the determination of substantial equivalence. A comparison of critical components can be carried out at the level of the food source (*i.e.* species) or the specific food product. Critical components are determined by identifying key nutrients, key toxicants and anti-nutrients for the food source in question. The comparison of key nutrients should be between the modified variety and non-modified comparators with an appropriate history of safe use. Any difference identified would then be assessed against the natural ranges published in the literature for commercial varieties or those measured levels in parental or other edible varieties of the species (FAO, 1996). The comparator used to detect unintended effects should ideally be the near isogenic parental line grown under identical conditions. While the comparative approach is useful as part of the safety assessment of foods derived from plants developed using recombinant DNA technology, the approach could, in general, be applied to foods derived from new plant varieties that have been bred by other techniques.

## SECTION I - BACKGROUND

### A. Introduction

1. Sugarcane is one of the oldest cultivated plants (James, 2004) and has been described as one of the world's most efficient living collectors of solar energy, storing this energy in the form of fibre and fermentable sugars (FAO, 1988).

2. The sugarcane plant is a tall perennial tropical grass belonging to the genus *Saccharum*, and is closely related to other tropical grasses such as sorghum and maize. The plant forms a single unbranched stem that reaches an average height of 3 to 4 metres. The stem diameter ranges from 3 to 5 cm depending on the species and it is the stems (stalks or canes) from which sugar (sucrose) is extracted.

3. There are two confirmed wild species of *Saccharum*, and four domesticated ones (Bakker, 1999). The two wild species are *S. spontaneum* L. and *S. robustum* E. W. Brandes & Jeswiet ex Grassl. *S. spontaneum* can be found throughout the tropical areas of Africa as well as in Asia and Oceania, whereas *S. robustum* is restricted to New Guinea and neighbouring islands.

4. The four domesticated species are *Saccharum officinarum* L. (the noble cane), *S. edule* Hassk., *S. barberi* Jeswiet and *S. sinense* Roxb. Noble canes are thought to be derived from *S. robustum* (Bakker, 1999). Noble canes have high sucrose content and a soft rind and were the original soft, sweet tasting chewing cane. Varieties of noble cane formed the basis of the earliest sugar production industries. Little, if any, noble cane is now grown for commercial sugar production. *S. edule* is restricted to Melanesia and Indonesia and is considered to be a mutant of *S. officinarum*. *S. barberi* has thin stalked hardy canes and is suited to semitropical and temperate climates. This species is believed to have arisen in India as a hybrid of *S. spontaneum* and *S. officinarum* (Bakker, 1999). Sugar was first manufactured from canes of this species. *S. sinense* has tall, vigorous, hardy canes and arose from hybridisation between *S. spontaneum* and *S. officinarum*.

5. Modern cultivated varieties of sugarcane are hybrids derived from breeding between the species of former commercial importance. The result of these breeding programmes is that modern hybrid sugarcane varieties incorporate the vigour and hardiness of *S. spontaneum* and *S. sinense* coupled with the high sugar content of *S. officinarum* and *S. barberi*.

### B. Production

6. Sugarcane, which is grown on approximately 24 million hectares in 102 countries in tropical and subtropical zones of both Northern and Southern hemisphere countries (FAOSTAT, 2009), is the world's leading sugar producing crop, accounting for about 75% of world sugar supply (Dillon *et al.*, 2007). The rest of the world's sugar supply is produced from sugar beet, which is grown in the temperate zones of the Northern hemisphere (OECD, 2002).

7. Brazil is the world's largest sugarcane producer, having produced around 670 million tonnes in 2009 (FAOSTAT). Other major sugarcane producers are India, China, Thailand, Mexico, Pakistan, Colombia, Australia, Argentina, United States and other countries as listed in Table 1. Brazil, India, Thailand and China account for 50% of the world's sugar production and 59% of world sugar exports (USDA, 2009).

8. While a large amount of sugarcane cultivation is directed towards sugar production, a number of countries also direct significant amounts into fuel ethanol production. In Brazil, for example, the recent trend has been to direct greater than 50% of the sugarcane crop into ethanol production (USDA, 2009).

**Table 1. Main sugarcane producing countries**

Country	Production in 2009 (million metric tonnes, MMt)
Brazil	671.4
India	285.0
China	116.2
Thailand	66.8
Mexico	49.5
Pakistan	50.0
Colombia	38.5 <sup>a</sup>
Australia	31.4
Argentina	29.9 <sup>a</sup>
United States	27.5
Philippines	22.9
Indonesia	26.5 <sup>a</sup>
South Africa	20.5 <sup>a</sup>
Guatemala	18.0
Egypt	17.0 <sup>a</sup>
Vietnam	15.2
Cuba	14.9
Peru	10.1
<b>World</b>	<b>1,661.3<sup>b</sup></b>

Source: FAOSTAT (2009)

<sup>a</sup> FAO estimate

<sup>b</sup> May include official, semi-official or estimated data

## C. Harvesting and processing

### 1. Harvesting

9. Sugarcane is harvested when its sucrose content is at its highest, and glucose and fructose content at its lowest. In Brazil, for example, industrial harvesting of sugarcane starts when the sucrose content is between 12.3% and 16% (Lavanholi, 2008). Traditionally the sugarcane is burnt before harvest to remove leaves, weeds and other trash that might interfere with milling; however, it is now relatively common for sugarcane to be harvested green. The leafy tops of the cane stalks are removed and the stalks are cut off at ground level and either transported whole or chopped into small lengths called billets before being delivered to the mill for processing. In some countries, sugarcane tops are a major harvesting by-product and are frequently used for livestock feed during the harvest season.

## 2. Processing

10. The primary objective of sugarcane processing is to extract as much sucrose as possible from the plant stems. Processing, which is essentially a series of separations of non-sugars from sucrose, traditionally takes place in two stages: (i) removal of juice from the cane stalks and extraction of cane or raw sugar; and (ii) refinement of raw sugar to white and brown refined products. In Brazil, most of the sugarcane mills integrate sugar and ethanol production, allowing some by-products of the sugar processing to be used as substrate for ethanol production.

11. Sugarcane juice is obtained by pressing sugarcane stalks; this is a part of both industrial and artisanal processing. The steps involved in industrial sugarcane processing are summarised below and in Figure 1 (for more detailed descriptions see also Clarke, 1988; Chen and Chou, 1993; Godshall, 2003). A number of foodstuffs are also derived from artisanal sugarcane processing, which is described below and in Figure 2. Extraction rates using artisanal processing tend not to be as efficient as industrial systems.

### *Cane sugar production*

12. Harvested sugarcane stems are chopped, shredded and then crushed using roller mills to extract the juice. Alternatively, the juice can be extracted using a diffuser (this is known as diffusion). Imbibition with water enhances the extraction of juice. Sucrose extraction using a diffusion system averages about 97-98%, compared to 90-91% using a traditional milling system (Godshall, 2003); extraction of non-sugars may however be higher with the diffusion system (Clarke, 1988). The fibrous material exiting the last mill or the drying mills after the diffuser and once all the cane juice has been extracted is called *bagasse*. Bagasse contains roughly 50% moisture, small amounts of residual sugar (1-3%) and the remainder being plant fibre (Paturau, 1989). Bagasse is primarily used as a fuel in the cane factory to generate power but when surplus exists it may also be directed to other uses such as paper making and animal feed.

13. The collected juice is strained to remove large particles and then clarified using heat and lime – a process known as clarification. Lime is added to adjust the pH to prevent inversion of sucrose, and the temperature of the juice is raised to over 100°C. A heavy precipitate, called “mud” forms which is separated from the juice in the clarifier, and then either returned to the diffuser or filtered to produce *filtercake*. Filtercake is the main processing waste from raw sugar production and contains about 15-30% fibre, 5-15% crude protein, 5-15% sugar, 5-15% crude wax and fats, and 10-20% ash (Paturau, 1989). Filtercake has minimal feed use and no food use and is mainly used as a soil conditioner/fertiliser. In some production systems, sulphur dioxide (SO<sub>2</sub>) and small quantities of soluble phosphate may also be added. Sulphur dioxide is used to acidify the juice to coagulate the soluble solids and decrease the juice viscosity. These methods are often used in the production of direct consumption sugar.

14. Following clarification, the juice is concentrated using evaporation to produce syrup. The syrup is then further concentrated by boiling under vacuum until it becomes supersaturated, then seeded with crystalline sugar in a vacuum pan to initiate the crystallisation of sucrose from the mother liquor. The mixture of sugar and mother liquor is called *massecuite*.

15. Centrifugation is used to separate the sugar crystals from the *massecuite*. The resultant separated mother liquor is called *molasses* (called the “A molasses” or “first molasses”), which is typically subjected to further rounds of crystallisation to maximize the sugar yield. The molasses from the second round of crystallisation (called the “B molasses” or “second molasses”) is of much lower purity than the first molasses. The final molasses or “C molasses” is typically referred to as blackstrap molasses. Molasses is one of the main by-products of sugarcane processing. Molasses has a variety of food and feed uses, in addition to being a valuable raw material for the fermentation industry, where it is used principally to

produce industrial ethanol, but also alcoholic beverages (rum), acetic acid, butanol, acetone, citric acid and glycerol (Paturau, 1989).

16. In places where the sugar and ethanol production are integrated, it is more common to direct the second or even the first molasses for fermentation to ethanol. Alternatively, some countries, especially in Latin America, use molasses to produce the distilled alcoholic beverage called rum.

17. The raw sugar is washed, dried and placed in large storage bins ready for refining. Raw sugar is typically about 98% pure. While the majority of raw sugar that is produced is destined for refining, in many countries a number of raw sugar products for direct consumption are also produced. These include the white raw sugar products known as plantation or mill white sugar and blanco directo, as well as the speciality brown sugar products known as demerara and turbinado sugar.

18. Typically, the processing of sugarcane yields about 70% water, 15% bagasse, 10% sugar, 3% molasses, and, if produced, 2% filtercake (Fuller, 2004).

