

# Main NTCs and characterization protocols in products derived from sugarcane

## Principales NTC y protocolos de caracterización en productos derivados de caña de azúcar

Leonardo Moreno-Chacón<sup>1</sup>  
Diego Suarez-Peñaranda<sup>2</sup>

<sup>1</sup>Servicio Nacional de Aprendizaje SENA; Universidad Industrial de Santander (Colombia). Email: [anlmoreno@sena.edu.co](mailto:anlmoreno@sena.edu.co); [almorenoch@unal.edu.co](mailto:almorenoch@unal.edu.co)  
orcid: <https://orcid.org/0000-0002-1402-6178>

<sup>2</sup>Servicio Nacional de Aprendizaje SENA (Colombia). Email: [dfsuaresp@sena.edu.co](mailto:dfsuaresp@sena.edu.co)  
orcid: <https://orcid.org/0000-0002-3139-4239>

Received: 15-03-2021 Accepted: 11-08-2021

**How to quote:** Moreno-Chacón, Leonardo; Suarez- Peñaranda, Diego (2021). Main NTCs and characterization protocols in products derived from sugarcane. *Informador Técnico*, 85(2), 184 -218.  
<https://doi.org/10.23850/22565035.3631>

### Abstract

Products derived from sugar cane (*Saccharum officinarum* L.) are produced by one of the rural agro-industries with the longest tradition in Colombia. In order to establish the main indicators and protocols that allow the bromatological, phytochemical, and antioxidant characterization of products derived from *S. officinarum*, a literature search was carried out through the Icontec and Scopus documentary bases, in the period between January 1990 and February 2021. The foregoing, under guidelines that would lead to establishing a global overview of research and development trends, analysis of final products, and identification of the main standardized and non-standardized protocols. Thus, it was possible to identify the main CTS (Colombian Technical Standards) and the most used protocols for the quantification of physicochemical indicators and some metabolites of interest, confirming and establishing their positive effects on animal and human health, as an immunological enhancer, antitoxic, cytoprotective, anticarcinogenic and antioxidant. Additionally, it was possible to determine that heavy metals (lead, mercury, cadmium, arsenic), furfural, 5-hydroxymethylfurfural, and acrylamide are the main pollutants on which a mitigation strategy should be established. This work highlighted the need to generate a national policy that enables the quantification of the required physicochemical indicators, the content of bioactive compounds, and the presence of dangerous contaminants in products derived from sugar cane, in order to comply with the legal regulations for the distribution and trading of sugary products in the national and international market and, why not, start their diversification.

**Keywords:** acrylamide; anticancer; antioxidant; heavy metals; panela; *Saccharum officinarum* L.

### Resumen

Los productos derivados de la caña de azúcar (*Saccharum officinarum* L) conforman una de las agroindustrias rurales de mayor tradición en Colombia. Con el fin de establecer los principales indicadores y protocolos que permitan la caracterización bromatológica, fitoquímica y antioxidante de productos derivados de *S. officinarum*,

se realizó un rastreo bibliográfico a través de la base documental del Icontec y Scopus, en el periodo comprendido entre enero de 1990 y febrero de 2021. Lo anterior, bajo lineamientos que permitieran establecer un panorama mundial sobre las tendencias de investigación y desarrollo, análisis de productos finales e identificación de los principales protocolos normalizados y no normalizados. Fue así como se lograron identificar las principales NTC (Normas Técnicas Colombianas) y los protocolos más empleados para la cuantificación de los indicadores fisicoquímicos y de algunos metabolitos de interés, confirmando y estableciendo sus efectos positivos para la salud animal y humana, como potenciador inmunológico, antitóxico, citoprotector, anticariógeno y antioxidante. Adicionalmente, se logró determinar que los metales pesados (plomo, mercurio, cadmio, arsénico), furfural, 5-hidroximetilfurfural y acrilamida son los principales contaminantes sobre los cuales se debe establecer una estrategia de mitigación. Con esto, se hace evidente la necesidad de generar una política nacional que posibilite cuantificar los indicadores fisicoquímicos exigidos, el contenido de compuestos bioactivos y la presencia de contaminantes peligrosos en los productos derivados de la caña de azúcar, con el fin de dar cumplimiento a la normativa legal para la distribución y comercialización de productos azucarados en el mercado nacional e internacional y, por qué no, iniciar su diversificación.

**Palabras clave:** acrilamida; anticancerígeno; antioxidante; metales pesados; panela; *Saccharum officinarum* L.

## 1. Introduction

In recent decades, the insertion in the international market of agro-industrial products of Colombian origin has been one of the main objectives of the National Government and regional governments. The rural agro-industrial chain of sugarcane products deserves attention, and wider possibilities for improvement, so that small agricultural production units can keep, optimize, or increase their participation in the markets in a more dynamic, sustainable, and profitable way, through activities of transformation and adding of value to the agricultural raw materials generated.

Different types of products are made from sugar cane, the most representative is raw cane honey, refined cane honey, molasses, honey for alcoholic fermentation, block panela, pulverized panela, panela cubes, unrefined sugar, refined sugar, smoothies, inter alia (Jaffé, 2012). Each of them has different characteristics of elaboration, packaging, and processing, but there is no clarity about the requirements for its legal and safe trading, thus, each company imposes its requirements and price.

The Colombian Technical Standards (NTC, after its acronym in Spanish) can shed some light on some minimum verification parameters to achieve a safe circulation of products, but they have not been widely disclosed among producers, they are outdated, and are comprised of basic and rudimentary analytical techniques, among other disadvantages; but they are required by regulatory entities, such as the National Institute of Medication and Food Surveillance (Invima), or by the purchasers. Moreover, these NTCs have failed to explore groups of molecules of increasing interest, such as phenols, antioxidant metabolites, free amino acids, inter alia; furthermore, they fail to contemplate, for example, the quantification of furfural, 5-hydroxymethylfurfural or acrylamide, toxic molecules that have been detected in some products derived from *S. officinarum*, especially in products wherein, through their manufacturing process, such molecules increase considerably due to poor control in the processing time (Mesias; Delgado-Andrade; Gómez-Narváez; Contreras-Calderon; Morales, 2020).

Besides, it is known that the productive sector in our country does not yet have a culture of process quality, and therefore, poor regulatory systems to ensure the safety of food and comply with quality standards through the analysis of its products are usually implemented. According to the Development and Technological Innovation Survey, EDIT (National Administrative Department of Statistics [DANE], 2013), which was carried out by the National Administrative Department of Statistics (DANE), during the period 2005-2012, the number of companies that reported to obtain quality certification, either regarding process or product, remained

below 25 % of the total companies surveyed. One of the shortcomings that lead to this situation is the low level of service development for the determination of quality, such as laboratory tests, equipment calibration, standardization, accreditation, and others. Deficiencies in the technical capacity of the laboratories have resulted in a low supply of accredited tests and geographical concentration in capital cities, far from the “trapiches” (local mills) and production centers, which increases the costs for entrepreneurs who want to guarantee the quality of their products to trade in the national or foreign markets (Castro; Grove; Balcázar; Estupiñán, 2013; National Council for Economic and Social Policy [Conpes], 2016). Similarly, the EDIT (DANE, 2020) of the period 2018-2019 showed that there are obstacles associated with the environment, the low offer of inspection, testing, certification, and verification services reported by more than 50 % of the companies surveyed.

The foregoing highlights the need to generate a national strategic program that enables the quantification of the indicators required in the different NTCs, as well as other physicochemical parameters, such as the content of bioactive compounds and the presence of dangerous contaminants in products derived from sugarcane, which are produced in different regions of Colombia, in order to comply with the legal regulations for the distribution and trading of sugary products in the international and international market, and to initiate the diversification of their uses. Next, a review of the current NTCs will be made, together with the protocols of bromatological, nutritional, phytochemical, and antioxidant capacity characterization of products derived from *S. officinarum*, in order to verify its effectiveness and the possibility of renewal or modification.

## 2. Methodology

The NTC review was carried out on the website of the Colombian Institute of Technical Standards and Certification, Icontec (2021), using the following tracking keywords: cane honey, sugar cane, and panela. On the other hand, the research reports were tracked using primary sources contained in the Scopus database platform. The keywords of each aspect explored are reported in Table 1. The observation period was between January 1990 and February 2021. The selection criteria applied for the research articles consisted of a series of requirements where at least three citations were necessary, as well as a description of the specified technique and methodology, and the use of quantitative results, supported by statistical analysis. For articles and book chapters, the criteria established was that the sources of theoretical foundations should not exceed the established time range.

**Table 1.** Keywords of each of the general lines of search in the aspects explored in cane honey and panela derivatives on the Scopus platform

General lines	Keywords
Determination of global research and development trends, with emphasis on bromatology, nutrition, phytochemicals, and antioxidant capacity	Panela
	Muscovado
	Raw sugar
	Brown sugar
	Sugarcane
Analysis of possible final products, with emphasis on bromatology, nutritional, phytochemicals, and antioxidant capacity	Sugarcane extracts
	Sugarcane products
	Sugarcane extract
	Crude sugarcane bagasse
Identification of national capacities	Sugarcane Straw
	Evaluated within the general lines, exploring the reports generated in Colombia

Source: own elaboration.

## 3. Results

The results of the search performed on the Icontec and Scopus data platforms are shown below.

### 3.1. Colombian Technical Standards

The exclusive search of the NTC yielded the list of current standards for the different products derived from *S. officinarum*, which are found in Tables 2 and 3. These standards can be classified into two groups, one related to the characterization of physicochemical parameters and the other one that seeks to establish and measure the microbial safety of the product.

Within the first kind (Table 2) NTC 1779:2017 (Colombian Institute of Technical Standards and Certification [Icontec], 2017a) stands out. This standard presents the Method of Lane and Eynon as a way to determine monosaccharides (reducing sugars). It is based on the ability of monosaccharides to reduce a copper solution under basic and heating conditions and is based on the provisions of The International Commission for Uniform Methods of Sugar Analysis-ICUMSA GS 4/3-7:2011 (International Commission for Uniform Methods of Sugar Analysis [ICUMSA], 2011a). Likewise, NTC 570:2012 (Icontec, 2012a), provides information on how to determine the percentage or content of ash in sugar, honey, syrups, and cane extracts by the sulfated ash methodology and by the conductimetric method. It is based on ICUMSA-GS3/4/7/8-11:2000 (ICUMSA, 2000), ICUMSA-GS 2/3/9-17:2011 (ICUMSA, 2011b) and ICUMSA-GS 1/3/4/7/8-13:1994 (ICUMSA, 1994).

On the other hand, NTC 1856:2010 (Icontec, 2010) describes two ways of determining sulfur dioxide, qualitatively and quantitatively. The qualitative test is performed with iodized starch paper, it is prepared by moistening filter paper with a 1 % starch solution, with a drop of the solution of interest, if the product contains sulfurous acid, the paper impregnated with solution takes on a more or less intense brown color by the action of sulfuric acid released. This reaction is very sensitive. The quantitative determination is based on the treatment of an acidulated sugar solution that drags the Sulphur dioxide by distillation, collecting it in an iodine solution. Excess iodine is assessed, and sulfur dioxide is calculated from quantified iodine. On the other hand, for the same parameter, there is the NTC 5970:2012 (Icontec, 2012b), which uses as a reference ICUMSA GS 2/1/7-33:2009 (ICUMSA, 2009a). In a spectrophotometric method, after a reaction with formaldehyde, the formed sulfite/rosaniline complex is spectrophotometrically quantified at a wavelength of 560 nm.