#### *Refined sugar production*

19. The aim of the refining process is to remove the colour and reduce the soluble ash concentration to acceptable levels. The process involved in refining raw sugar can vary from country to country but typically follows a series of basic steps. The first step in refining is to remove the surface layer of molasses from the sugar crystals (affination). This is achieved by washing the raw sugar with warm saturated syrup which softens the adhering molasses layer and then using centrifugation to separate the sugar crystals from the syrup (typically called the 'affination syrup'). The affination syrup can be recycled, either by using it in a raw sugar washing step, or by melting to recover additional sugar, leaving a final syrup known as refinery blackstrap molasses. Affination typically removes about 65-70% of the colour, ash and non-sucrose sugars present in the original raw sugar. The washed sugar crystals are dissolved in water to yield syrup often referred to as melt liquor. The melt liquor must then be decolourised before the refined sugar can be crystallised from the liquor.

20. Decolourisation is conducted in two stages: the primary stage involves a carbonation, sulphitation or phosphatation process. Carbonation consists of adding lime to the melt liquor and then bubbling carbon dioxide through the liquor to produce a calcium carbonate precipitate. Sulphitation consists of adding lime to the melt liquor and then bubbling sulphur dioxide through the liquor to produce a calcium sulphate precipitate. Phosphatation uses phosphoric acid, lime and a polyacrylamide flocculent to produce a calcium phosphate precipitate. The secondary stage involves the use of carbonaceous adsorbents (*e.g.* granular activated carbon) or ion exchange resins as decolourising agents. Crystallisation is the final step in the refining process, and typically follows the same sequence as used for the crystallisation of cane sugar, involving a series of crystallisation steps under vacuum.

21. The recovered sugar is dried and graded prior to packing, while the syrup is recycled for further recovery. The final syrup is used as the starting material for specialty products such as brown sugar and inverted syrups.

#### *Ethanol production*

22. The juice used in ethanol production undergoes similar treatment as juice used in sugar production (Figure 1). Fermentation is the most important phase in ethanol production. It starts with the preparation of the must, which is a sugar solution, whose concentration is adjusted so fermentation becomes more efficient. The must is prepared from molasses, juice and water, so that the mixture reaches a

final concentration in the range of 16° to 23° Brix (% soluble solids). The must is then mixed with the yeast suspension and after 4 to 12 hours fermented wine is produced and sugars (sucrose, glucose and fructose) are converted into ethanol. The wine has an ethanol content of 4% to 7% and is centrifuged to recover the yeasts, which can be used again or incorporated into animal feed, after drying and deactivating. After the yeasts are separated, the wine undergoes a distillation process, producing a distillate, which is commonly designated as “phlegm” (at 40 to 50°GL)<sup>1</sup>, and a residue designated as “vinasse”, which goes to the fields and is used as fertiliser or as animal feed. The rectification phase is a dehydration process, involving fractional distillation in columns using multiple trays, which concentrates the ethanol in the phlegm from distillation so to obtain hydrated ethanol (96°GL) at the end and remove impurities, such as higher homologous alcohols, aldehydes, esters, amines, acids and bases. For the production of 99.7°GL anhydrous alcohol, cyclohexane is used as a dehydrating agent in an additional dehydration phase.

### *Artisanal processing*

23. Although most of the sugarcane production is devoted to sugar and ethanol production, there are some foodstuffs derived from artisanal sugarcane processing (Figure 2) which can be important regionally. The most widespread of these is sugarcane candy commonly known as panela or rapadura.<sup>2</sup> India and Colombia are the major producers of panela (rapadura), accounting for 66% of world production, estimated at 13 million tons (FAO, 2007). Muscovado sugar, which is produced in a similar fashion to rapadura, differs from brown sugar because this last product is obtained by adding molasses to refined white sugar while the production of muscovado sugar does not include refining steps. Sugarcane syrup is produced through the concentration of the sugarcane juice, and is also called “*liquid rapadura*”, due to its similarity with this product.

24. The production of artisanal sugarcane derivatives is more simplified compared to sugar and ethanol production as it entails very few refining steps (César *et al.*, 2003).

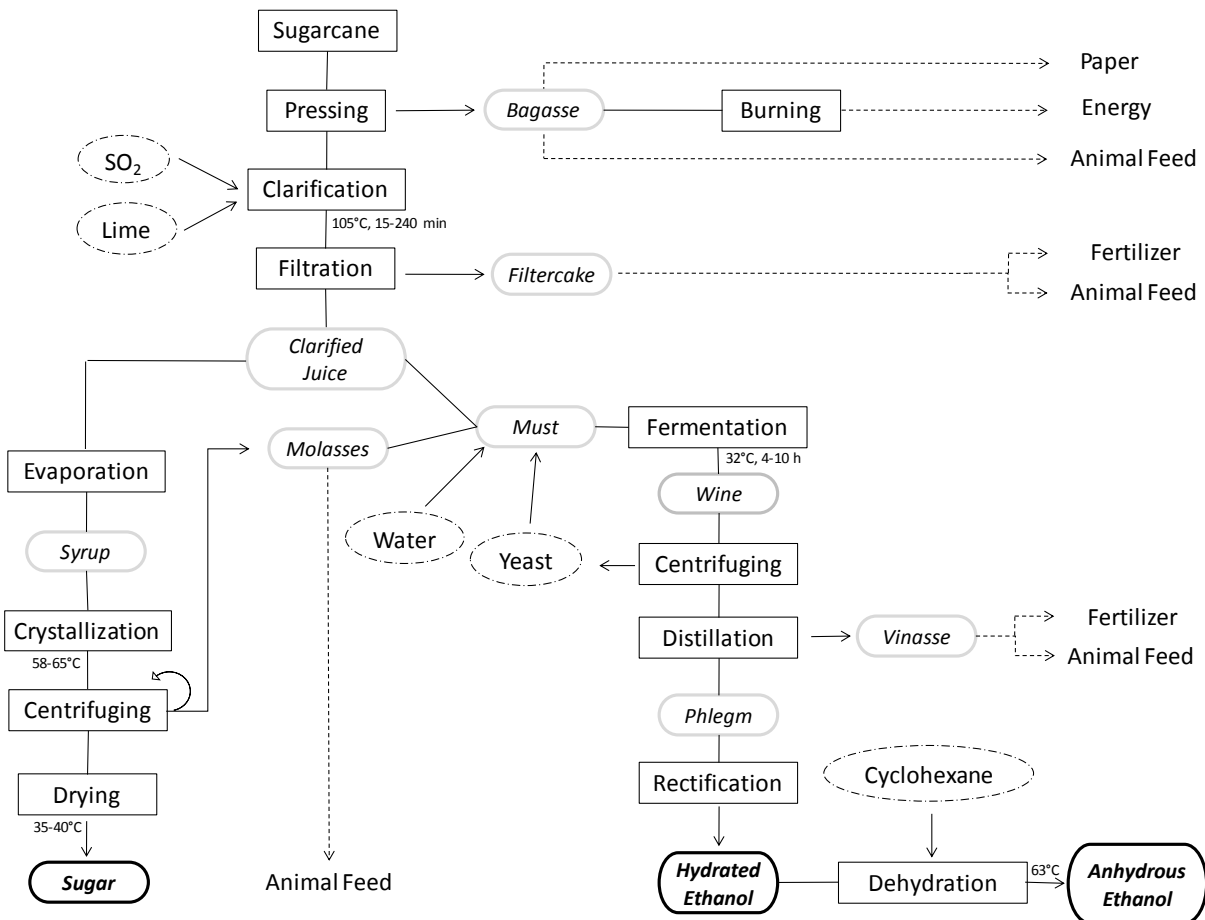
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<sup>1</sup> Alcohol by volume, referred to as degrees Gay-Lussac, or °GL.

<sup>2</sup> Also called papelón, raspadura, chancaca, atado dulce, piloncillo, empanizado, panocha, gur and jaggery, depending on the production country.

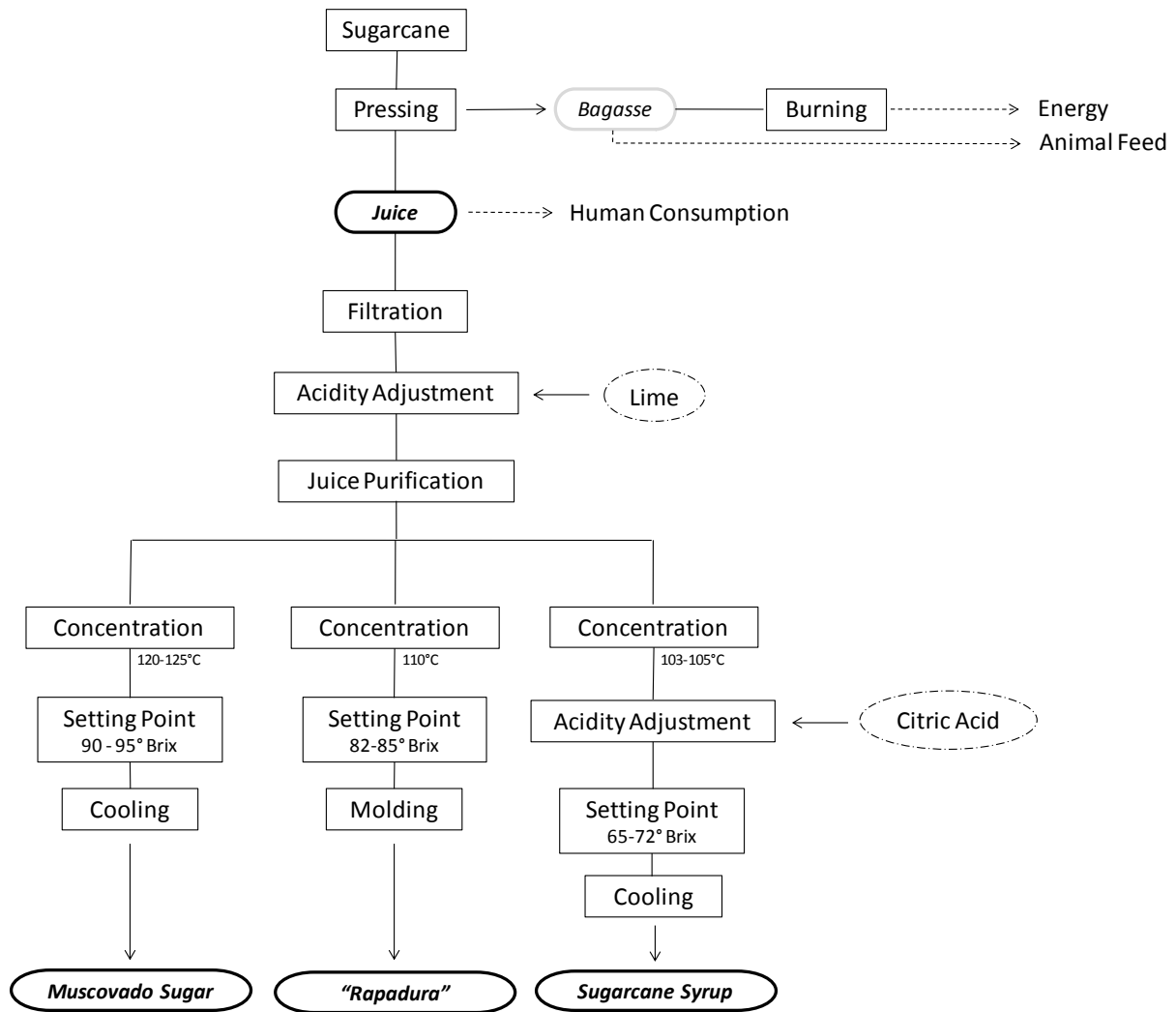


**Figure 1. Sugarcane industrial processing**



Source: Cheavegatti-Gianotto *et al.* (2011)