NTC 6385:2020 (Icontec, 2020a) establishes SPRI's rapid starch spectrophotometric method for determining sugar-soluble starch and other process materials (extracts and honey). Potassium iodide (KI) and potassium iodate (KIO<sub>3</sub>) is added to the sample. Whereas starch is comprised of amylose and amylopectin, iodine reacts with amylose to form a blue/purple complex. The spectrophotometric reading is performed at 600 nm. On the other hand, NTC 1846:2020 (Icontec, 2020b) establishes the requirements and the tests applicable to sugarcane honey (*S. officinarum*). NTC 440:2015 (Icontec, 2015) is a reference for food products. Test methods: NTC 573:2013 (Icontec, 2013), Sugar. Terminology: NTC 587:1994 (Icontec, 1994a), Food and beverage industries. Cane molasses: NTC 1779:2017 (Icontec, 2017a), meladura and cane honey. Method to determine total reducing sugars in molasses and cane honey, after hydrolysis by the Lane and Eynon procedure at constant volume: NTC 1856:2010 (Icontec, 2010), Alcoholic beverages, Cane honey, and Determination of sulfur dioxide. And finally, the NTC 1311:2009 (Icontec, 2009) is the one that provides the requirements and methods that must be met by panela intended for human consumption. It includes the protocols for the qualitative identification of dyes, the determination of a foreign matter, moisture content, ash, total sugars, reducers, and phosphorus, as well as the identification of calcium metals, sodium, potassium, and iron, and heavy metals such as lead and arsenic.

**Table 2.** Colombian Technical Standards in force for the different products derived from *S. officinarum* related to physico-chemical parameters

NTC	Title	Object
NTC 1779:2017 (Icontec, 2017a)	Meladura and cane honey. Method for determining total reducing sugars in molasses and cane honey, after hydrolysis by the Lane and Eynon procedure at constant volume.	This standard establishes the method for determining the total sugars expressed as a reducer in cane honey by the Lane-Eynon method (modified).
NTC 570:2012 (Icontec, 2012a)	Sugar, honey, syrups and cane extracts, test methods for determining ashes.	This standard establishes the test methods to determine ash by gravimetry and conductimetry, in any type of sugar, extracts, syrups, and cane honey.
NTC 1856:2010 (Icontec, 2010)	Alcoholic beverages, cane honey, determination of sulfur dioxide.	This standard sets forth the methods for qualitatively and quantitatively determining the Sulphur dioxide content in cane honey.
NTC 6385:2020 (Icontec, 2020a)	Sugar. Determination of soluble starch in sugar and process materials using SPRI's rapid starch method.	This standard establishes the SPRI fast starch method, to determine sugar-soluble starch and other process materials (extracts and honey).
NTC 1846:2020 (Icontec, 2020b)	Virgin sugarcane honey.	This standard establishes the requirements to be met and the tests applicable to virgin sugarcane honey ( <i>Saccharum officinarum</i> L.), used as a raw material for industry.
NTC 5970:2012 (Icontec, 2012b)	Sugar, extracts, and cane syrups, determination of sulfite with the colorimetric method of rosaniline.	This standard establishes the test method for the colorimetric determination of SO <sub>2</sub> and it is applicable to extracts and syrups and to white, special white, refined and raw sugar.
NTC 3442:2011 (Icontec, 2011)	Alcoholic beverages, cane taffias.	This standard determines the requirements and test methods to be met by cane taffias used in the production of rums and certain alcoholic beverages which, due to their characteristics, require this raw material.
NTC 410:1999 (Icontec, 1999)	Alcoholic beverages, cane liquor, cane, cachaça or gill.	This standard establishes the requirements and tests that must be met by the alcoholic beverages made from cane, cachaça or gill.

NTC	Title	Object
NTC 440:2015 (Icontec, 2015)	Foodstuffs, test methods.	This standard determines the test methods for determining the physical and chemical characteristics of foodstuffs.
NTC 573:2013 (Icontec, 2013)	Sugar, terminology.	This standard establishes the definitions of the most commonly used terms in the cane sugar industry.
NTC 587:1994	Food industries and beverage industries, cane molasses.	This standard establishes the requirements that must be met by cane molasses used in animal feed and the production of alcohols, yeasts, and related industries.
NTC 2369:1994 (Icontec, 1994b)	Food industries, acrylamide-derived flocculants used in the clarification of drinking water and sugarcane extracts and syrups.	This standard establishes definitions and classification, general conditions, requirements, tests, packaging, labeling and handling precautions.
NTC 1311:2009 (Icontec 2009)	Agricultural products, panela.	Establishes the requirements and tests that must comply with the panela intended for human consumption.

Source: own elaboration.

The safety of products derived from *S. officinarum* is established by the rules provided in Table 3. They describe how to count coliforms, *Escherichia coli*, molds, yeasts, and mesophilic bacteria.

**Table 3.** Current Colombian Technical Standards for the different products derived from *S. officinarum* in matters of safety parameters

NTC	Title	Object
NTC 3953:2017 (Icontec, 2017b)	Sugar, extracts, molasses, and cane honey, determination of coliforms and <i>Escherichia coli</i> , technique of the most probable number (MPN).	This standard provides general guidelines for counting coliforms and <i>Escherichia coli</i> in granulated sugar, liquid sugar, powdered sugar, extracts, molasses, and cane honey by calculating the most likely number (MPN).
NTC 3954:2017 (Icontec, 2017c)	Sugar, extracts, syrups, and cane honey, determination of molds and yeasts, plate counting method.	This standard establishes the method for determining the count of molds and yeasts in granulated sugar, liquid sugar, extracts, molasses, and cane honey by the plate counting technique.

NTC	Title	Object
NTC 6086:2017 (Icontec, 2017d)	Sugar, extracts, molasses, and cane honey, detection and count of coliforms or <i>Escherichia coli</i> or both, plate counting method.	Establishes the test method for detecting and counting coliforms, <i>Escherichia coli</i> or both in granulated sugar, lichen sugar, extracts, molasses, and cane honey by the plate counting technique.
NTC 3908:2017 (Icontec, 2017e)	Sugar, extracts, molasses, and cane honey, aerobic mesophilic bacteria count, plate count method.	Establishes the test method to determine the count of aerobic mesophilic bacteria in granulated sugar, liquid sugar, extract, molasses, and cane honey by the plate counting technique.
NTC 1311:2009 (Icontec 2009)	Agricultural products, panela.	Establishes the requirements and tests that must comply with the panela intended for human consumption.

Source: own elaboration.

Sampling or other sampling plans may be governed by the following standards:

- NTC-ISO 2859 (Icontec, 2002) parts 1, 2, 3 or 4: sampling procedures for attribute inspection. Part 1: Sampling plans determined by the acceptable quality level (NAC) for batch-to-batch inspection.
- NTC-ISO 3951-1, 2, 3, 4 and 5 (Icontec, 2009): sampling procedures for variable inspection. Part 1: Specification for simple sampling plans classified by acceptable quality level (NAC) for batch-to-batch inspection for a single quality characteristic and a single NAC.

### 3.2. Tracking sources on the Scopus platform

During the years 1990 to 2021 (February), in the Scopus database platform, the following results were found for the keywords of each of the general lines in the aspects explored in cane honey and its derivatives.

#### • Identification of global research and development trends

- **Panela:** this keyword yielded 485 primary documents, 228 secondary documents and 300 patents. Within the primary documents, since 2017, more than 40 entries have been submitted per year, in 2020 the largest number was registered, with 55 entries. At an international level, Brazil and Colombia have the highest number of entries, with 87 and 76, respectively. As for the kind of documents, the majority of figure is presented in the article 375-type, moreover, the most referenced area of study are agricultural and biological sciences with 241, followed by the social sciences, with 80 entries. The summary of the information is reported in Figure 1.

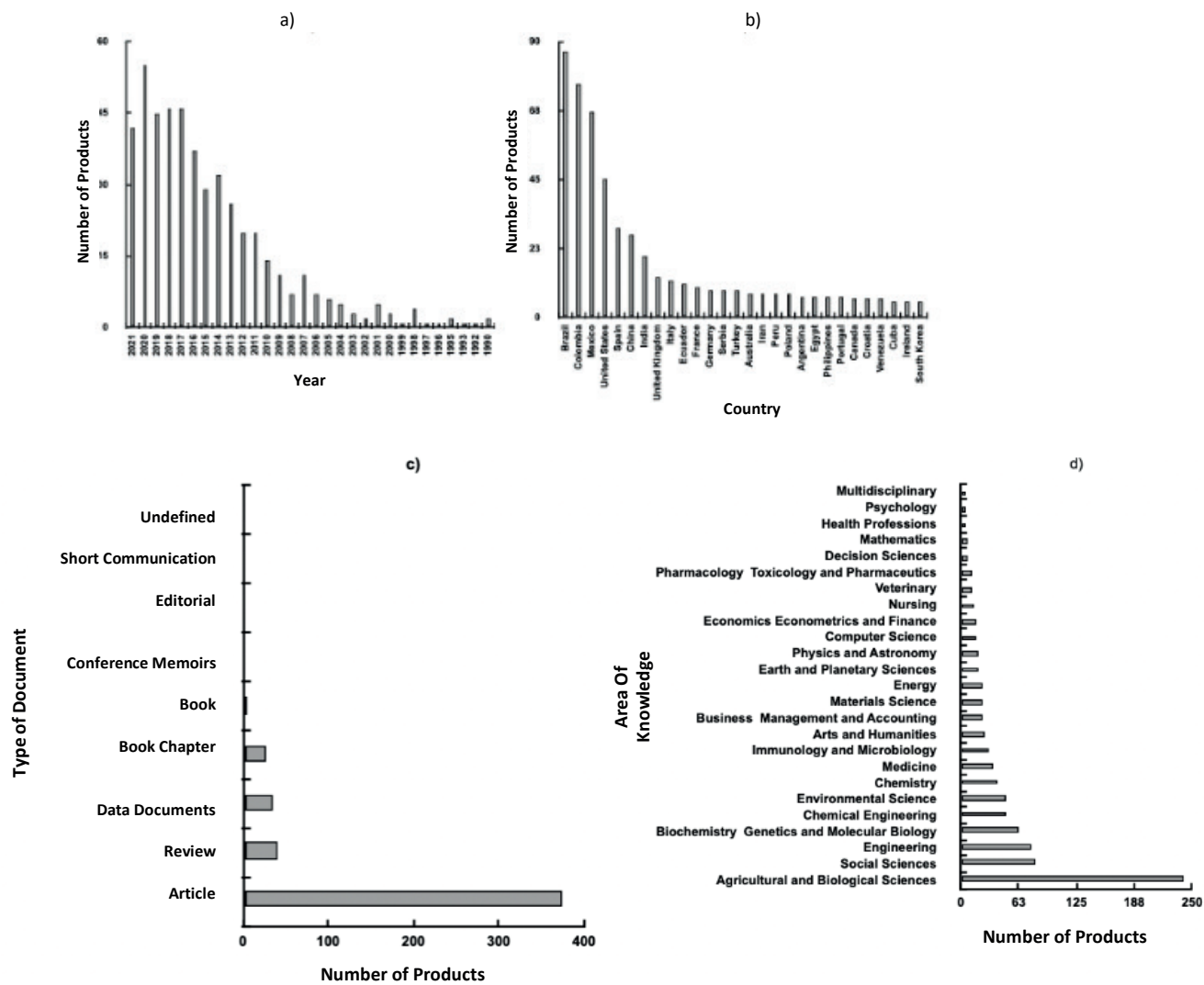


Figure 1. Analysis of the primary documents found for the keyword "panela" in the Scopus database platform, arranged by a) year, b) country, c) type of document, d) area of knowledge  
 Source: own elaboration.

- **Muscovado:** 21 primary documents, 4 secondary documents and 5216 patents. In the set of primary documents, the year with the highest number of entries is 2021, with 4, in the same way, it is evident that after 2019 this number of entries has been increasing. The countries that have reported the most documents are the Philippines and China, with 5 and 3, respectively. Colombia submits one report. The type of most referenced documents were the articles, with 14. Within the areas covered by the documents, the subareas of agricultural and biological sciences stand out with 11, and the area of biochemical genetics and molecular biology, with 4 entries. The summary of the information is reported in Figure 2.

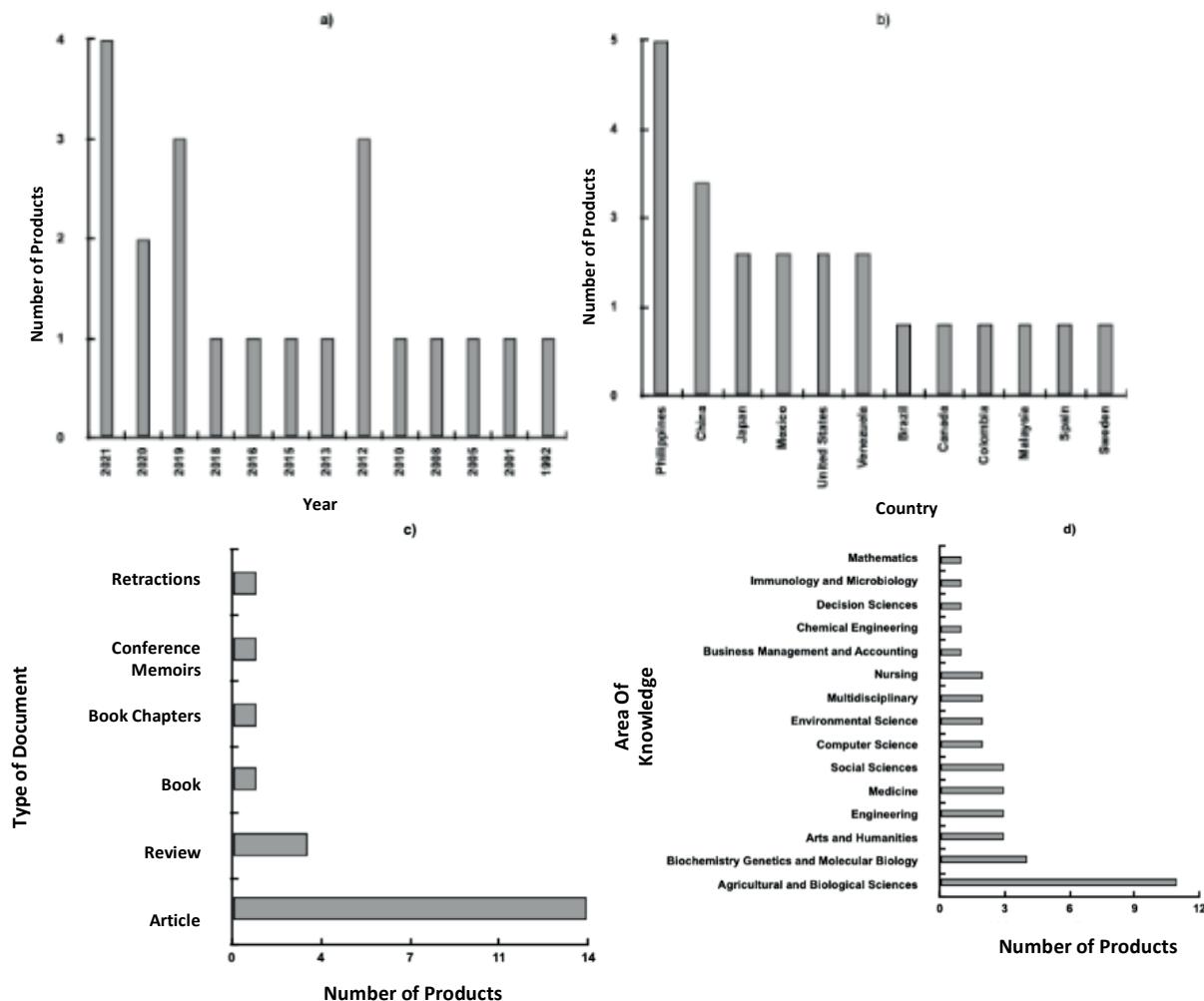


Figure 2. Analysis of the primary documents found for the keyword "muscovado" in the Scopus database platform, arranged by a) year, b) country, c), d) area of knowledge  
Source: own elaboration.

- **Raw sugar:** This keyword yielded 5,5,133 primary documents, 385 secondary documents and 277,163 patents. As of 2011, more than 2,000 documents have been reported per year, with 2020 presenting the highest number, with 6,283. So far in 2021, there are 3,924. At an international level, China has 8,782 and the United States has 6,980. In Colombia there are 468, and it is surpassed in Latin America by Mexico with 1,039, and by Argentina with 473. In the types of documents, the articles present 40,789, revisions add up to 6,935 and book chapters resulted in 3,778. Of particular interest are the areas in which these documents are located, the subareas of agricultural and biological sciences with 21,205 and the area of biochemical genetics and molecular biology with 12,517, microbiology and immunology with 5,794, medicine 3,824, and in pharmacology, toxicology, and pharmacy with 2,702. The summary of the information is reported in Figure 3.

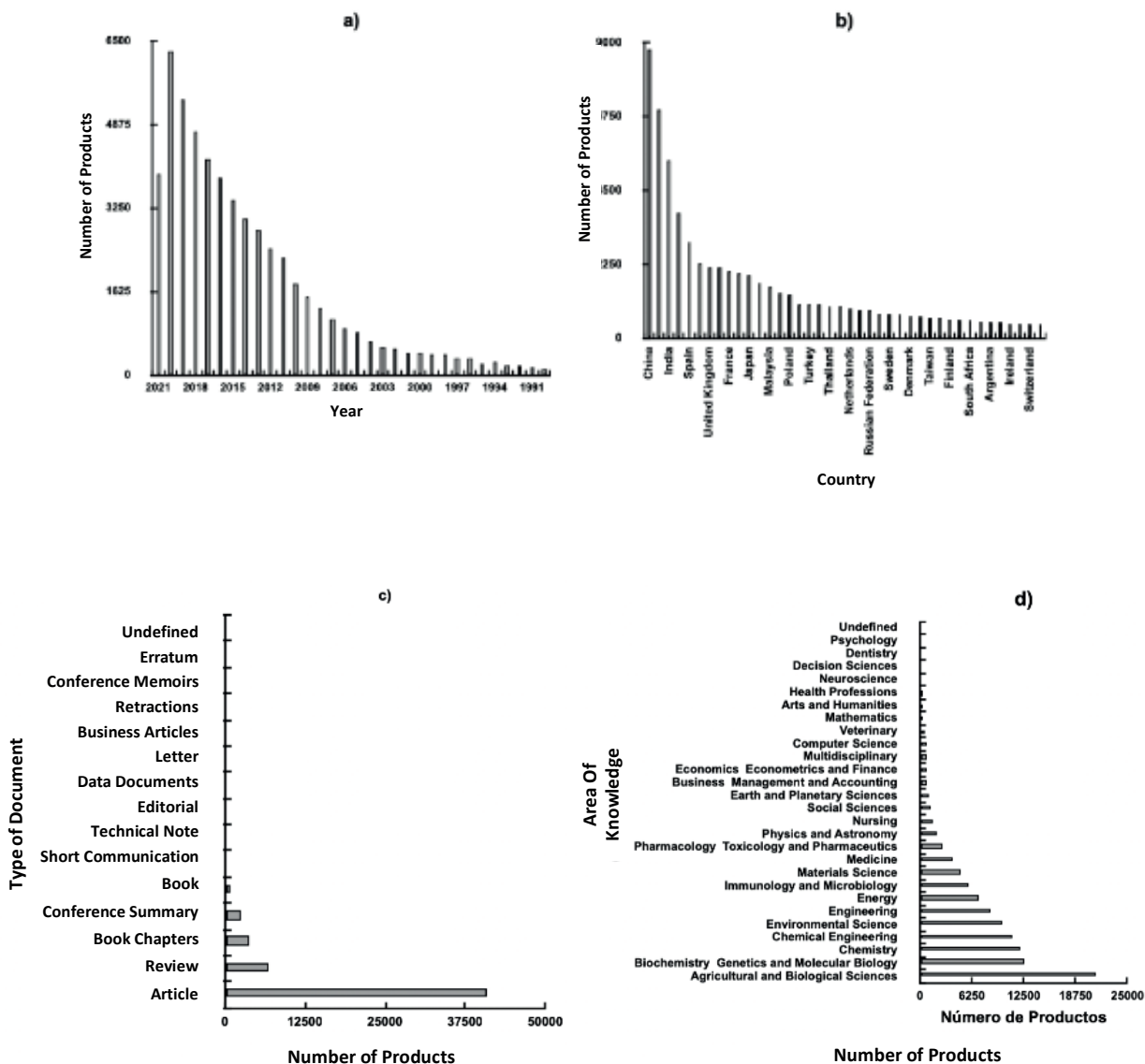


Figure 3. Analysis of the primary documents found for the keyword "Raw sugar" in the Scopus database platform, arranged by a) year, b) country, c) type of document, d) area of knowledge  
Source: own elaboration.

- **Brown sugar:** yielded 186,850 primary documents, 263 secondary documents and 220,484 patents. After 2014, more than 10,000 entries have been submitted per year, where 2020 is the one that registers the most entries, with 15,312, and 9,438 so far in 2021. The countries that report the highest number are the United States, China, the United Kingdom and Germany with 60,824, 20,159, 17,425 and 13,503, respectively. Colombia is 595 documents. Articles are the most recurrent way to report information, with 129,918, followed by reviews, with 33,565. The area of biochemical genetics and molecular biology with 61,236 articles, agricultural and biological sciences with 53,063, and medicine with 42,101. The summary of the information is reported in Figure 4.

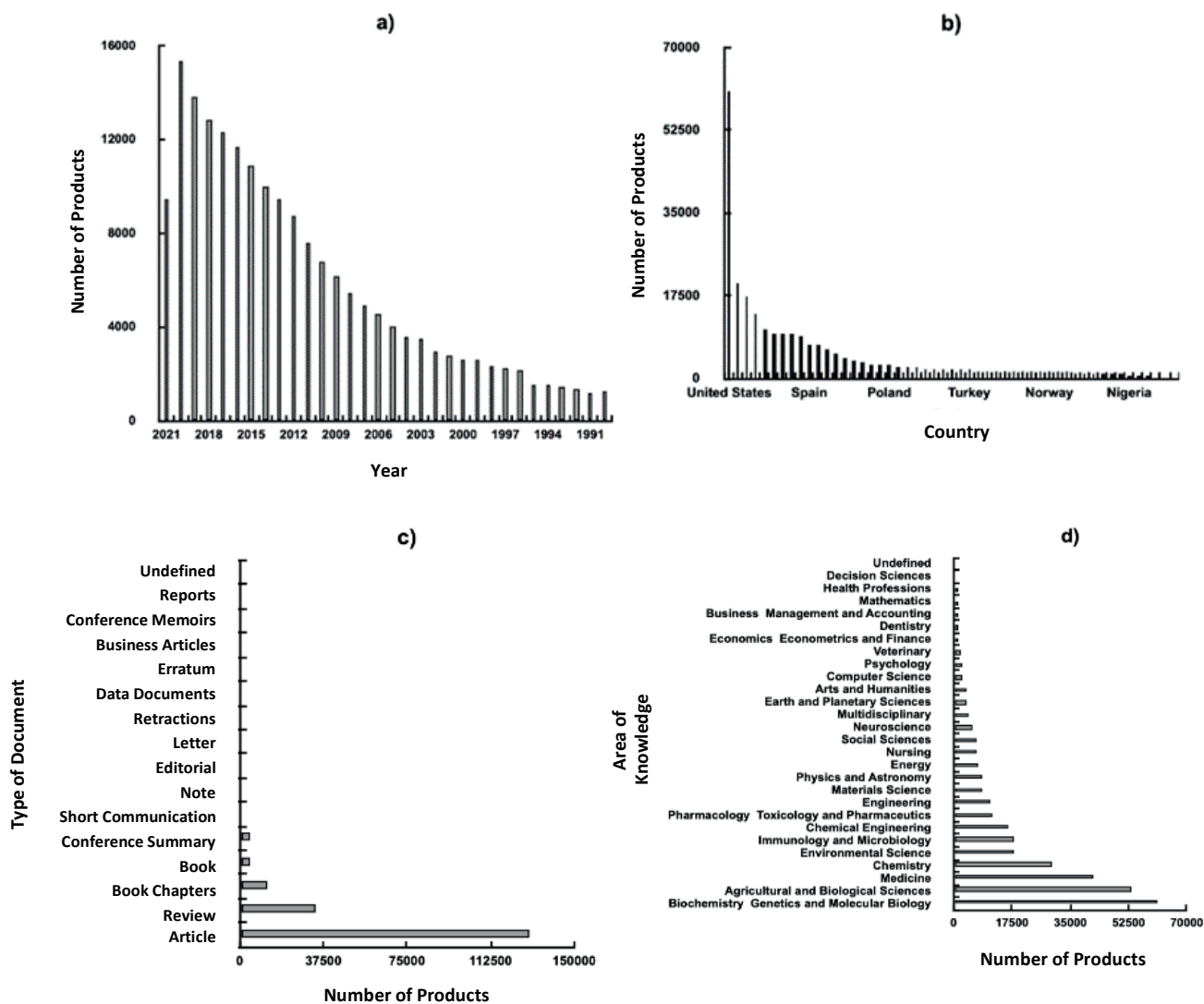


Figure 4. Analysis of the primary documents found for the keyword "Brown sugar" in the Scopus database platform, arranged by a) year, b) country, c) type of document, d) area of knowledge

Source: own elaboration.