Figure 2. Sugarcane artisanal processing



Source: Cheavegatti-Gianotto *et al.* (2011)

## D. Uses

25. The main products obtained from sugarcane processing are sugar (sucrose) and ethanol. Ethanol is used mainly as a biofuel.
26. Sugar, as the main food product obtained from sugarcane, is primarily used as a sweetener. Sugar is also used as a preservative, for example for jams and fruits.
27. Beyond industrial sugar, sugarcane is also used to produce artisanal products such as sugarcane juice, muscovado sugar, sugarcane syrup, rapadura and other similar sugarcane candies. Sugarcane juice may also be fermented and then distilled to produce a type of rum called cachaça, which is Brazil's most popular distilled alcoholic beverage.
28. In some regions, sugarcane is grown specifically for fresh juice production. These varieties are distinct from the hybrid varieties grown for commercial sugar production. In Malaysia, for example, particular varieties of noble canes (*S. officinarum*), which have a softer and less fibrous stem, are grown specifically for fresh juice production (Yusof *et al.*, 2000).
29. While most sugarcane production is intended for sugar and ethanol production, the crop is also cultivated in many countries to be fed to all classes of livestock (FAO, 1988). It is commonly used as feed when availability of conventional forage sources is scarce, for example, during drought conditions, or during winter when the productivity of other forages is low.
30. Since sugarcane is available during the dry season, when it is needed most, it is commonly offered *in natura* to livestock during this period, but it is also possible to ensile it.
31. Sugarcane juice is also used as feed and is an excellent readily-available carbohydrate source for all classes of livestock, but is mainly used for monogastrics, particularly pigs.
32. The sugarcane crop also produces a number of by-products (sugarcane tops, bagasse, filtercake, molasses and vinasse) after harvest and processing, which are increasingly being recognised as valuable feedstuffs. Feed products obtained from sugarcane are high in fibre and/or energy and therefore are primarily used in ruminant feeding, especially cattle. To meet nutritive requirements, feed rations containing sugarcane or its by-products are usually combined with other feed products.
33. Sugarcane tops, the major sugarcane by-product, are usually left in the field after harvest but are used for feed purposes in some countries. They are typically offered *in natura* and are highly palatable with good voluntary consumption indices.
34. Bagasse is primarily used as combustible fuel for power generation at the processing factory. When not used as fuel, bagasse is mainly used for the manufacture of pulp and paper products, building materials (utilising the cellulose component), and furfural and its derivatives (utilising the hemicellulose component) (Cheesman, 2005).
35. Bagasse has also been recognised as a potential feedstuff for large ruminants where it has been used as a roughage ingredient in beef and dairy rations (Pate, 1979). Its use however is typically restricted to 15 to 30% of dry matter due to its low digestibility and palatability, high lignin, and very low nitrogen content. Digestibility can be improved through the use of various chemical or thermo-mechanical treatments, but hydrolysis by steam treatment is most commonly used. Bagasse palatability can also be improved through the addition of molasses.

36. Until recently, bagasse did not have any food uses, however, new technology has enabled bagasse to be used as a source of dietary fibre in processed and baked foods (KFSU, 2009).

37. Molasses is primarily used to produce either alcohol (potable alcohol or industrial/fuel ethanol) or for animal feeding. In preparing silage for animal feed, the quality can be improved with silage additives such as fibre-degrading enzymes used alone, or in combination with a bacterial inoculant. For low sugar crops, such as grasses and legumes, the concentration of fermentable sugars can be raised with molasses, whey, or cereal grains to facilitate growth of lactic acid-producing bacteria. There are some minor food uses for molasses. Molasses is used as a sweetener and as syrup accompanying other foods, and also as the starting product for the preparation of other edible syrups such as treacle. Molasses is also fermented and then distilled to produce rum. Since the mid 1960s, bacterial fermentation of molasses is used in countries such as Brazil to produce monosodium glutamate, a flavour enhancer commonly referred to as MSG.

38. Filtercake is mainly used as fertiliser. As this by-product has moderate levels of protein, varying from 5.3 to 16%, its use for animal feed has been tried in many countries. However, filtercake also contains relatively high levels of wax (15%), which hampers its digestibility, limiting its use in animal feed to a minimum.

39. Vinasse, the residue produced from the ethanol distillation process, is almost completely used as fertiliser. It has only minimal use in animal feed because of its liquid and corrosive characteristics.

#### **E. Appropriate comparators for testing new varieties**

40. This document suggests parameters that sugarcane breeders should measure when developing new modified varieties. The data obtained in the analysis of a new sugarcane variety should ideally be compared to those obtained from the original non-modified variety from which the new sugarcane variety was obtained<sup>3</sup>, grown and harvested under the same conditions.<sup>4</sup> The comparison can also be made between values obtained from new varieties and data available in the literature, or chemical analytical data generated from other commercial sugarcane varieties.

41. Components to be analysed include key nutrients and toxicants. Key nutrients are those which have a substantial impact in the overall diet of humans (food) and livestock (feed). These may be major constituents (fats, proteins, and structural and non-structural carbohydrates) or quantitatively more minor compounds (vitamins and minerals). Key toxicants are those toxicologically significant compounds known to be inherently present in the species, whose toxic potency and levels may have an impact on human and animal health. Standardized analytical methods and appropriate types of material should be used, adequately adapted to the use of each product and by-product. The key components analysed are used as indicators of whether unintended effects of the genetic modification influencing plant metabolism have occurred or not.

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<sup>3</sup> Typically this would be a *near isogenic* line however this term is not appropriate in the case of sugarcane breeding, because no backcrossing is done.

<sup>4</sup> For additional discussion of appropriate comparators, see the Guideline for the Conduct of Food Safety Assessment of Foods Derived from Recombinant DNA Plants CAC/GL 45/2003 of the Codex Alimentarius Commission (paragraphs 44 and 45).

## F. Breeding characteristics screened by developers

42. The characteristics most commonly sought by sugarcane breeders are those that have the greatest economic importance and include productivity, disease resistance, as well as various quality parameters (Cox *et al.*, 2000; Berding *et al.*, 2004).

43. Productivity is measured as sucrose yield per hectare and is influenced by cane yield and sugar content. Sugar content is the most economically important of all the characteristics screened and is therefore an important objective of sugarcane breeding programmes; although the evidence indicates that most productivity gains to date have been delivered via improvements in cane yield (Berding *et al.*, 2004; Jackson, 2005).

44. Disease resistance has historically been a major focus of sugarcane breeding programmes, with limited genetic variation for resistance or tolerance being available for most diseases of sugarcane (Berding *et al.*, 2004). Most sources of resistance come from wild canes, specifically *S. spontaneum* (Walker, 1987). Major diseases of international distribution and importance include ratoon stunting disease (bacterial), leaf scald (bacterial), smut (fungal), red rot (fungal), rust (fungal)<sup>5</sup>, and mosaic (viral)<sup>6</sup> (Rott and Girad, 2000).

45. Important sugarcane quality parameters include those used to determine millability and juice quality. For milling, the major influencing characteristic is cane fibre, where both fibre quantity and quality are of interest (Berding *et al.*, 2004). Fibre quantity is routinely measured in selection trials, where varieties with excessively high or low fibre content are discarded (Cox *et al.*, 2000). In addition, tests on milling performance are conducted on all varieties being propagated for potential release. These tests measure characteristics such as fibre length and shear strength.

46. The characteristics routinely measured to determine juice quality are Brix (% soluble solids) and Pol (apparent sucrose in juice) (Mackintosh, 2000). These measures, corrected for fibre content, allow determination of the levels of impurities in the juice (*i.e.* Brix minus Pol equals the total impurities in the juice), and also enables an estimation of the percentage of recoverable sucrose from the juice (referred to as commercial cane sugar (CCS), or estimated recoverable crystal (ERC)).

47. CCS is calculated from measurements of brix, pol, and fibre (BSES, 1984). While not a direct measurement of sucrose content, CCS tends to be highly correlated with and similar to sucrose % on a fresh weight basis (Muchow *et al.*, 1996). In Australia, the average CCS is about 13% but values occasionally reach 17 or 18% (Jackson, 2005). Some countries use chemical “ripeners” (*e.g.* glyphosate) which can increase sucrose content by 0.5 to 2.0% in early harvested crops (Solomon and Li, 2004). Despite concerted efforts through conventional and molecular breeding, the stored sucrose content of elite sugarcane cultivars has remained static for several decades (Jackson, 2005).