- **Sugar cane:** 61,663 primary documents, 6,039 secondary documents and 54,379 patents. As of 2012, more than 3,000 entries are registered per year, 2020 registers, the highest number with 5,074 entries, in the current year there are 3,043. The countries that report the most documents are Brazil and the United States with 11,838 and 9,259, respectively. Colombia has 885 records. Articles are the most published type of paper on this topic with 47,910, representing around 78 %. The areas of publication are focused on agricultural and biological sciences with 24,990, environmental sciences with 13,323, and biochemical genetics and molecular biology with 10,818. The summary of the information is reported in Figure 5.

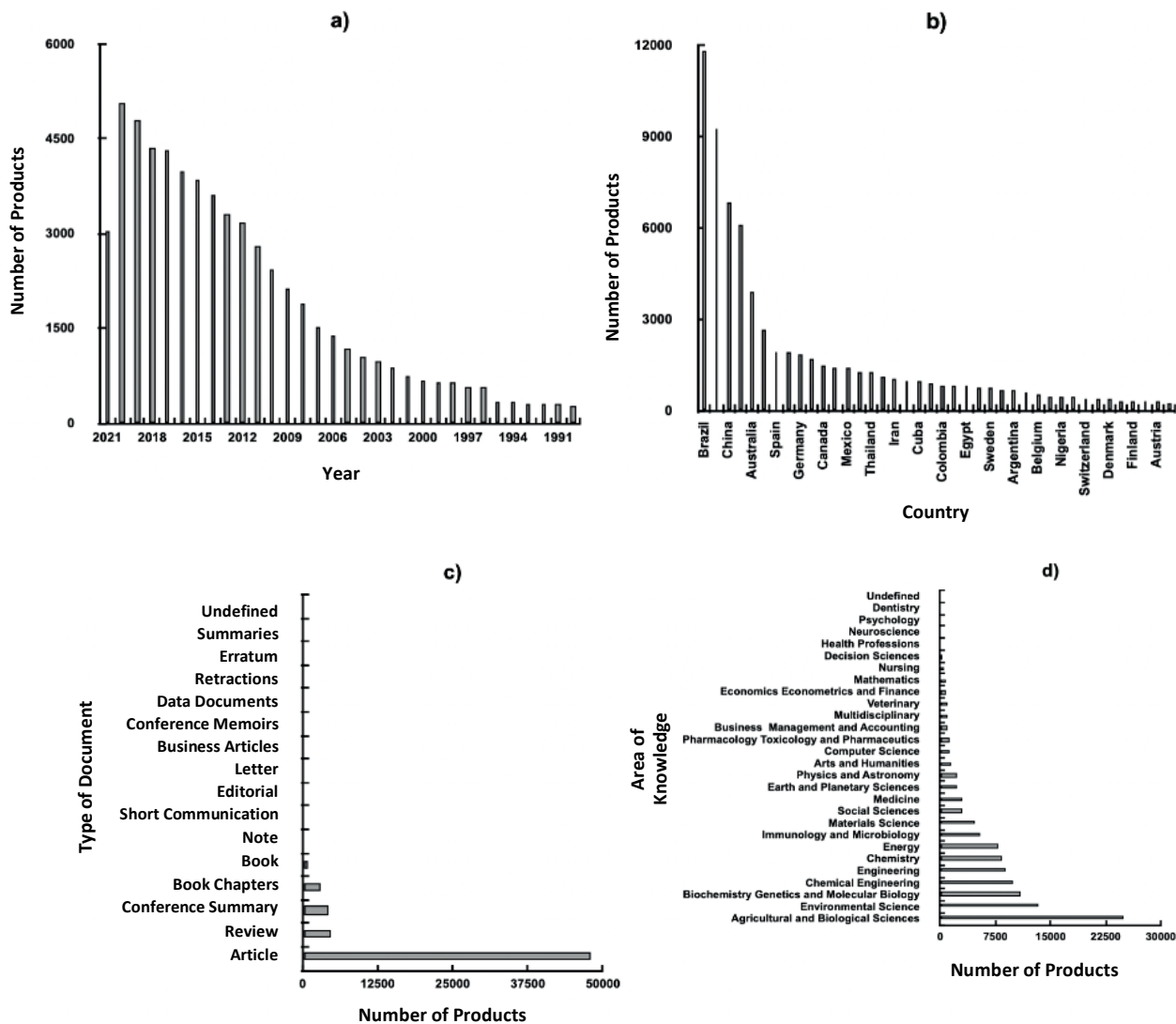


Figure 5. Analysis of the primary documents found for the keywords "Sugar cane" in the Scopus database platform, arranged by a) year, b) country, c) type of document, d) area of knowledge  
Source: own elaboration.

- **Sugar cane extracts:** This keyword yielded 7,470 primary documents, 12 secondary documents and 27,466 patents. Within the years, there is an increase in the number of publications, from 2013, as there have been more than 400 per year. The year 2020 has the highest number with 751, in the current year, 517 have been made. Brazil leads the publications on this subject with 18 % with 1,367 entries, followed by the United States with 12 % represented in 906 documents. Colombia registers 64 entries. The most generalized type of documents are the articles with 5,594, and those related to agricultural and biological sciences have the largest number with 3216. The summary of the information is reported in Figure 6.

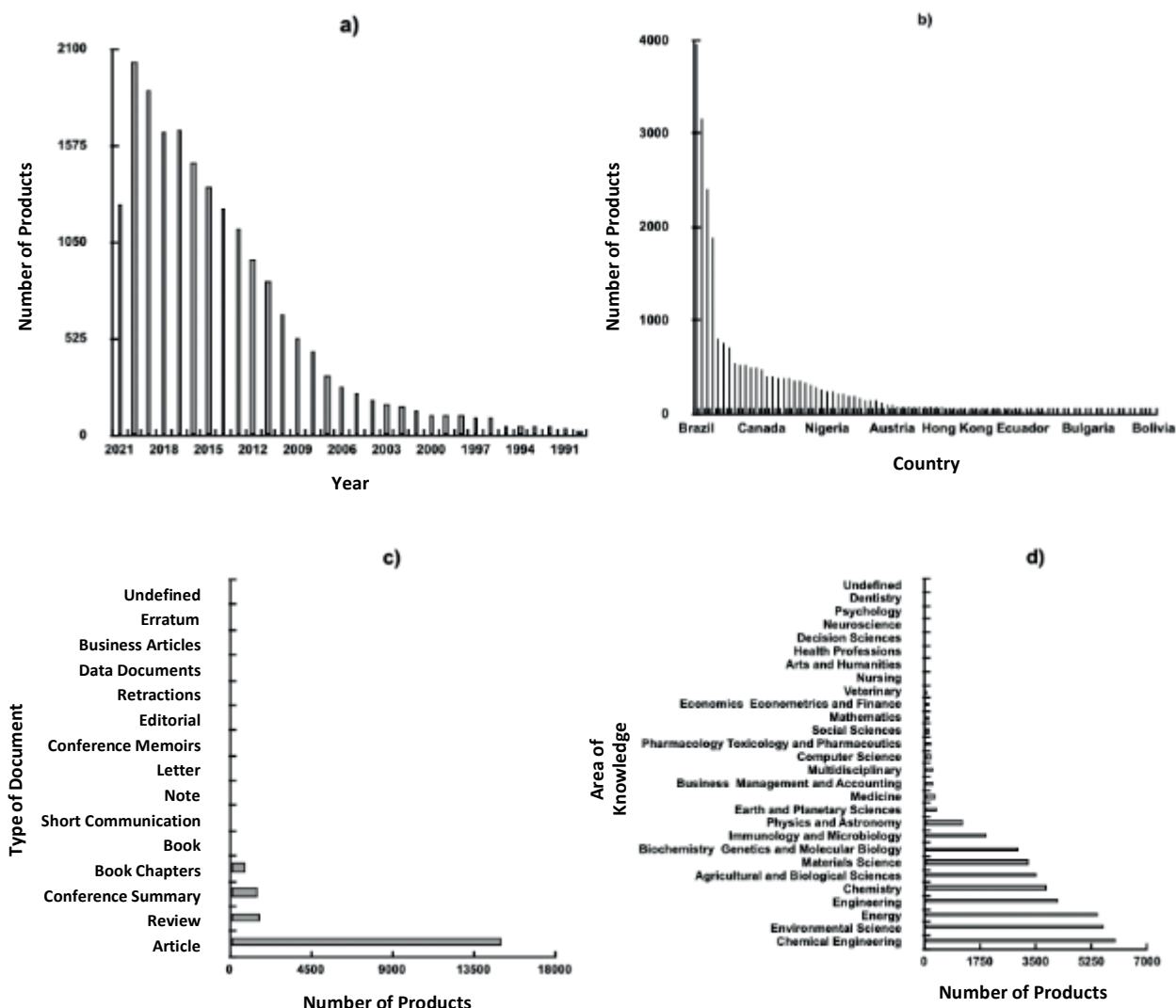


Figure 6. Analysis of the primary documents found for the words "Sugar cane extracts" in the Scopus database platform, arranged by a) year, b) country, c) type of document, d) area of knowledge  
Source: own elaboration.

### • Analysis of possible final products

- **Sugar cane products:** this keyword yielded 28,152 primary documents, 135 secondary documents, and 49,899 patents. Since 2016, more than 2,000 entries have been submitted per year, 2020 is the one in which more documents have been generated with 2,864. So far in 2021, there are 1,813 entries. The countries with the highest number of documents generated are Brazil with 4,873, the United States with 4,119, and China with 3,518. Colombia registers 432 documents. Articles are the most generated kind of document with 20,833. The summary of the information is reported in Figure 7.