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<sup>5</sup> Common rust and orange rust

<sup>6</sup> Sugarcane mosaic virus (SCMV) and sorghum mosaic virus (SrMV)

## SECTION II - NUTRIENTS

### A. Sugar

48. The Codex Standard for Sugars (Codex Alimentarius Commission, 2001) describes refined white sugar, intended for human consumption, as purified and crystallised sucrose (saccharose) with a polarisation not less than 99.7 °Z<sup>7</sup>. Generally speaking, refined white sugar contains about 99.93% sucrose, with minor amounts of water, invert or reducing sugars (glucose and fructose), ash, colour components plus other organic non-sugar compounds (Clarke, 1988). Although these minor components typically make up less than 0.1% of sugar content, they may affect the quality of the sugar and its behaviour during storage (van der Poel *et al.*, 1998).

49. The sucrose content of raw sugar varies, but is mainly in the range of 97 to 99.5% sucrose.

### B. Sugarcane juice

50. Sugarcane juice is an opaque, viscous liquid of brownish to deep green colour, whose composition varies within limits according to the variety, age and health of the sugarcane, environment, agricultural planning (maturation, harvest period, handling, transportation and storage), pests and diseases.

51. The chemical composition of sugarcane juice is given in Table 2. The extracted juice has high water content (about 85%) and contains mainly sucrose and reducing sugars like glucose and fructose. The sugar content is heavily influenced by the maturity of the cane at harvest, with sucrose content increasing with maturity and glucose and fructose content generally decreasing (Qudsieh *et al.*, 2001). The protein content is negligible. In terms of the total amino acid content, the most abundant are aspartic acid, glutamic acid and alanine (van der Poel *et al.*, 1998). The amino acid content of sugarcane juice is given in Table 3.

### C. Molasses

52. The composition of molasses tends to be highly variable. It is primarily influenced by the processing technology used rather than differences in plant composition.

53. All grades of molasses contain significant amounts of sugars. The chemical composition of final molasses is given in Table 4. In addition to high levels of sugars, molasses is also characterised by having no fat or fibre, and very little protein.

54. Molasses products are low in phosphorus but are reasonably good sources of other minerals such as calcium and potassium (Table 5), although the levels can be quite variable.

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<sup>7</sup> °Z (sugar degrees) is the unit of the International Sugar Scale.

55. The vitamin content of sugarcane is not considered to be of any nutritional significance due to the wide variation and low content of most of the important vitamins (Curtin, 1973).

#### **D. Bagasse**

56. Sugarcane bagasse typically contains approximately 40-50% moisture, and 1-3% sugar, with the remainder as fibre (Payne, 1991). The fibre fraction includes cellulose, hemicellulose and lignin.

57. The quantity and composition of bagasse varies with variety and maturity of the cane, harvesting practices (green or burnt cane, degree of removal of cane leaves and tops), and the milling process, particularly the amount and temperature of water used for imbibition (van der Poel *et al.*, 1998). The composition of bagasse is given in Tables 6 and 7.

#### **E. Whole cane**

58. Sugarcane is considered a semi-perennial since it has to be replanted, on average, every four years. This means that a plant is in the field all year round and, therefore, subject to seasonal variation in its nutrient composition.

59. The most important constituent in sugarcane is sucrose, which is typically measured in the plant stalk. Sucrose content can be quite variable, typically ranging from 9 to 20% (fresh weight basis) (Berding, 1997). On a dry weight basis, sucrose content in the stalk can reach as high as 60%. Reported ranges for dry matter sucrose content of varieties grown in Australia include 39.2–59.7% (Berding, 1997) and 30–55% (Inman-Bamber *et al.*, 2009).

60. Sugarcane is typically harvested when the maturation index (MI), which is the ratio between the brix of the stalks tip and base, ranges between 0.85 and 1.0. Maturation indexes over 1.0 indicate that the sugarcane is losing its energetic potential due to the sucrose inversion process (dos Anjos *et al.*, 2008).

61. In certain countries, such as Australia, the main feed product derived from sugarcane production is sugarcane tops (SCT), which are left in the field after harvest. In other countries, such as Brazil, it is the whole plant (tops and stalks) that is used as a feed product. In terms of their use as feed, there is no agreed stage of maturity or age when whole cane or tops are harvested, which again can lead to wide variation in reported composition.

62. In the case of SCT, composition will also depend on the point at which the top is cut from the cane (Fuller, 2004). Typically, SCT consist of three distinct parts – the leaves, the bundle leaf sheath and variable amounts of immature cane (Naseeven, 1988). As sugarcane tops include the green leaves and the upper young portion of the stalk, they contain a reasonable amount of protein compared to other types of sugarcane forages, *e.g.* chopped whole sugarcane (Dixon, 1977) (Table 8).

63. Likewise, a moderate level of crude protein exists in whole sugarcane but only if harvested at a very young age (Pate *et al.*, 1984). This, however, is counteracted by the lower digestibility of young sugarcane compared to mature sugarcane which has a lower fibre and increased sucrose content (Pate, 1979). The composition of mature whole sugarcane is given in Table 9.

**Table 2. Composition of sugarcane juice**

Constituent	Crude, On-farm <sup>a</sup>		Factory <sup>b</sup>	Range
	Perez, 1997	AFRIS <sup>c,d</sup>	Perez, 1997	
Moisture (%)	76–84	76.2	81–85	76–85
Total Sugars (%DM)	84–90	NR	77–85	77–90
Ash (%DM)	2.5–2.8	0.93	3.3–4.8	0.9–4.8
Crude Protein (%DM)	NR	0.19	NR	-
Calcium (%DM)	NR	0.06	NR	-
Phosphorus (%DM)	NR	0.06	NR	-

NR = Not reported

<sup>a</sup> Juice is typically extracted using a simple motorised, draught powered or human operated roller mill<sup>b</sup> Water is typically added<sup>c</sup> Animal Feed Resources Information System, FAO, accessed May 2009<sup>d</sup> Reported as single values



**Table 3. Amino acid composition of sugarcane juice**

<b>Amino Acid</b>	<b>g/100 g dry matter</b>
Aspartic Acid	0.08–0.13
Glutamic Acid	0.03–0.06
Alanine	0.04–0.08
Valine	0.02–0.04
Threonine	0.01–0.05
Isoleucine	0.01–0.02
Glycine	0.01–0.02
Leucine	Trace
Lysine	Trace
Serine	Trace
Arginine	Trace
Phenylalanine	Trace
Tyrosine	Trace
Histidine	Trace
Proline	Trace
Methionine	Trace
Tryptophan	Trace

*Source:* Roberts and Martin (1959)

Table 4. Composition of final molasses

Constituent	AFRIS <sup>a,b</sup>	Curtin, 1973 <sup>b</sup>	Wythes <i>et al.</i> , 1978 <sup>c</sup>	NRC, 1982 <sup>b</sup>	Chang-Yen <i>et al.</i> , 1983 <sup>c</sup>	Figuroa and Ly, 1990 <sup>b</sup>	Bortolussi & O'Neill, 2006 <sup>d</sup>	Johnson and Miller, 2007 <sup>b</sup>	Range
Moisture (%)	26	25	23.6	25	27.76	16.5	23.4 ± 0.09, 23.5 ± 0.1	31.1	16.5–31.1
Crude Protein (%DM)	4.2	3.0	NR	5.8	NR	NR	NR	4.86	3.0–5.8
Ash (%DM)	8.6	8.1	13.6	13.1	11.28	9.8	17.5 ± 0.1, 17.6 ± 0.11	18.4	8.1–18.4
Sucrose (%DM)	NR	NR	45.8	NR	NR	40.2	45.2 ± 0.12, 45.4 ± 0.13	34.8	34.8–45.8
Total Sugars (%DM)	NR	48	65.3	NR	NR	58.3	63.8 ± 0.13, 63.7 ± 0.14	NR	48–65.3

NR = Not reported

<sup>a</sup> Animal Feed Resources Information System, FAO, accessed May 2009<sup>b</sup> Reported as single values<sup>c</sup> Values are means<sup>d</sup> The values are means ± standard error for two sugarcane growing regions in Australia

Table 5. Mineral composition of final molasses

Mineral	Curtin, 1973 <sup>a</sup>	Wythes <i>et al.</i> , 1978 <sup>b</sup>	NRC, 1982 <sup>a</sup>	Johnson and Miller, 2007 <sup>a</sup>	Range
Calcium (%DM)	0.8	1.15	1.00	0.97	0.8–1.15
Phosphorous (%DM)	0.08	0.07	0.11	0.74	0.07–0.74
Magnesium (%DM)	0.35	0.61	0.43	NR	0.35–0.61
Potassium (%DM)	2.4	5.19	3.84	3.03	2.4–5.19
Sodium (%DM)	0.2	0.1	0.22	NR	0.1–0.22
Chloride (%DM)	NR	2.98	3.10	NR	2.98–3.10
Sulphur (%DM)	0.8	0.73	0.47	NR	0.47–0.8
Copper (mg/kg DM)	NR	10.7	79.0	NR	10.7–79.0
Iron (mg/kg DM)	NR	247	250.0	NR	247–250.0
Manganese (mg/kg DM)	NR	82	56.0	NR	56.0–82
Zinc (mg/kg DM)	NR	11.6	30.0	NR	11.6–30.0
Cobalt (mg/kg DM)	NR	2.7	1.21	NR	1.21–2.7

NR = Not reported

<sup>a</sup> Reported as single values<sup>b</sup> Values are means

Table 6. Composition of bagasse

Constituent	Clarke, 1978	Pate, 1979 <sup>a</sup>	Kaushal <i>et al.</i> , 1980 <sup>b</sup>	de Carvalho, 2006 <sup>c</sup>	dos Anjos <i>et al.</i> , 2008	Rabelo <i>et al.</i> , 2010 <sup>c</sup>	Range
Moisture (%)	NR	49.0	NR	59.89	48.8 <sup>c</sup>	50, 60-65	48.8–65
Crude Protein (%DM)	NR	2.4	2.00, 1.54	2.32	0.8–2.32	NR	0.8–2.4
Crude Fibre (%DM)	NR	43.0	NR	NR	58.5 <sup>c</sup>	NR	43.0–58.5
Cellulose (%DM)	45.3–58.4	41.6	44.1, 43.3	NR	NR	35.8	35.8–58.4
Lignin (%DM)	14.3–22.3	12.6	12.2, 14.2	NR	NR	9.91, 20.2	9.9–22.3
Hemicellulose (%DM)	22.3–31.8	NR	41.8, 42.4	NR	NR	16.4	16.4–42.4
Acid Detergent Fibre (%DM)	NR	54.9	55.9, 59.8	38.34	54.4–64.89	NR	38.3–64.9
Neutral Detergent Fibre (%DM)	NR	83.4	85.9, 85.7	59.02	88.3–93.72	NR	59.0–93.7
Ether Extract (%DM)	NR	0.86	0.72, 0.86	0.07	0.6–1.68	NR	0.07–1.7
Ash (%DM)	1.0–3.9	1.70	3.05, 2.10	1.22	NR	1.6, 2.2	1.0 -3.9