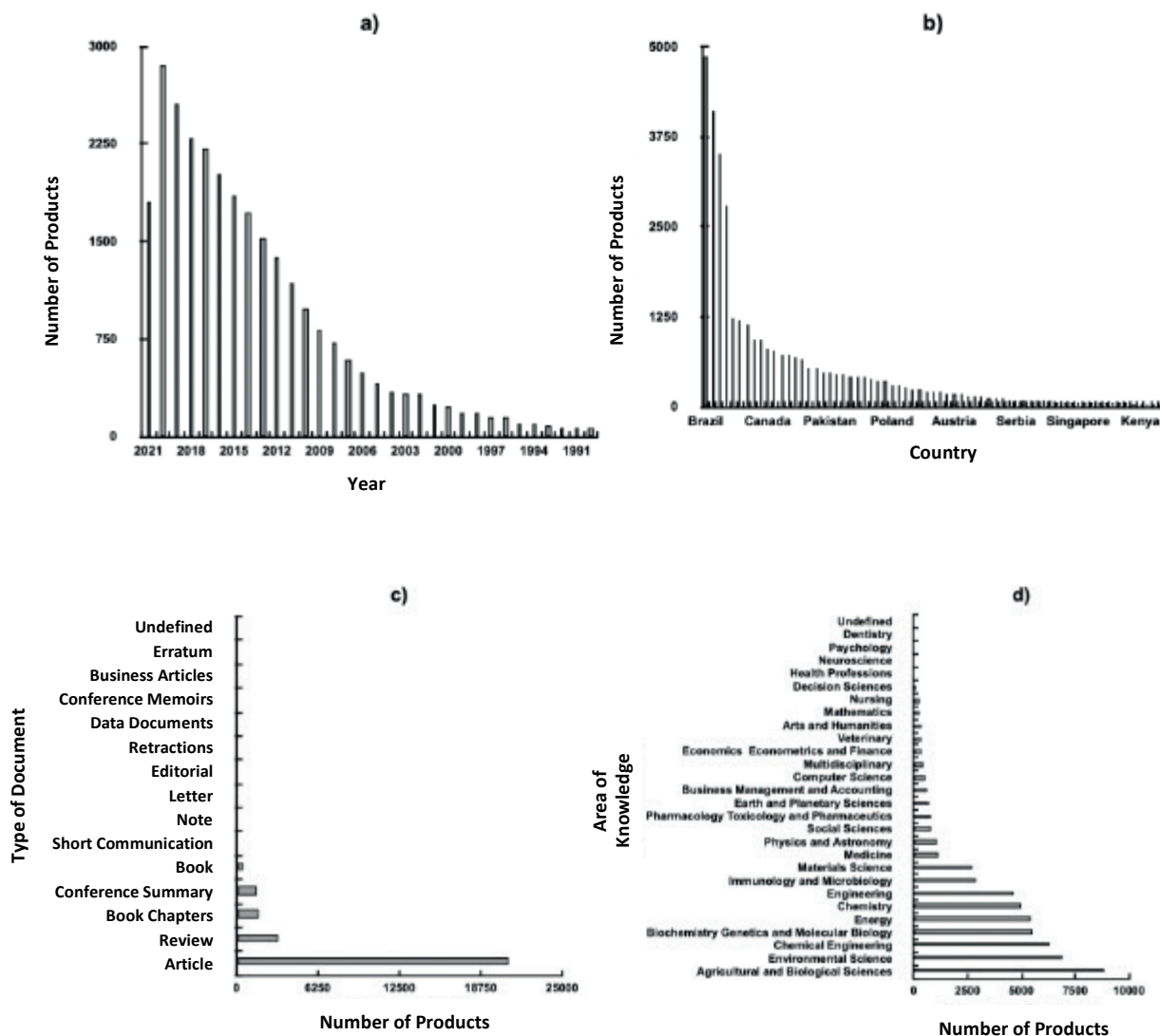


Figure 7. Analysis of the primary documents found for the words "Sugar cane products" in the Scopus database platform, arranged by a) year, b) country, c) type of document, d) area of knowledge  
Source: own elaboration.

- **Sugar cane extracts:** this keyword yielded 7,474 primary documents, 251 secondary documents, and 10,775 patents. Publications in this line have increased in recent years, so much so, that from 2017 more than 500 are registered per year and in 2020 666 were reported. India registers 16.6 % of publications with 1,237 and Colombia has published 2 % with 147 documents. Articles constitute 75 % of the type of documents generated, represented in a total of 5,595. The most explored subarea is agricultural and biological sciences, which have the highest number with 3,735. The summary of the information is reported in Figure 8

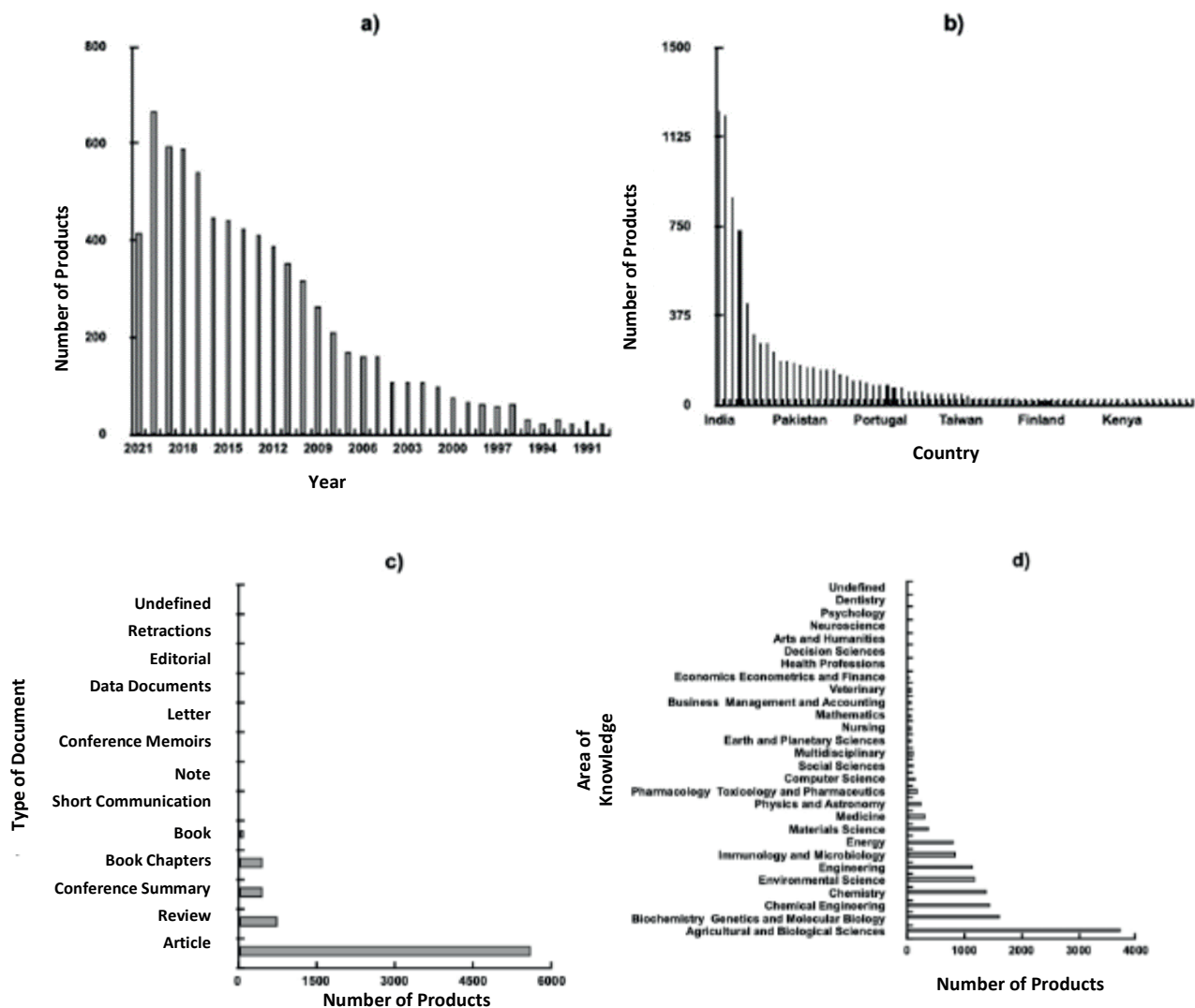


Figure 8. Analysis of the primary documents found for the word "Sugar cane extract" in the Scopus database platform, arranged by a) year, b) country c), type of document, d) area of knowledge

Source: own elaboration.

- **Crude sugarcane bagasse:** this keyword yielded 19,382 primary documents, 5 secondary documents, and 2,289 patents. Since 2017, more than 1,500 entries have been registered per year, and 2020 is the year that shows the most documents. The country with the most entries is Brazil with 3,961, followed by China with 3,157 and Colombia with 308 entries. Articles remain the most widely used way to report findings with 15,096. The sub-areas with the highest volume of entries, there is chemical engineering with 6,032, environmental sciences with 5,668, and energy with 5,468. The summary of the information is reported in Figure 9.

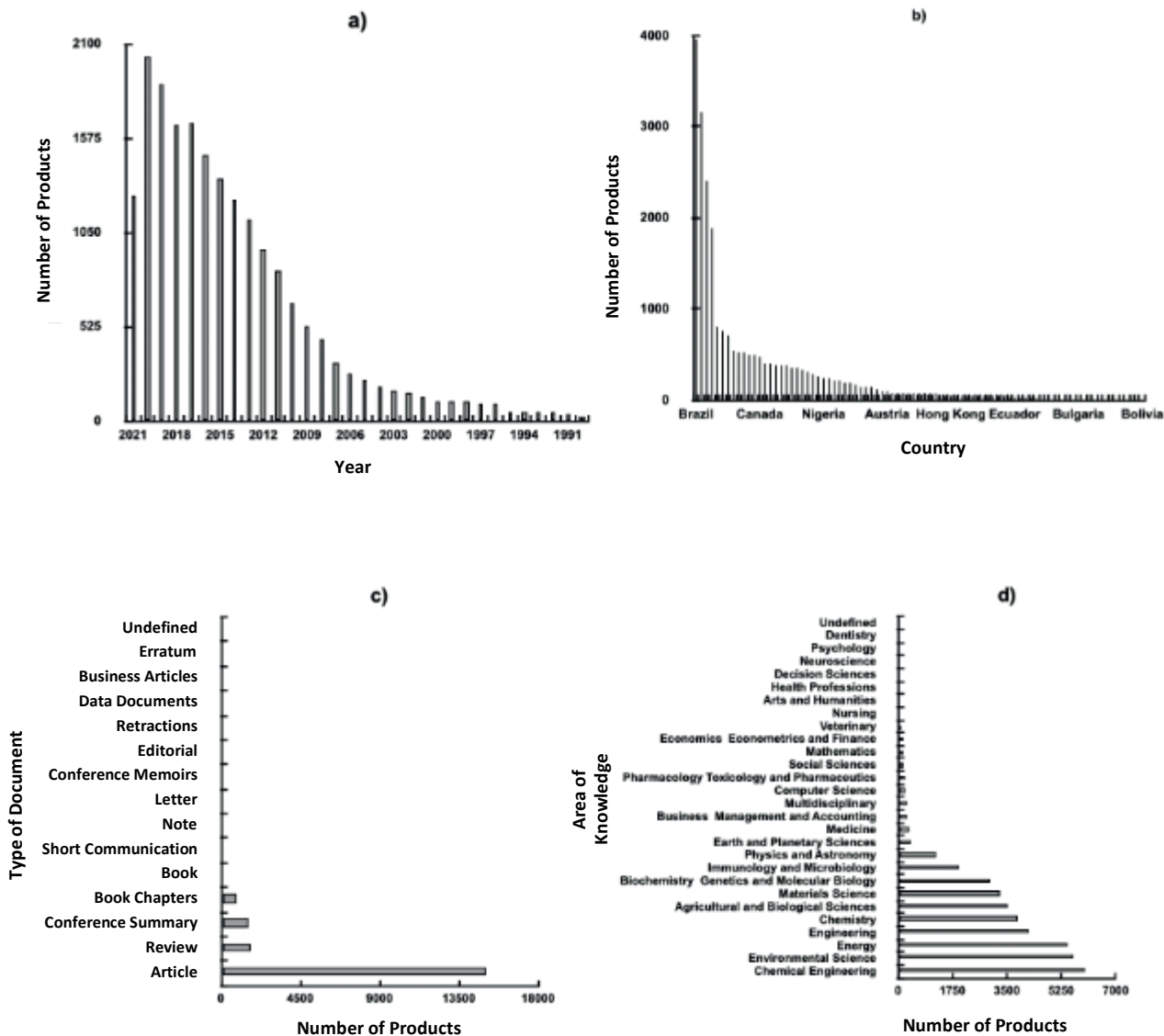


Figure 9. Analysis of the primary documents found for the word "Sugarcane bagasse" in the Scopus database platform, arranged by a) year, b) country c), type of document, d) area of knowledge  
Source: own elaboration.

• **Sugarcane straw:** this keyword yielded 27,833 primary documents, 120 secondary documents, and 6,891 patents. Since 2013 more than 1,000 entries are presented per year for this keyword. The year with the highest number of entries was 2020 with 4,613, in 2021, to date, the figure adds up to 2,989. The country with the most entries is China with 7,008, followed by Brazil, India, and the United States with 3,858, 3,788, and 2,883, respectively. Colombia reports 289 documents. Articles are the most recurrent form of entry with 21,948, followed by reviews with 3209 and book chapters with 1,347. In the subareas of these documents, environmental sciences show 9,995, energy 7,696, and chemical engineering 7,747. The summary of the information is reported in Figure 10.