NR = Not reported

<sup>a</sup> Values are means of two samples<sup>b</sup> Reported as single values from two different sugar mills in India<sup>c</sup> Reported as single values

**Table 7. Mineral composition of bagasse**

<b>Mineral</b>	<b>Pate, 1979<sup>a</sup></b>	<b>Kaushal <i>et al.</i>, 1980<sup>b</sup></b>	<b><i>Range of values</i></b>
Calcium (%DM)	0.15	0.274, 0.161	<i>0.15–0.274</i>
Phosphorous (%DM)	0.09	0.0032, 0.0018	<i>0.0018–0.09</i>
Sulphur (mg/kg DM)	NR	1375, 925	<i>925–1375</i>
Sodium (mg/kg DM)	NR	29, 56	<i>29–56</i>
Potassium (mg/kg DM)	NR	108, 78	<i>78–108</i>
Magnesium (mg/kg DM)	NR	535, 375	<i>375–535</i>
Zinc (mg/kg DM)	NR	31, 22	<i>22–31</i>
Iron (mg/kg DM)	NR	345, 220	<i>220–345</i>
Copper (mg/kg DM)	NR	52, 8	<i>8–52</i>
Manganese (mg/kg DM)	NR	30, 18	<i>18–30</i>

NR = Not reported

<sup>a</sup> Values are means of two samples<sup>b</sup> Reported as single values

Table 8. Composition of sugarcane tops

Constituent	Dixon, 1977 <sup>a</sup>	Preston, 1977 <sup>b</sup>	Mahatab <i>et al.</i> , 1981 <sup>b</sup>	Naseeven, 1988 <sup>c</sup>	Rangnekar, 1988 <sup>d</sup>	Range
Moisture (%)	68.7	73.1	NR	71.0 ± 2.3	NR	68.7–73.1
Crude Protein (%DM)	4.0	NR	5.60	5.9 ± 0.7	6.2	4.0–6.2
Crude Fibre (%DM)	36.3	NR	33.31	33.5 ± 2.1	30.9	30.9–36.3
Ether Extract (%DM)	1.5	0.84	1.70	1.7 ± 0.3	1.5	0.8–1.7
Ash (%DM)	9.2	7.87	5.93	8.5 ± 2.1	8.5	5.9–9.2
Nitrogen Free Extract (%DM)	49.0	NR	53.46	50.3 ± 3.9	52.9	49.0–53.5

NR = Not reported

<sup>a</sup> Values obtained from pooled samples<sup>b</sup> Reported as single values<sup>c</sup> The values are means ± standard deviation<sup>d</sup> Values are means

**Table 9. Composition of mature whole sugarcane**

Constituent	Banda and Valdez, 1976 <sup>a</sup>	Kung Jr. and Stanley, 1982 <sup>b</sup>	Pate <i>et al.</i> , 1984 <sup>c</sup>	Rangnekar, 1988 <sup>c</sup>	Oliveira <i>et al.</i> , 2007	Pereira <i>et al.</i> , 2000 <sup>d</sup>	Fernandes <i>et al.</i> , 2001	Azêvedo <i>et al.</i> , 2003	de Souza França, 2005	Santos <i>et al.</i> , 2006	dos Anjos <i>et al.</i> , 2008	Range
Moisture (%)	77.8 ± 1.76	68.50	74.2	70.0	72.46–74.06	72.20	70.5–80.9	69.3–76.9	73.10–77.55	68.53–70.71	67.46–75.37	67.5–80.9
Crude Protein (%DM)	2.89 ± 0.35	1.79	2.3	2.3	2.17–2.62	2.50	2.2–3.2	NR	1.89 – 3.34	3.51–4.08	NR	1.8–4.1
Crude Fibre (%DM)	25.0 ± 1.66	27.7	22.7–35.9	30.1	NR	NR	NR	NR	NR	NR	NR	22.7 – 35.9
Ether Extract (%DM)	0.81 ± 0.22	1.13	NR	1.3	NR	NR	NR	NR	NR	NR	NR	0.8–1.3
Neutral Detergent Fibre (%DM)	NR	NR	52.7	NR	40.86–42.31	57.83	44.8–51.2	43.8–52.6	46.90–54.33	48.60–56.88	39.4–77.6	39.4–77.6
Acid Detergent Fibre (%DM)	33.4 ± 1.48	34.2	35.4	NR	25.51–27.17	NR	NR	24.3–31.6	NR	26.24–36.88	24.95–54.37	24.3–54.4
Ash (%DM)	NR	3.94	4.3	6.2	1.29–1.43	NR	1.2–1.8	NR	NR	NR	NR	1.2–6.2

NR = Not reported

<sup>a</sup> Values are means ± standard error<sup>b</sup> Values obtained from pooled samples<sup>c</sup> Values are means<sup>d</sup> Reported as single values

### SECTION III - OTHER CONSTITUENTS

#### A. Sugarcane allergens

64. There are no reports in the literature of food-related allergic reactions to sugarcane. There is also no known or putative food, respiratory or contact allergens listed for sugarcane in the Food Allergy Research and Resource Program (FARRP) Protein AllergenOnline Database (Version 10).<sup>8</sup>

65. A small number of literature reports exist of sugarcane pollen acting as an airborne allergen (e.g. Agata *et al.*, 1994; Chakraborty *et al.*, 2001). In countries such as Australia, however, it is reported that commercial sugarcane cultivars rarely flower or produce seed in the field, therefore exposure to sugarcane has not been associated with any reports of allergic responses (OGTR, 2008).

#### B. Anti-nutrients and toxicants

66. There are virtually no reports in the literature relating to the presence of anti-nutrients in sugarcane.

67. In terms of anti-nutritional properties, sugarcane generally has low digestibility due to its high fibre content (dos Anjos *et al.*, 2008). This is the case for both monogastrics and ruminants. Bagasse in particular has very poor digestibility and may also have a depressing effect on feed intake. Lignin is the key element that limits the digestibility of fibre. In ruminants, lignin is thought to interfere with microbial degradation of fibre polysaccharides by acting as a physical barrier (Buxton and Redfearn, 1997).

68. According to one unconfirmed report, sugarcane contains the cyanogenic glycoside, dhurrin ( $\beta$ -D-glucopyranosyloxy-(S)-p-hydroxymandelonitrile), which is the same cyanogenic glycoside found in *Sorghum* spp. (De Rosa *et al.*, 2007). The concentration of cyanogenic glycosides in plants varies with the variety, stage of growth, season, time of day and certain environmental as well as agronomic factors (e.g. application of fertiliser). Generally, however, young plants, new shoots and regrowth often contain the highest concentrations of cyanogenic glycosides (Knight and Walter, 2001). Extensive processing of sugarcane will naturally reduce levels of any dhurrin and therefore of exposure to hydrogen cyanide through consumption of sugarcane by animals or humans.

69. Cyanogenic glycosides themselves are relatively non-toxic (EFSA, 2004 and 2007). However, when plant tissues are damaged or stressed, this can result in the hydrolysis of the cyanogenic glycosides by the bacterial enzyme  $\beta$ -glucosidase, leading to the release of free hydrogen cyanide (HCN), which is potentially toxic to both animals, especially ruminants, and humans. Enzymatic conversion of cyanogenic glycosides is enhanced when the plant is chewed, crushed, frozen, wilted or subjected to drought (Knight and Walter, 2001).

70. Few data are available on the dhurrin content of sugarcane. Foliar extracts from young sugarcane seedlings have been reported to contain dhurrin at the level of 4.3 mg/g fresh weight (range 3.4 to 5.6 mg/g

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<sup>8</sup> [www.allergenonline.org](http://www.allergenonline.org)



fresh weight) after wounding (De Rosa *et al.*, 2007). Theoretically, this amount of dhurrin may yield a level of HCN which is potentially harmful to livestock. However, it is not known how representative this reported level is of sugarcane varieties in general, nor are data available on the HCN potential of mature leaves, which are more likely to be fed in whole or in part to livestock. Only a single inconclusive report could be found of cyanide poisoning of livestock (cattle) attributed to feeding of sugarcane under extreme conditions of prolonged drought (Seifert and Beller, 1969). Due to a lack of detail in this report, the information cannot be confirmed. Moreover, the absence of other substantiated reports in the literature suggests that, in practice, the feeding of sugarcane to livestock does not represent a risk in terms of cyanide toxicity. The presence of dhurrin in sugarcane is also most unlikely to represent a risk to humans because extensive processing will reduce or remove both dhurrin and hydrogen cyanide prior to consumption.

## SECTION IV- SUGGESTED CONSTITUENTS TO BE ANALYSED RELATED TO FOOD USE

### A. Key products consumed by humans

71. The main food product derived from sugarcane is sugar, which is almost pure sucrose with low traces of reducing sugar. Other food products are molasses, sugarcane juice and various candies.

72. Although unprocessed sugarcane as a whole is not very often used for human consumption, in some producer countries it is common for sugarcane to be consumed *in natura*, where the harvested stalk is sucked to extract the juice; however, there is almost no intake of its indigestible fibre content. Fresh sugarcane juice is also sold by many street vendors in Southeast Asia, South Asia and Latin America and in some countries may also be bottled for local distribution. It is also gaining popularity in countries such as Australia where it can be purchased fresh from juice bars, cafes and restaurants. The juice must be consumed soon after extraction as it is rapidly oxidised. The oxidation, which is caused by the activity of polyphenol oxidase, can be reduced using thermal and chemical pre-treatments of stalks prior to juice extraction, significantly prolonging the shelf life of the juice (Eissa *et al.*, 2010).