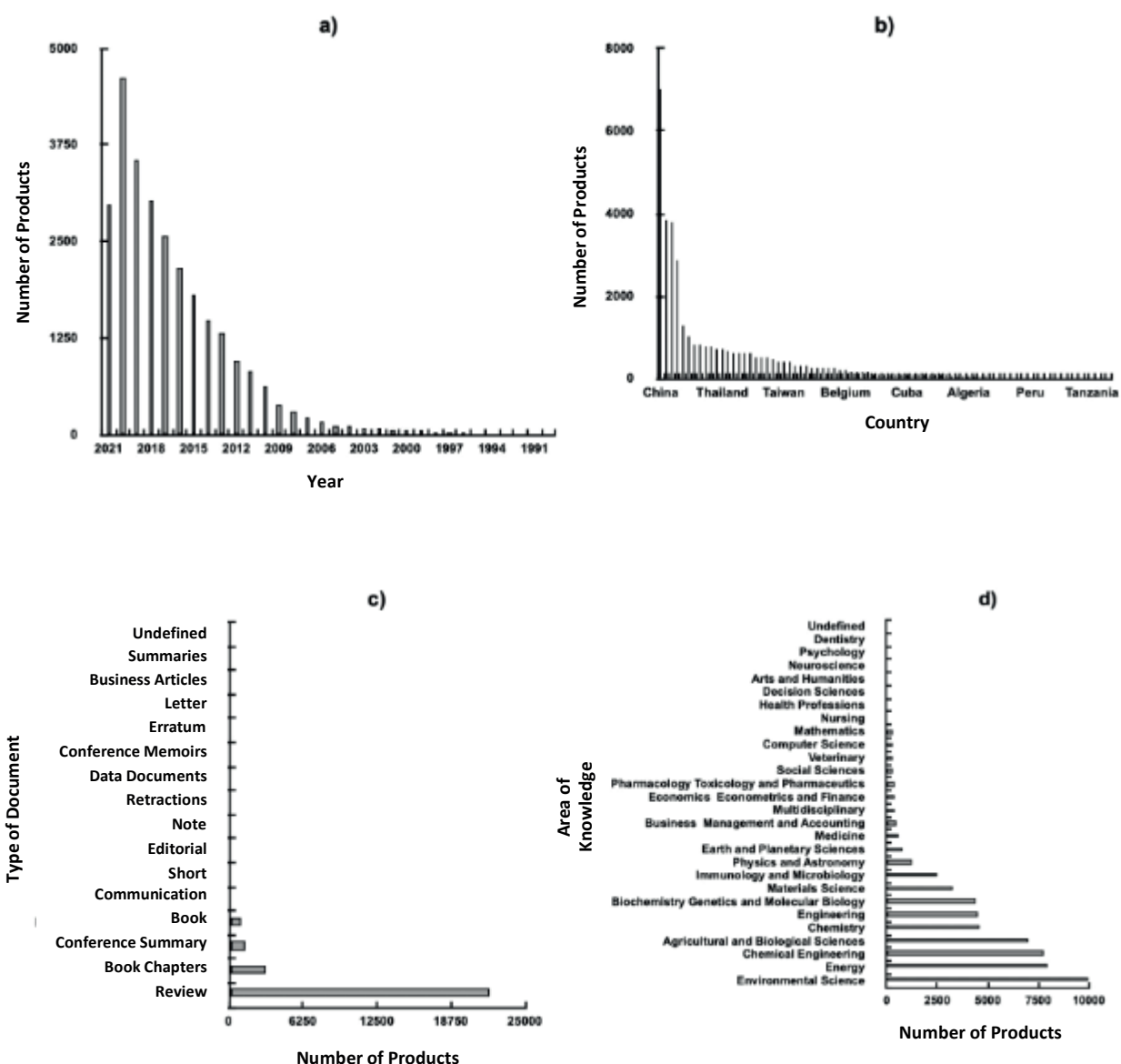


Figure 10. Analysis of the primary documents found for the word Sugarcane straw in the Scopus database platform arranged by a) year, b) country c), type of document, d) area of knowledge  
Source: own elaboration.

### 3.3. Other characterization protocols

The protocols described by the different NTCs are limited in scope. Therefore, the protocols not contained in the NTCs listed in Tables 2 and 3, or that are not used as references thereto, are described below, which can be explored to measure other indicators of quality, the content of biomolecules or contaminants relevant to the industry of products derived from the use of sugar cane. These protocols can be divided into two: normalized and non-standardized.

### • **Standardized protocols**

This group of standards and protocols correspond to determinations referred to in Codex Alimentarius (Food and Agriculture Organization [FAO], 2019), for sugary products and honey:

- **Moisture Content:** this determination presents several methodological options for the sugar matrix or similar products such as honey. There is ISO 1741:1980 (International Organization for Standardization [ISO], 1980a) and ISO 1742:1980 (ISO, 1989b), which determine the content of water by heating using a vacuum furnace for sugars.

- **pH:** this measurement is performed potentiometrically by the ICUMSA GS 1/2/3/4/7/8-23 method (ICUMSA, 2009b).

- **HPLC sugars:** ISO 10504:2013 (ISO, 2013a) refers to the methodology for determining reducing sugars, glucose, and fructose, by HPLC with a refractive index detector. It can also be used to measure disaccharides, such as sucrose or other ingredients. It is a technique that allows for measuring monosaccharides, disaccharides, and other polysaccharides, that enables the measurement of total and reducing sugars, in less time and in a more accurate, repeatable, and reproducible way.

- **Color:** ICUMSA GS9/1/2/3-8 (ICUMSA, 2011c) shows a methodology to determine the color of sugars or mixtures thereof. It is important to determine this parameter, since the addition of dyes is common in products such as panela or smoothies, with the aim of deceiving the consumer by simulating the color of the product.

### • **Non-standard protocols**

Next, the possible protocols that can be adapted for the measurement of other parameters in sugarcane products are presented:

- **HPLC Sugars (Glyad, 2002):** 100 g of product is weighed and poured into an Erlenmeyer flask with 250 mL glass stopper, dissolved with 200 mL of distilled water. Then, they are poured into a 500 mL volumetric flask and reinforced with distilled water. The sample solution is then filtered through 0.22 $\mu$ m membranes before injection. The chromatographic separation of sugars (sucrose, fructose, and glucose) is achieved with an HPLC system in isocratic mode. Samples are analyzed in a carbohydrate column (250 x 4.6 mm I.D., 5 $\mu$ m) equipped with a protective column (12.5 x 4.6 mm D.I.). The temperatures of the column and the refractive index detector (RID) are set at 30 and 35 °C, respectively. The mobile phase is comprised of acetonitrile and water (75:25, v/v), with a flow of 1.0 mL/min. The injection volume is 10  $\mu$ L. Maltose is used as an internal standard for quantification. The content is reported as mg sugar/100 g fresh product.

- **Determination of total phenolic content (TPC) and total flavonoid content (TFC):** TPC and TFC are measured using the method established by Wang, Melnyk, Tsao, and Marcone (2011). The TPC of each sample is calculated by the regression equation of the gallic acid-AG calibration curve. The results are expressed in milligrams of gallic acid equivalents per 100 mg dry weight of fresh product (mg AG/100 mg). The TFC of each sample is calculated using the regression equation of the catechin calibration. The results are expressed as catechin milligrams equivalents/100 mg of fresh product (mg CE/100 mg).

- **Measurement of antioxidant activity by oxygen radical absorption (ORAC):** the antioxidant activity of sugarcane products is determined by ORAC assay, as described by Wootton-Beard, Moran, and Ryan (2011) and Thaipong, Boonprakoba, Crosby, Cisneros-Zevallos, and Hawkins (2006). In the ORAC assay, all reagents are prepared freshly and dissolved in phosphate buffer (75 mM, pH 7.4). Trolox (used as standard) and samples are diluted to serial concentrations with tampon phosphate and 20  $\mu$ L is transferred to a 96-well black wall

plate (Corning Scientific, Corning, NY, USA). Followed by the addition of 200  $\mu\text{L}$  of fluorescein sodium salt (0.96  $\mu\text{M}$ ). After incubation of 20 min at 37 °C, 20  $\mu\text{L}$  of 119 mM Acid2,2'-azino-bis-(3-ethylbenzothiazoline)-6-sulfonic-ABAP are added to each well. Fluorescence intensity is measured every 5 min for 35 cycles at an excitation wavelength of 485 nm and at an emission wavelength of 535 nm. Results are expressed as  $\mu\text{mol}$  equivalents of Trolox per milligram of fresh produce ( $\mu\text{mol TE}/\text{mg}$ ).

- **Measurement of antioxidant activity by peroxy radical scavenging capacity (PSC):** in the PSC assay (Shahidi; Zhong, 2015), 100  $\mu\text{L}$  of fresh produce or its extract is added to a lack microplate of 96 wells. Then, 100  $\mu\text{L}$  of 33.15  $\mu\text{M}$  Dichloro-dihydro-fluorescein diacetate-DCFH and 50  $\mu\text{L}$  of 2,2'-azino-bis-(3-ethylbenzothiazoline)-6-sulfonic-ABAP 200 mM acid are added. The microplate is incubated at 37 °C for 40 min in darkness. Fluorescence is measured at the excitation wavelength of 485 nm and the emission wavelength of 535 nm. The EC50 of the sample and the PSC value are expressed as  $\mu\text{mol}$  equivalents of vitamin C-VC per mg of fresh product ( $\mu\text{mol VC}/\text{mg}$ ).

- **Determination of reduction potential by ferric reducing antioxidant power (FRAP):** the FRAP test is evaluated according to the method of Benzie and Strain (1996). The FRAP reagent is prepared on the same day of measurement, 200  $\mu\text{L}$  of FRAP reagent and 200  $\mu\text{L}$  of the sample are used. The mixture is incubated at 37 °C for 10 min in darkness. Absorbance is measured at 593 nm relative to a target of reagents also incubated at 37 °C. FRAP data are determined for samples against a known FRAP value standard, ferrous sulfate- $\text{FeSO}_4$  is usually used. The results are expressed as mg  $\text{FeSO}_4/100$  g fresh weight.

- **Lipid peroxidation assay:** lipid peroxidation assays are performed according to the protocol proposed by Jiang, Hunt, and Wolfe (1992).  $\text{Fe}^3$  generated by oxidation of  $\text{Fe}^{2+}$  by hydroperoxides can be determined using ferric ion-sensitive dyes as an indirect measure of hydroperoxide concentration. The results are expressed as mg  $\text{Fe}^3/100$  g fresh weight.

- **Bacterial growth:** bacterial growth, according to the method established by Zhao, Chen, Zhao, and Yu (2015) is used to evaluate the antimicrobial activity of an extract. It is suggested to test the bacteria *Staphylococcus aureus*, *Listeria monocytogenes*, *Escherichia coli*, and *Salmonella typhimurium*. In small Petri dishes or bacterial growth plates, bacteria are grown to a concentration of 106-107 CFU/mL in agar supplemented with 200  $\mu\text{L}$  of extract. Sterile water is used as a negative control and a broad-spectrum antibiotic as a positive control. Dishes are stored in the refrigerator for 6 h at 4 °C and then incubated at 37 °C for 20 h. The antibacterial effect of the extract is evaluated by measuring and comparing the diameters of the inhibition zones, all tests should be performed at least in triplicate.

- **Minimum bacterial inhibitory concentration:** it is determined using standard inocula of 105 CFU/mL of the following suggested bacteria or with any other bacteria of interest: *S. aureus*, *L. monocytogenes*, *E. coli* and *S. typhimurium*. The dilution method is used in series of Nedorostova, Kloucek, Kokoska, Stolcova, and Pulkrabek (2009) and Andrews (2001). The culture means is supplemented with the following final concentrations of extract 0; 0,1562; 0,315; 0,625; 1,25; 2,5; 5.0 and 10.0 mg/mL. Then incubated for 18-24 h at 37 °C with stirring at 150 rpm, the lowest concentration of the extract, necessary to visibly inhibit growth, is determined by counting bacteria by Neubauer chamber. Sterilized distilled water is used as a negative control and a broad-spectrum antibiotic with positive control.

- **Phenolic diversity and derivatives:** the method was reported by Zheng *et al.* (2017), who employed high-resolution mass spectrophotometry-HRMS and proton nuclear magnetic resonance hydrogen-deuterium-HDNMR. The authors report that free phenolic compounds are extracted from powdered or liquid products according to a method previously reported by Wen *et al.* (2015). The sample (100 g) is extracted twice with 1,5 L from a 1:1:1 mixture of acetone 40 %, methanol 40 %, and hydrochloric acid 5 % in water, under dark conditions for 12 h at ambient temperature. The suspension is then combined and centrifuged at 3,500 rpm for 20 min at 4 °C. The supernatant is then collected and concentrated at less than 5 mL by a rotavaporator at a maximum

of 40 °C under a vacuum. The extract is taken to a final volume of 25 mL with the addition of a 20 % methanol solution and stored at -40 °C until further analysis.