73. Few other food uses currently exist for sugarcane, primarily because of the fibrous nature of the stalk. However, recently sugarcane bagasse has been used as a source of dietary fibre for human consumption (KFSU, 2009). Steam, heat and pressure treatment is used to break down the cellulose and hemicellulose in the bagasse which is then dried and milled as edible plant fibre.

### B. Suggested analyses for food use

74. Sugarcane's main contribution to the human diet is sugar, mainly in the form of sucrose, and this is primarily obtained through the consumption of refined sugar, with lesser contributions from products such as molasses, candies and sugarcane juice, depending on the country. Sugarcane is not a significant source of other nutrients, although developments in processing and biotechnology may see this change in the future.

75. While sugar is the main food product derived from sugarcane, analyses of the composition of sugar would be of little value for comparative assessment as sugar is composed almost entirely of sucrose, with only trace amounts of other substances. Analyses of other food products such as molasses, would be equally uninformative as molasses composition, in particular, is highly dependent on the refining process used and therefore may be highly variable. These processed products should therefore not be used as the basis for the comparison of different varieties of sugarcane.

76. As sugarcane is not a significant source of other nutrients, it is recommended that only major constituents be measured for the purpose of comparison, and that these be measured in whole cane (comprising stalks and leaves). The exception to this is sucrose content, which is traditionally measured in the stalk only. Few data are available for sucrose content of whole sugarcane. Since the level of key constituents may vary with maturity of sugarcane, it is recommended that the analytes to be compared are measured in plants harvested at a similar stage of maturity.

77. The key constituents suggested to be analysed in sugarcane intended for human consumption are shown in Table 10.

**Table 10. Suggested constituents to be analysed for food use**

<b>Constituent</b>	<b>Whole Sugarcane</b>
Moisture	X
Crude Protein	X
Fat (Ether Extract)	X
Crude Fibre	X
Ash	X
Sucrose	X (stalk)

## SECTION V - SUGGESTED CONSTITUENTS TO BE ANALYSED RELATED TO FEED USE

### A. Key products consumed by animals

78. To compensate for its low mineral and protein levels and low dry matter digestibility, sugarcane is commonly used in combination with other, richer nutritional feeds, or has its composition improved by addition of nitrogen and sulphur salts during feed formulation. It is also possible to improve the digestibility of sugarcane, using sodium hydroxide treatments for example, which break down the fibre content.

79. Sugarcane tops are used for feed purposes in some countries and are highly palatable. They are mostly fed to large ruminants, but because of their low nutritional quality, they are typically only offered to animals following physical, chemical or biological pre-treatment to increase their nutritional quality. In Australia, sugarcane tops are often conserved as hay during the harvest season (June to December) and fed to cattle during drought conditions (McKenzie and Griffiths, 2007). Sugarcane tops can also be ensiled, and generally are comparable to fresh tops in terms of their feeding value (Deville *et al.*, 1979).

80. Fresh chopped whole sugarcane is often fed to cattle in sugarcane growing regions. In these situations the crop must be harvested daily as sugarcane “sours” rapidly and becomes unpalatable if left for any length of time after chopping (Kung and Stanley, 1982). In studies undertaken in Florida, where fresh-chopped whole sugarcane was fed at levels from 20 to 77% of the diet dry matter (with the remainder supplied by corn, citrus pulp and cottonseed meal) the rate of gain, feed utilisation and carcass quality decreased as the percentage of sugarcane in the diet increased (Pate *et al.*, 1984). Fresh-chopped sugarcane has been found to have only 70% the value of corn silage when used as a major diet ingredient (Creek and Squire 1976). Best results are achieved when sugarcane is fed at moderate levels (30-40%).

81. Whole sugarcane can be ensiled like other forage crops, but its nutritive value is significantly reduced. This is largely because of the sugar content, which is fermented readily to ethanol, and the high moisture content, which produces excessive seepage losses (Pate *et al.*, 1984). In order to avoid alcoholic fermentation, which decreases nutritional content, palatability and animal consumption, it is necessary to add preservatives such as quick-lime, urea, sodium hydroxide, potassium sorbate or *Lactobacillus buchneri* to the material to be ensiled.

82. Sugarcane tends not to be used for grazing as the sugarcane stool<sup>9</sup> can be destroyed by overgrazing or grazing for extended periods.

83. The main sugarcane derivatives that are fed to animals are sugarcane juice and molasses. The fermentable carbohydrates in sugarcane juice (sucrose, glucose and fructose) are completely digestible by both ruminant and non-ruminant livestock and are increasingly being used in tropical countries as a viable alternative to starch in cereal grains (Preston, 1988). As sugarcane juice contains virtually no protein, such diets are supplemented with protein extracted from soybean meal or fishmeal (Speedy

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<sup>9</sup> The cluster of cane stalks arising from germination of sugarcane setts, or the regrowth which comes from the buds remaining in the stubble after fully grown stalks are harvested.

*et al.*, 1991) or other sources such as cassava (Preston, 1988). When fed at 40% of the dry matter intake, gains of up to 800 g/day in pigs have been achieved (Speedy *et al.*, 1991).

84. Molasses is often used to supplement cattle grazing poor-quality roughages when energy intake is a limiting factor. However, molasses is a poor source of protein and needs to be supplemented with urea as a non-protein source of nitrogen for sustaining high levels of production. Molasses is also extremely palatable to livestock and therefore is often used to mask unpalatable feed ingredients. Its physical properties also enable it to improve ration composition by minimising fines, dustiness and ingredient separation. For these latter two uses, only low concentrations (5-10%) are required (Preston, 1983). Production responses in cattle to molasses fed at 25-30% of total dry matter intake are about 70% that of grain; molasses efficiency drops off at levels greater than 25-30% of the diet and in rations where there are inadequate levels of roughage and protein (Ashwood, 2008).

## B. Suggested analyses for feed use

85. The composition of sugarcane by-products such as molasses tends to be highly variable and influenced heavily by the processing technology used. It is therefore recommended that these processing by-products not be used as the basis for the comparison of sugarcane varieties.

86. Sugarcane is generally fed to livestock as either sugarcane tops or as whole sugarcane, stalks and leaves together. Therefore, analyses should be done either of sugarcane tops or of whole sugarcane depending on the prevailing feeding practice. Since the level of key constituents may vary with maturity of sugarcane, it is recommended that the analytes to be compared are measured in plants harvested at a similar stage of maturity.

87. The key constituents suggested to be analysed in sugarcane intended for animal consumption are shown in Table 11. Acid detergent fibre (ADF) and neutral detergent fibre (NDF) are relevant analytes particularly for ruminant feed.

**Table 11. Suggested constituents to be analysed for animal feed**

Constituent	Sugarcane tops	Whole sugarcane
Moisture	X	X
Crude Protein	X	X
Fat (Ether Extract)	X	X
Ash	X	X
Crude Fibre <sup>10</sup>	X	
Acid Detergent Fibre		X
Neutral Detergent Fibre		X
Sucrose		X (stalk)

<sup>10</sup> Crude fibre is typically a component of proximates analysis.

## SECTION VI - REFERENCES

- AFRIS (Animal Feed Resources Information System of the FAO), Feed category: *Sugarcane and By-products*, FAO online database, [http://www.fao.org/ag/aga/agap/frg/AFRIS/index\\_en.htm](http://www.fao.org/ag/aga/agap/frg/AFRIS/index_en.htm) (accessed May 2009).
- Agata, H., N. Kondo, A. Yomo, T. Muraki, S. Shinoda, O. Fukutomi, Y. Kato, T. Nishida, M. Shinbara and T. Orii (1994), "Sensitization to sugar cane pollen in Okinawan allergic children", *Asian Pac. J. Allergy Immunol. Vol. 12*, pp. 151-154.
- dos Anjos, I.A., D.N. Silva and M.P. Campana (2008), "Cana-de-açúcar como Forrageira", In: *Cana-de-açúcar* (eds. Dinardo-Miranda, L.L. Vasconcelos, A.C.M. & Landell, M.G.A.) Campinas: Instituto Agrônômico.
- Ashwood, A. (2008), "By-Product Feeds for Beef Cattle", *Brahman News, December 2008, Issue 161*, Australian Brahman Breeders' Association Limited, available online at [www.brahman.com.au/technical\\_information/nutrition/ByProductfeeds.html](http://www.brahman.com.au/technical_information/nutrition/ByProductfeeds.html) (accessed March 2011).
- Azêvedo, J.A.G., J.C. Pereira, P.C.S. Carneiro, A.C. Queiroz, M.H.P. Barbosa, A.M. Fernandes and F.P. Rennó (2003), "Avaliação da Divergência Nutricional de Variedades de Cana-de-açúcar (*Saccharum* spp.)", *Rev. Bras. Zootec. Vol. 32*, pp. 1431-1442.
- Bakker, H. (1999), *Sugar Cane Cultivation and Management*, Kluwer Academic/Plenum Publishers, New York.
- Banda, M. and R.E. Valdez (1976), "Effect of Stage of Maturity on Nutritive Value of Sugar Cane", *Tropical Animal Production Vol. 1*, pp. 94-97.
- Berding, N. (1997), "Clonal Improvement of Sugarcane Based on Selection for Moisture Content: Fact or Fiction", In: *Proceedings of the 1997 Conference of the Australian Society of Sugar Cane Technologists* (ed. B.T. Egan), Watson Ferguson and Company, Brisbane, pp. 245-253.
- Berding, N., M. Hogarth and M. Cox (2004), "Plant Improvement of Sugarcane", In: *Sugarcane*, Second Edition (ed. G. James), Blackwell Science, Victoria, pp. 20-53.
- Bortolussi, G. and C.J. O'Neill (2006), "Variation in Molasses Composition from Eastern Australian Sugar Mills", *Aust. J. Exp. Agriculture Vol. 46*, pp. 1455-1463.
- BSES (Bureau of Sugar Experiment Stations) (1984), *The Standard Laboratory Manual for Australian Sugar Mills, Vol. 1. Principles and Practices*, Bureau of Sugar Experiment Stations, Indooroopilly, Queensland.
- Buxton, D.R. and D.D. Redfearn (1997), "Plant Limitations to Fiber Digestion and Utilization", *J. Nutr. Vol. 127*, pp. 814S-818S.
- de Carvalho, G.G.P., A.J.P. Pires, C.M. Veloso, A.F. Magalhães, M.A.L. Freire, F.F. da Silva, R.R. Silva, and B.M.A. de Carvalho (2006), "Valor Nutritivo do Bagaço de Cana-de-açúcar Amonizado com Quatro Doses de Uréia", *Pesq. agropec. bras. Vol.41*, pp. 125-132.
- César, M.A.A., J.B.P. Chaves and F.C. da Silva (2003), "Pequenas Indústrias Rurais de Cana-de-Açúcar: Melado, Rapadura e Açúcar Mascavo" (eds. F.C. da Silva, M.A.A. César, & C.A.B. da Silva), *Brasília Embrapa Informação Tecnológica Vol. 1*, pp. 53-82.

- Chakraborty, P., S. Gupta-Bhattacharya, I. Chowdhury, M.R. Majumdar and S. Chanda (2001), "Differences in Concentrations of Allergenic Pollens and Spores at Different Heights on an Agricultural Farm in West Bengal, India", *Annals of Agricultural and Environmental Medicine Vol. 8*, pp. 123-130.
- Chang-Yen, I., P.L. Bodoie and R. Mohammed (1983), "Chemical Analysis of Seven Nutrient Elements in some Sugar-cane Products and By-products", *Trop. Agric. (Trinidad) Vol. 60*, pp. 41-43.
- Cheavegatti-Gianotto, A., H.M.C de Abreu, P. Arruda, J.C. Bepalhok Filho, W.L. Burnquist, S. Creste, L. di Ciero, J.A. Ferro, A.V. de Oliveira Figueira, T. de Sousa Filgueiras, M.d.F. Grossi-de-Sá, E.C. Guzzo, H.P. Hoffmann, M.G. de Andrade Landell, N. Macedo, S. Matsuoka, F. de Castro Reinach, E. Romano, W.J. da Silva, M. de Castro Silva Filho and E. César Ulian (2011), "Sugarcane (*Saccharum X officinarum*): A Reference Study for the Regulation of Genetically Modified Cultivars in Brazil", *Tropical Plant Biology, Vol. 4, No. 1*, pp. 62-89.
- Cheesman, O.D. (2005), *Environmental Impacts of Sugar Production: The Cultivation and Processing of Sugarcane and Sugar Beet*, CABI Publishing, United Kingdom.
- Chen, J.C.P and C.C. Chou (1993), *Cane Sugar Handbook: A Manual for Cane Sugar Manufacturers and their Chemists*, 12<sup>th</sup> Edition, John Wiley & Sons, New York.
- Clarke, M.A. (1978), "Cane Sugar", In: *Encyclopaedia of Chemical Technology*, 3<sup>rd</sup> Edition, Volume 3 (eds. R.E. Kirk & D.F. Othmer), John Wiley & Sons, New York, pp 434-438.
- Clarke, M.A. (1988), "Sugarcane Processing: Raw and Refined Sugar Manufacture", In: *Chemistry and Processing of Sugar beet and Sugarcane* (eds. M.A. Clarke & M.A. Godshall), Elsevier Science Publishers B.V., Amsterdam, pp. 162-175.
- Codex Alimentarius Commission (2001) "Codex Standard for Sugars", *Codex Standard Series No. 212-1999*, available online at [www.codexalimentarius.net/download/standards/338/CXS\\_212e\\_u.pdf](http://www.codexalimentarius.net/download/standards/338/CXS_212e_u.pdf) (accessed March 2011).
- Codex Alimentarius Commission (2003, Annexes II and III adopted in 2008), *Guideline for the Conduct of Food Safety Assessment of Foods Derived from Recombinant DNA Plants - CAC/GL 45/2003*, available online at [www.codexalimentarius.net/download/standards/10021/CXG\\_045e.pdf](http://www.codexalimentarius.net/download/standards/10021/CXG_045e.pdf) (accessed March 2011).
- Cox, M., M. Hogarth, G. Smith (2000), "Cane Breeding and Improvement", In: *Manual of Cane Growing* (eds. M. Hogard & P. Allsopp), Bureau of Sugar Experimental Stations, Indooroopilly, Australia, pp. 91-108.
- Creek, M.J. and H.A. Squire (1976), "Use of a Slaughter Technique for Technical and Economic Evaluation of Sugarcane and Maize Silage Based Rations", *Trop. Anim. Prod. Vol. 1*, pp. 56-65.
- Curtin, L.V. (1973), "Effect of Processing on the Nutritional Value of Molasses", In: *Effect of Processing on the Nutritional Value of Feeds, Proceedings of a symposium*, Gainesville, Florida, 11-13 Jan.1972, National Academy of Science, pp. 286-296.
- De Rosa Jr. V.E., F.T.S. Nogueira, P. Mazzafera, M.G.A. Landell and P. Arruda (2007), "Sugarcane Dhurrin: Biosynthetic Pathway Regulation and Evolution", *Proc. Int. Soc. Sugar Cane Technol. Vol. 26*, pp. 958-962.
- Deville, J., Y. Wong You Cheong, P. Leclezio and P. Duvivier (1979), "The Production of Silage from Sugar Cane Tops and its Use as Fodder for Cattle", *Trop. Anim. Production Vol. 4*, pp. 134-137.
- Dillon, S.L., F.M. Shapter, R.J. Henry, G. Cordeiro, L. Izquierdo and L.S. Lee (2007), "Domestication to Crop Improvement: Genetic Resources for *Sorghum* and *Saccharum* (Andropogoneae)", *Annals of Botany Vol. 100*, pp. 975-989.

- Dixon, F.M. (1977), "Sugarcane for Beef Production: Derinded Sugarcane and Chopped Cane Compared with Hay and Citrus Pulp", *Trop. Anim. Prod. Vol. 3*, pp. 104-108.
- EFSA (European Food Safety Authority) (2004), "Opinion of the Scientific Panel on Food Additives, Flavourings, Processing Aids and Materials in Contact with Food (AFC) on Hydrocyanic Acid in Flavourings and other Food Ingredients with Flavouring Properties", *The EFSA Journal Vol. 105*, pp. 1-28.
- EFSA (European Food Safety Authority) (2007), "Opinion of the Scientific Panel on Contaminants in the Food Chain on a request from the Commission related to cyanogenic compounds as undesirable substances in Animal Feed", *The EFSA Journal Vol. 434*, pp. 1-67.
- Eissa, H.A., A.N. Shehata, M.T. Ramadan and H.S. Ali (2010), "Preservation of Sugarcane Juice by Canning 1. Effect of Thermal and Chemical Pre-treatments on the Enzymatic Browning of Sugarcane Juice", *Journal of American Science Vol. 6*, pp 883-888.
- FAO (Food and Agriculture Organization of the United Nations) (1988), "Sugarcane as Feed" (eds. R. Sansoucy, G. Aarts & T.R. Preston), *FAO Animal Production and Health Paper No.72*, FAO, Rome.
- FAO (2007), "Panela Production as a Strategy for Diversifying Incomes in Rural Areas of Latin America", *AGSF Working Document No. 6*, Food and Agriculture Organisation of the United Nations, Rome.
- FAOSTAT (2009), FAO Statistics online database, <http://faostat.fao.org/> (accessed March 2011).
- FARRP (Food Allergy Research and Resource Program) Protein AllergenOnline Database (Version 10), the University of Nebraska-Lincoln, USA, available online at [www.allergenonline.org](http://www.allergenonline.org) (accessed March 2011).
- Fernandes, A.M., A.C. Queiroz, R.P. Lana, J.C. Pereira, L.S. Cabral, A. Vittori and E.S. Pereira (2001), "Estimativas da Produção de Leite por Vacas Holandesas Mestiças, segundo o Sistema CNCPS, em Dietas Contendo Cana-de-açúcar com Diferentes Valores Nutritivos", *Rev. Bras. Zootec. Vol. 30*, pp. 1350-1357.
- Figuerola, V. and Ly, J. (1990), *Alimentación Porcina No Convencional*, Colección GEPLACEA, Serie DIVERSIFICACION, Mexico pp. 215.
- Fuller, M.F. (ed.) (2004), *Encyclopedia of Farm Animal Nutrition*, CABI Publishing.
- Godshall, M.A. (2003), "Sugar and Other Sweeteners", In: *Riegel's Handbook of Industrial Chemistry*, 10<sup>th</sup> Edition (ed. J.A. Kent), Kluwer Academic Press, New York, pp. 329-361.
- Inman-Bamber, N.G., G.D. Bonnett, M.F. Spillman, M.L. Hewitt and J. Xu (2009), "Source-sink Differences in Genotypes and Water Regimes Influencing Sucrose Accumulation in Sugarcane Stalks", *Crop & Pasture Science Vol. 60*, pp. 316-327.
- Jackson, P.A. (2005), "Breeding for Improved Sugar Content in Sugarcane", *Field Crops Research Vol. 92*, pp. 277-290.
- James, G.L. (2004), "An Introduction to Sugarcane", In: *Sugarcane*, Second Edition, (ed. G. James), Blackwell Science, Victoria, pp. 1-19.
- Johnson, B.J. and W.F. Miller (2007), *Effect of Cane Molasses on Absorptive Capacity of Rumen Papillae in Dairy Cows during the Dry Period and Early Lactation*, available online at <http://www.afia.org/Afia/Files/Liquid%20Feed%20Research%20Papers/Brad%20Johnson-KSU%202007.pdf> (accessed March 2011).
- Kaushal, J.R., V.K. Kakkar, N.S. Malik and G.S. Makkar (1980), "Chemical Composition of Sugarcane Bagasse and Filter-mud and the Effect of Source and Alkali Treatment on the *In vitro* Dry Matter Digestibility of Bagasse", *Indian Journal of Dairy Science Vol. 34*, pp. 458-462.