The semi-solid residue is collected for the extraction of bound phenolic compounds, which are extracted from the residues after the extraction of free phenols according to a method previously reported by Adom and Liu (2002) and Wang, Chen, Xie, Ju, and Liu (2013). The waste is digested in a 50 mL bottle containing 20 mL of 2 M sodium hydroxide with a stirring speed of 60 rpm at room temperature for 1.5 h under a nitrogen atmosphere. Subsequently, the mixture is neutralized with 1 M hydrochloric acid and extracted with hexane to remove lipids from the mixture. It is then extracted with 20 mL of linden acetate five times. The extracted fractions are gathered and put into the rotavaporator at a maximum of 40 °C under vacuum. The bound phenols are reconstituted at 10 mL with the addition of 20 % methanol. Extracts are stored at -40 °C until further analysis. The run is done in a ZORBAX RRHD SB-C18 column (50 × 2.1 mm D.I., 1.8 µm), Agilent Corporation, USA). The column is kept at 20 °C and at a flow rate of 0.2 mL/min.

- **The diversity of phytosterol-type derivatives by HPLC:** the analysis is carried out according to Novak et al. (2017). A sample of 100 g of product is deposited in a volumetric flask with 200 mL of anhydrous ethanol. Then, it is placed in an ultrasonic bath at 40 kHz for 1 h at 50 °C. Then it is filtered. Ethanol is added until the final volume of the extract is reached at 250 mL. The identification and quantification of phytosterols are carried out according to the method proposed by Indyk, Lawrence, and Broda (1993). Separation is performed on a Moon 5l Column C-18 (250 × 4.6 mm D.I., Phenomenex Ltd.) using mobile phases: methanol and water in a 100:4 ratio (in volume). The injection volume is 20 µL, the flow rate is 1.2 mL/min and the wavelength used for detection should be 205 nm. All analyses are carried out at a temperature of 30 °C. Quantification is based on external calibration and final concentrations are expressed as mg/100 g sample.

- **Determination of acrylamide by high-performance liquid chromatography (HPLC):** the samples are collected at different stages of the panela production process (extraction, pre-cleaning, clarification and liming, evaporation, and concentration, plotting and sweeping), to later be analyzed by HPLC according to the method established by Vargas, Talero, Trujillo, and Caballero (2014), for which the following procedure is performed: for liquid samples, 10.00 mL of cane extract are taken and dissolved in 100 mL of deionized and filtered water. As for the solid samples, 10.00 g are weighed in the stages of evaporation and concentration (honey) and in the plotting and sweeping (panela), to later be pulverized in a mill with extra-fine blades; consecutively the product is dissolved in 100 mL of HPLC-type water and centrifuged at 4,000 rpm for 30 min, to remove most of the solids present; each sample is injected into the equipment in triplicate, subsequently, the data reported by the equipment is extracted from the areas under the curve, and it is therefore interpolated into the equation of the line, and the concentration of analyte present in each of the samples is determined. A C18 column (150 × 4.6 mm, ID) is used with a particle size of 5 µm, at a temperature of 23 °C and a flow of 0.5 mL/min, with a UV-Vis detector at 210 nm. The injection volume is 20µL, an isocratic elution is performed with acetonitrile: water, 1:24 (v/v). To perform the chromatographic run, each of the acrylamide standards and samples of panela or cane products were injected. The running time is 6 min for acrylamide standards because after this time no more signals appeared; and 30 min for the samples, to observe if new signals appeared during this running time. A stock solution of acrylamide, 100 mg/kg is prepared using an analytical grade reagent, acrylamide electrophoresis 99.9 % Merck. This solution is prepared using a class A volumetric balloon. Subsequently, solutions are made at different concentrations of 0; 4; 1; 2; 5; and 10 mg/kg respectively to obtain the calibration curve for the quantification of acrylamide in the samples. Final concentrations are expressed as mg/100 g of the sample.

## 4. Discussion of results

After the information tracking, it could be established that four other species of the genus *Saccharum* have been used to produce cane or sugar honey: *S. barberi*, known as "Indian cane" or "fine" cane; *S. robustum*; *S. sinense*,

known as "Chinese cane"; and *S. spontaneum*, which is known as "wild cane" and is used for hybridization purposes (FAO, 2014; Jaffé, 2012). Focused on the production chain of *S. officinarum*, some technological and market problems were identified (FAO, 2014). The main problems pertain to the low competitiveness of small mills, the poor quality of derived products, lack of homogeneity, environmental damage due to the consumption of firewood and rubber on stoves, restrictions on expanding the market due to the requirements given by the legal regulations for the marketing of sugary products (FAO, 2014), and the need to verify phenolic diversity, antioxidant metabolites and the presence of toxic trace elements, such as heavy metal or acrylamide.

The NTC establishes a valid and current starting point for the start of the product characterization process for the products derived from *S. officinarum*, but it is not enough due to the limited set of parameters thereby evaluated. Considering the tracking made by Icontec (Tables 2 and 3), for cane honey products, the set of NTCs can be divided into two groups, one pertains to the characterization of some physicochemical parameters (Table 2), and the other aims to determine the microbial safety of the product (Table 3). The first group of NTC enables the quantification of some physicochemical parameters and contents of follow-up molecules, mostly sugar and ethanol, which include the NTC 1779:2017 (Icontec, 2017a), NTC 570:2012 (Icontec, 2012a), NTC 1856:2010 (Icontec, 2010) and NTC 6385:2020 (Icontec, 2020a) (Table 2). The tests and parameters to be quantified and reported to establish the physical and chemical characteristics of sugar cane products, such as extracts, syrups, alcoholic fermented and the various types of white sugar, special white sugar, refined and raw sugar are recorded under NTC 1846:2020 (Icontec, 2020b), NTC 3442:2011 (Icontec, 2011) and NTC 440:2015 (Icontec, 2015) (Table 2). The requirements or terminology are set out in NTC 587:1994 (Icontec, 1994a) and NTC 573:2013 (Icontec, 2013). The determination of additives is set forth in NTC 5970:2012 (Icontec, 2012b) and NTC 2369:1994 (Icontec, 1994b) (Table 2). Finally, as for Panela, there is NTC 1311:2009 (Icontec, 2009), which establishes the requirements and tests that panela intended for human consumption must meet (Table 2).

When delving into the content of some NTCs, for example, NTC 1779:2017 (Icontec, 2017a), whereby the content of reducing sugars is determined, it can be noted that it shows a methodological sequence that can lead to several sources of error, which results in the technique being followed by a wide range of associated uncertainty. Some sources of uncertainty are the preparation of the Fehling solution A and B, titration of a boiling solution, the diverse volumetric material, and the endpoint of the titration. HPLC liquid chromatography with a refractive index detector is a reliable, robust alternative with a lower degree of associated uncertainty, as described in ISO 10504:2013 (ISO, 2013a), which also offers less analysis time, produces less residue, and allows quantification in a single run.

On the other hand, the NTC 1856:2010 (Icontec, 2010) shows two ways of determining sulfur dioxide, the two methodologies constantly used, not only in the sugar industry but in other foods. Its adaptation is very complex in laboratories, due to its requirements in terms of equipment, preparation of solutions, false positives, and interferences. The standardized alternatives presented are equally wasteful: ISO 5379:2013 (ISO, 2013b) presents the determination by acidimetry and nephelometry; the ICUMSA GS 2/3-35 (ICUMSA, 2011e) and Nordic Committee on Food Analysis (1990), in their NMKL 135, present a determination by an enzymatic method that is difficult to use, although less wasteful than ISO 5379:2013 (ISO, 2013b); the AOAC Official Method 990.28 presents the determination by the Monier-Williams method, which is also complex to adapt and obtain reproducible measurements. There are other non-standardized methods such as Ho-so *et al.* (2014), where HPLC is used, but these methodologies are still in the process of validation and adaptation to complex food matrices. This determination continues to be a challenge for analytical chemistry.

Finally, NTC 1311:2009 (Icontec, 2009), besides having the issue related to the foregoing determinations, shows a qualitative criterion: it uses color by means of the wool staining test. To determine the color, there are standardized protocols that must be adopted, because, in the panela industry, this is instrumental to determine the ill-intentioned inclusion of dyes to deceive the consumer by simulating an optimal color of the product. This can and must be implemented under NTC 1311:2009 (Icontec, 2009) the ICUMSA GS9/1/2/3-8 (ICUMSA, 2011d), which shows how to determine the color of sugars or mixtures thereof. Regarding the second group,

there are the NTCs that aim to determine some microorganisms which are harmful to human health, including *Escherichia coli*, molds, yeasts, and aerobic mesophilic bacteria, included in the NTC 3953:2017 (Icontec, 2017b), NTC 3954:2017 (Icontec, 2017c), NTC 6086:2017 (Icontec, 2017d) and NTC 3908:2017 (Icontec, 2017e) (Table 3).

Consequently, the limitations of the NTC are clear, regarding the fact that, although they respond to generate basic standards for the trading of products derived from *S. officinarum*, they also fail to contemplate the quantification of vitamins, antioxidants, phenols, anthocyanins or phytosterols, or a contaminant such as acrylamide. However, why is it relevant to measure these groups of molecules? Let's review some scientific evidence that can help us answer this question.

Cane honey and the products made therefrom, such as panela, have great potential in nutritional and commercial terms. In nutritional terms, its share of daily consumption of caloric sweeteners (g/person/day) for 2007 was 46 % in Myanmar, 20 % in Bangladesh, 19 % in Colombia, 10 % in India, and 10 % in Pakistan (Jaffé, 2012). Sucrose is the most important component of cane extract derivatives, between 76.55 and 89.48 %, followed by reducing sugars (3.69 to 10.5 %) and water (1.5 to 15.8 %). The relatively large range of moisture content is due to differences in the conditions of the manufacturing process of this mainly artisanal product. The mineral (ash) content is relatively high (0.3-3.6 %). The protein content ranges from 0.37 to 1.7 % and fat content from 0 to 0.1 %.

The basic difference between cane extract derivatives and refined sugar is the presence in the former of reducing sugars and significant amounts of minerals and other minor constituents, such as phenols, as reported by Semwal, Jai Singh, Kumar, and Malik (2021). The nutritional and functional difference will depend mainly on the determination of this group of minor components (Shaheen *et al.*, 2013; Nimrouzi *et al.*, 2014). At least two rare or complex sugars with functional potential have been identified in cane extract derivatives. D- Psicose, a C-3 epimer of D-Fructose, is one of them, present in small amounts in commercial carbohydrate foods or agricultural products. It has 70 % the sweetness of sucrose, but no calories (Cheung *et al.*, 2012). It has been found that in the derivatives of cane extract there are relatively high amounts of this sugar. In animal models, it has been claimed that D- Psicose has antihyperglycemic properties and antiatherosclerosis effects (Cheung; Oh; Lee, 2012).

An early study in 1949 with anemic rats indicated that the iron in panela is easily absorbed and produces high hemoglobin levels within 18 days (Jaffé; Ochoa, 1949). Two studies support these findings in humans. Olivares, Pizarro, Hertrampf, Fuenmayor, and Estévez (2007) found that the iron adsorption of wheat noodle soup was significantly higher when consumed with panela-sweetened lemonade (11 %), compared to the same meal without lemonade. The analysis was performed with 13 women and was measured by a double isotopic method. Arcanjo, Pinto, Arcanjo, and Amancio (2009) recorded a statistically significant increase in hemoglobin in pre-school children, associated with the consumption of a panela drink with ascorbic acid. Current strategies focus on improving diets and dietary patterns, as well as food fortification with iron and direct supplementation of iron intake (World Health Organization [WHO], 2001); and, more recently, the so-called biofortification, which seeks to increase the iron content in staple crops, by genetic means or by fertilization (Sautter; Gruissem, 2010). The development of consumer products based on cane honey, or any of the cane derivatives, maybe y be a relatively inexpensive and market-friendly strategy, which could be industrially and commercially attractive. A similar idea is reported by Watanabe, Nakabaru, Taira, Ueno, Kawamitsu (2016) and Scheid *et al.* (2020), but in a culture of basidiomycetes.