- KFSU (Australian company, Queensland) (2009), *Dietary Fibre from Sugarcane*, website [http://www.kfibre.com/user-assets/Profile\\_Fibacel\\_3\\_09\\_REV2.pdf](http://www.kfibre.com/user-assets/Profile_Fibacel_3_09_REV2.pdf) (accessed March 2011).
- Knight, A.P. and R.G. Walter (2001), *A Guide to Plant Poisoning of Animals in North America*, Teton NewMedia, United States of America, 367 p.
- Kung Jr., L. and R.W. Stanley (1982), "Effect of Stage of Maturity on the Nutritive Value of Whole-Plant Sugarcane Preserved as Silage", *Journal of Animal Science Vol. 54*, pp. 689-696.
- Lavanholi, M.G.D.P. (2008), "Qualidade da Cana-de-açúcar Como Matéria-prima Para Produção de Açúcar e Alcool", In: *Cana-de-açúcar* (eds, L.L. Dinardo-Miranda, A.C.M. Vasconcelos and M.G.A. Landell), Campinas: Instituto Agronomico de Campinas, 882 p.
- Mackintosh, D. (2000), "Sugar milling", In: *Manual of Cane Growing* (eds. M. Hogard & P. Allsopp), Bureau of Sugar Experimental Stations, Indooroopilly, Australia, pp. 369-377.
- Mahatab, S.N., M.M. Islam, A.H.M. Asaduzzaman and M.G. Uddin (1981), "The chemical Composition and Nutritive Quality of Sugarcane Tops", *Livestock Adviser*, June 1981, pp. 5-8.
- McKenzie, J. and C. Griffiths (2007), "Cane Tops as Cattle Fodder", *Primefact 314*, New South Wales Department of Primary Industry, New South Wales.
- Muchow, R.C., M.J. Robertson, A.W. Wood and B.A. Keating (1996), "Effect of Nitrogen on the Time-course of Sucrose Accumulation in Sugarcane", *Field Crops Res. Vol. 47*, pp. 143-153.
- Naseeven, R. (1988), Sugarcane tops as animal feed. In: 'Sugarcane as Feed' (eds. R. Sansoucy, G. Aarts and T.R. Preston) *FAO Animal Production and Health Paper No.72*, Food and Agriculture Organization of the United Nations, Rome.
- NRC (National Research Council) (1982), *United States-Canadian Tables of Feed Composition*, National Academy Press, Washington D.C.
- OECD (Organisation for Economic Cooperation and Development) (2002), "Consensus Document on Compositional Considerations for New Varieties of Sugar Beet: Key Food and Feed Nutrients and Anti-nutrients", *Series on the Safety of Novel Foods and Feeds No.3*, OECD Environment Directorate, Paris. Available online on the Biotrack website at <http://www.oecd.org/biotrack/> (accessed March 2011).
- OGTR (Office of the Gene Technology Regulator, Dept. of Health and Ageing, Australian Government) (2008), *The Biology of the Saccharum spp. (Sugarcane), Version 2: Feb.2008*, available online at [www.ogtr.gov.au/internet/ogtr/publishing.nsf/Content/riskassessments-1](http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/Content/riskassessments-1) (accessed March 2011)
- Oliveira, J.C. R.J. Nascimento and W.S.F. Brito (2007), *Demonstração dos Custos da Cadeia Produtiva da Rapadura: Estudo realizado no Vale do São Francisco*, Custos e @gronegocio on line 3 (Edição Especial) pp. 79-99, available online at <http://www.custoseagronegocioonline.com.br/edicao especial2007.html> (accessed March 2011).
- Pate, F.M. (1979), "Improving the Nutritive Value of Sugarcane Bagasse with Steam-pressure Treatment, 1979 Florida Beef Report, University of Florida, pp. 46-50.
- Pate, F.M., J. Alvarez, J.D. Phillips and B.R. Eiland (1984), "Sugarcane as a Cattle Feed: Production and Utilisation", In: *Florida Sugarcane Handbook* (ed R.A. Gilbert), University of Florida, Gainesville, available online at <http://edis.ifas.ufl.edu/pdf/files/AN/ANO4300.pdf> (accessed March 2011).
- Paturau, J.M. (1989), *By-Products of the Cane Sugar Industry: An Introduction to their Industrial Utilization*, 3<sup>rd</sup> Edition, Elsevier, Amsterdam.

- Payne, J.H. (1991), *Cogeneration in the Sugar Industry*, Elsevier, Amsterdam.
- Pereira, E.S., A.C. Queiroz, M.F. Paulino, P.R. Cecon, S.C. Valadares Filho, L.F. Miranda, A.M. Fernandes and L.S. Cabral (2000) “Determinação das Frações Protéicas e de Carboidratos e Taxas de Degradação *In vitro* da Cana-de-açúcar, da Cama de Frango e do Farelo de Algodão”, *Rev. Bras. Zootec. Vol. 29*, pp. 1887-1893.
- Perez, R. (1997), “Feeding Pigs in the Tropics”, *FAO Animal Production and Health Paper No. 132*, Food and Agriculture Organization of the United Nations, Rome.
- van der Poel, P.W, H. Schiweck and T. Schwartz (1998), *Sugar Technology: Beet and Cane Sugar Manufacture*, Verlag Dr. Albert Bartens KG, Berlin.
- Preston, T.R. (1977), “Nutritive Value of Sugar Cane for Ruminants”, *Tropical Animal Production Vol. 2*, pp. 125-142.
- Preston, T.R. (1983), “The Use of Sugarcane and By-products for Livestock”, In: *Chemistry and World Food Supplies: The New Frontiers CHEMRAWN II* (ed. L.W. Shemilt), Invited papers presented at the International Conference on Chemistry and World Food Supplies, Manila, Philippines, 6-10 December 1982, Pergamon Press, Oxford.
- Preston, T.R. (1988), “Fractionation of Sugarcane for Feed and Fuel”, In: “Sugarcane as Feed” (eds. R. Sansoucy, G. Aarts and T.R. Preston) *FAO Animal Production and Health Paper No. 72*, Food and Agriculture Organization of the United Nations, Rome.
- Qudsieh, H.Y.M., S. Yusof, A. Osman and R.A. Rahman (2001), “Physico-chemical Changes in Sugarcane (*Saccharum officinarum* var. Yellow Cane) and the Extracted Juice at Different Portions of the Stem during Development and Maturation”, *Food Chemistry Vol. 75*, pp. 131-137.
- Rabelo, S.C., A.C. da Costa, C.E.V Rossel (2010), “Aproveitamento de Resíduos Industriais”, In: *Cana-de-açúcar: Bioenergia, Açúcar e Álcool – Tecnologia e Perspectivas* (eds. F. Santos, A. Borém and C. Caldas), Viçosa, MG, pp. 465-486.
- Rangnekar, D.V. (1988), “Integration of Sugarcane and Milk Production in Western India”, In: “Sugarcane as Feed” (eds. R. Sansoucy, G. Aarts and T.R. Preston), *FAO Animal Production and Health Paper No.72*, Food and Agriculture Organization of the United Nations, Rome.
- Roberts, E.J. and Martin, L.F. (1959), “Progress in Determining Organic Non-sugars of Sugarcane Juice that Affect Sugar Refining”, In: *Proceedings of the 6<sup>th</sup> Technical Session on Bone Char (1959)* (ed. V.R. Deitz), Bone Char Research Project, Inc., pp. 67-99.
- Rott, P. and J.C. Girard (2000), “Sugarcane Producing Countries, Locations and their Diseases”, In: *A Guide to Sugarcane Diseases* (eds. P. Rott, R.A. Bailey, J.C. Comstock, B.J. Croft & A.S. Saumtally), CIRAD and ISSCT, Montpellier, France, pp. 323-336.
- Santos, R.V., A.R. Evangelista, J.C. Pinto, C.C.C. Couto Filho and R.M. Souza (2006), “Composição Química de Cana-de-açúcar (*Saccharum* spp.) e das Silagens com Diferentes Aditivos em Duas Idades de Corte”, *Cienc. Agrotec., Vol. 30*, pp. 1184-1189.
- Seifert, H.S. and K.A. Beller (1969), “Hydrocyanic Acid Poisoning in Cattle Caused by Grazing on Sugarcane (*Saccharum officinarum*) and Supplemental Feeding of Fruits of the Algarrobo Tree (*Prosopis juliflora*), *Berl. Munch Tierarztl. Wochenschr. Vol. 82*, pp. 88-91.
- Solomon, S. and Y. Li (2004), “Chemical Ripening of Sugarcane: Global Progress and Recent Developments in China”, *Sugarcane Agriculture Vol.6*, pp. 241-249.

- de Souza França, A.F., S. Queiroz Santos Mello, B. Rosa, A. de los Reyes Borjas, S. Piereira Mundim, M.R. Ferreira Maghalães, T.R. Aparecido de Matos and J. Gonçalves dos Reis (2005), “Avaliação do Potencial Produtivo e das Características Químico-Bromatológicas de Nove Variedades de Cana-de-Açúcar Irrigada”, *Livestock Research for Rural Development Vol. 17, Art #7*, available online at <http://www.lrrd.org/lrrd17/1/souz17007.htm> (accessed March 2011).
- Speedy, A. W., L. Seward, N. Langton, J. Du Plessis and B. Dlamini, (1991), “A Comparison of Sugarcane Juice and Maize as Energy Sources in Diets for Growing Pigs with Equal Supply of Essential Amino Acids”, *Livestock Research for Rural Development Vol. 3*, pp. 65-74.
- USDA (United States Department of Agriculture) (2009), *Sugar: World Production Supply and Distribution*, Foreign Agricultural Service, May 2009, available online at <http://www.fas.usda.gov/http/sugar/2009/May%20sugar%202009.pdf> (accessed March 2011).
- Walker, D.I.E.T. (1987), “Breeding for Disease Resistance”, In: *Sugarcane Improvement through Breeding* (ed. D.J. Heinz), Elsevier, Amsterdam, pp. 455-502.
- Wythes, J.R., D.H. Wainwright and G.W. Blight (1978), “Nutrient composition of Queensland molasses”, *Australian Journal of Experimental Agriculture and Animal Husbandry Vol. 18*, pp. 629-634.
- Yusof, S., L.S. Shian, and A. Osman (2000), “Changes in Quality of Sugarcane Juice upon Delayed Extraction and Storage”, *Food Chemistry Vol. 68*, pp. 395-401.