The cariostatic effect of cane honey and cane derivatives is presumably due to their phosphate content. But a synergistic effect of the addition of phosphates to a diet of brown sugar on the inhibition of dental caries in hamsters suggested the presence of additional bioactive substances (Stralfors, 1966). This has also been found in the collaboration between Ryukyus University and Japan's Taiyo Kagaku Co., which reported the isolation of two phenolic bioactive compounds from sugarcane molasses, which have inhibitory properties against the cariogenic bacteria *Streptococcus mutans* and *Streptococcus sobrinus* comparable to commercial antibacterial agents (Takara; Otsuka; Wada; Iwasaki; Yamashita, 2007) because of glucosyltransferase inhibition.

Antioxidant and cytoprotective activities are also found in brown sugar produced from panela, suggesting that the bioactive compounds behind these properties are transferred from cane honey (Seguí; Calabuig-Jimenez; Betoret; Fito, 2015). Researchers from the Central Institute of Food Technology Research and the University of Mysore, India, found that a brown sugar concentration of 4 mg/mL provided 97 % protection in a research model of NIH 3T3 cell oxidation (Harish Nayaka; Sathisha; Manohar; Chandrashekar; Dharmesh, 2009). On the other hand, a group from the Ehine Graduate School of Medicine and the Foundation of International Oriental Medicine Research showed that topical application for 19 weeks of the unsweetened fraction of brown sugar prevented chronic skin aging induced by UVB rays in an in vivo model with hairless mice with melanin (Sumiyoshi; Hayashi; Kimura, 2009). It is suggested that this may be due to the inhibition of increased expression of matrix metalloproteinase-2 and vascular endothelial growth factor (Harish Nayaka *et al.*, 2009). Similar results are reported by Zhao *et al.* (2018) and, Uchenna, Adaeze, and Steve (2015). Researchers from Japanese, Egyptian, Finnish, South Korean, Thai Universities and one Japanese sugar company have shown that brown sugar produced from panela has functionally and morphologically restorative effects in chicken intestines, with significant consequences for body weight gain, indicating a possible role in animal nutrition (El-Abasy *et al.*, 2004; Amer *et al.*, 2004).

Anticancer effects of sugarcane derivatives have been reported. Yoshimoto, Kurata, Fujii, and Hou (2008) found, through in vitro and in vivo experiments, that sugarcane vinegar depressed an induced mutation in *Salmonella typhimurium* TA98. The bioactive component, 3', 5'-di-O-methyltricetin is 3', 5'-di-O-methyl or tricetin, extracted by chromatography, estimated as phenolic, effectively depressed the proliferation of a promyelocytic leukemia cell line. Its administration to mice on a 5 % diet significantly stimulated the activity of killer cells and showed a tendency to depress tumor cell proliferation. The phenolic extract containing the glycosides tricetin (5,7,4-trihydroxy-3,5-dimethoxyflavone), apigenin (4,5,7-trihydroxy-flavone), and luteolin (3, 4, 5,7-tetradihydroxy-flavone), extracted from sugarcane extract by a Brazilian group, showed antiproliferative *in vitro* activity against several human breast cancer cell lines, with greater selectivity towards resistant NIC/ADR line cells (Duarte-Almeida; Novoa; Linares; Lajolo; Genovese, 2006).

Sucrose is the most important component of cane extract derivatives, between 76.55 and 89.48 %, followed by reducing sugars (3.69 to 10.50 %) and water (1.50 to 15.80 %). The relatively large range of moisture content is due to differences in the conditions of the manufacturing process of this mainly artisanal product. The mineral (ash) content is relatively high (0.3-3.6 %). The protein content ranges from 0.37 to 1.7 % and fat content from 0 to 0.1 %. No dietary fiber has been reported. The basic difference between cane extract derivatives and refined sugar is the presence in the former of reducing sugars and significant amounts of minerals and other minor constituents. The nutritional and functional difference will then depend on the determination of this group of minor components (Guerra; Mujica, 2010; Colombian Institute of Family Welfare [ICBF], 2014; Rodriguez; Segura, 2004; Waheed; Ahmad, 2008).

For minerals in cane extract derivatives, there are ranges for calcium, chloride, and potassium around 100 mg/100 g, followed by phosphorus, sodium, and magnesium around 10 mg/100 g, copper and iron around 1 mg/100 g, manganese and zinc around 0.1 mg/100 g and chromium and cobalt around 0.01 to 0.001 mg /100 g (Guerra; Mujica, 2010; ICBF, 2014; Rodriguez; Segura, 2004; Waheed; Ahmad, 2008).

As for the content of vitamins present in cane extract derivatives, vitamin A is reported in a range of 1.90 mg/100 g, carotenes 80.75 µg/100 g, vitamin B1 0.03 mg/100 g, vitamin B2 0.07 mg/100 g, vitamin B3 2.14 mg/100 g, vitamin B5 0.70 mg/100 g, vitamin B6 0.25 mg/100 g, vitamin B9 3.33 µg/100 g, vitamin C 4.23 mg/100 g, vitamin D2 2.17 mg/100 g and vitamin E 55.65 mg/100 g (ICBF, 2014; Shaheen *et al.*, 2013; Singh *et al.*, 2015; Waheed; Ahmad, 2008).

The antioxidant activity of cane extract derivatives has been quantified by free radical scavenging assays, these measures are difficult to compare due to different methodologies and units of measurement, but it has important antioxidant capabilities. The study published by Payet, Shum-Cheong-Sing, and Smadja

(2005) showed that the DPPH method obtains 22.1 % and the ABTS method between 47.1-51.3 % inhibition. Harish Nayaka *et al.* (2009), using the DPPH method, report 7.81 µg/ml EC50. Okabe *et al.* (2008), using the DPPH method, show 935.67 mmol Trolox equivalent/100 g. Phillips, Carlsen, and Blomhoff, (2009), using the RAP method, report 0.204 mmol/100 g. The relative importance of this antioxidant capacity has been partially addressed by Phillips *et al.* (2009), who calculated that the increase in antioxidant content that would result from the substitution of refined sugar with raw cane sugar would be 0.1 to 0.2 mmol per day. Intake of antioxidants from cane extract derivatives would be similar to the contribution of tea or fruits, which are considered high in antioxidants (Phillips *et al.*, 2009). Replacing refined sugar with cane extract derivatives can contribute significantly to the cumulative antioxidant content of the diet.

Since 2006, at least eight reports have been published on antioxidant activity in sugarcane leaves, other parts of the plant, sugarcane extract, and molasses (Abbas *et al.*, 2013). This activity has been quantified by assays of radical-capturing activity and others, such as DPPH, plasma ferric reducing capacity (FRAP), β-carotene/linoleic acid, and phosphomolybdenum reduction. All these studies agree on the relatively high antioxidant activity of sugarcane, sugarcane extract, and molasses, and on their potential functional importance. Antioxidant activity correlates significantly with the total phenolic content measured by the Folin-Ciocalteu enzyme (Harish Nayaka *et al.*, 2009; Payet *et al.*, 2005). Other studies identify individual phenolic antioxidant compounds in the sugarcane and sugarcane extract plant (Abbas *et al.*, 2013, 2014; Vila; Colombo; of Lira; Yariwake, 2008).

As for the contents of other bioactive molecules, Payet *et al.* (2005) report 25.96 mg gallic acid equivalent/100 g, and Harish Nayaka *et al.* (2009) 3873 mg gallic acid equivalent/100 g. Likewise, the presence of at least 15 phenolic aglycones (Galvez; Kwon; Genovese; Lajolo; and Shetty, 2008; Harish Nayaka *et al.*, 2009; Payet *et al.*, 2005) was identified and quantified through HPLC or NMR. The phenolic compounds in sugarcane have traditionally been of interest to sugar technologists as one of the causes of color in sugarcane products. A wide variety of plant pigments and natural dyes have been identified in the leaves and extract of sugarcane (Paton; Doung, 1992). The cane plant itself mainly supplies low molecular weight plant pigments: flavonoids, chlorophylls, carotenes, xanthophylls, and phenolic compounds, which provide approximately 30 % of the entire color of raw sugar. The rest is provided by high molecular weight dyes, many of them the product of chemical transformations during the processing of the cane (Paton; Doung, 1992).

More than twenty amino acids have been identified in cane extract derivatives, 70-80 % including Aspartic Acid-Asp, Asparagine-Asn, Glutamic Acid-Glu, and Glutamine-Gln (Nakasone; Ikema; Kobayashi, 1990). It is suggested that amino acids play an important role in the aroma formation of panela. The presence of amino acids was confirmed directly when acrylamide was detected in cane extract derivatives (Hoenicke; Gatermann, 2005). This substance is suspected to be carcinogenic, and it forms when carbohydrates and the amino acid asparagine are subjected to high temperatures, such as baking, frying, and roasting (Dybing *et al.*, 2005).

Thirty volatile compounds have been identified in cane extract derivatives by gas chromatography coupled to a mass spectrometer (GC-MS), most are furans, furanone, 2-acetylpyrrole, or 5-(hydroxymethyl) furfural, a product of thermal degradation of carbohydrates via caramelization or Maillard reactions during the manufacturing process (Payet *et al.*, 2005). Maillard glucose-amino acid reactions also produce different aromas depending on the amino acid (Wong; Aziz; Mohamed, 2008).

Jaffé (2012), in a review, identified 27 reports of a wide range of health effects of cane extract derivatives or extracts thereof, in in vitro or animal research models. Within that, only two articles report human trials. The bioactive compounds proposed as possible causes are minerals: Fe, Cr, and P in the form of phosphates and phenolic compounds. In two cases, specific bioactive polyphenols have been identified, such as tricetin, apigenin, and luteolin. The strongest evidence of an effect on health is the increase in the formation of hemoglobin and red blood cells caused by their iron content, reported in humans by at least two articles (Jaffé, 2012). The cause-and-effect relation between iron consumption and increased hemoglobin and red blood cells has been accepted

by the European Agency for Food Safety and therefore claims to this effect are permitted in Europe (European Food Safety Agency [EFSA], 2014). The statistically significant increase in hemoglobin in preschool children after the consumption of a beverage fortified with cane extract derivatives or its extracts has been demonstrated (Arcanjo *et al.*, 2009), which has led experts to consider it as a food fortifier (Nishad; Selvan; Mir; Bosco, 2017; Arcanjo; Amancio; Braga, 2013). Antiatherogenic effects have also been reported (Penson; Banach, 2021).

In Pakistan, toxic trace elements such as arsenic, bromine, mercury, antimony, and selenium have been detected by means of high-performance anion-exchange chromatography with conductivity detector (HPAEC-CD) in cane extract derivatives or extract thereof (Waheed; Ahmad, 2008), but its content is within the levels of human tolerance. Acrylamide (Hoenicke; Gatermann, 2005), a product of the manufacturing process, and its formation can be reduced or avoided by controlling some process parameters (Dybing *et al.*, 2005). In a recent study, Mesias *et al.* (2020) showed specific evidence of the evolution in the formation of acrylamide, such as the °Brix, pH, reducing sugars, furfural, browning, and phenols increase; and the humidity and asparagine content decrease. Thus, it was determined that the sample of freshly squeezed fresh extract and clarified extract and processed at temperatures below 100 °C did not contain levels of acrylamide; in contrast, the samples of concentrated extract at more than 100 °C to 60-65 °Brix, and in the sample of block panela produced at more than 120 °C, levels of 298+31 µg acrylamide/kg and 890+15 µg acrylamide/kg were found, respectively. This corroborates the previously reported evidence on the effect of heat treatments on acrylamide production, for example, in the study by Vargas *et al.* (2014) 800 µg acrylamide/kg panela product are reported; in unrefined sugar 140 µg acrylamide/kg product is reported (Hoenicke; Gatermann, 2005); in block panela, 540 µg acrylamide/kg product are reported (Gómez-Narváez *et al.*, 2019).

## 5. Conclusions

The foregoing is an overview of the different metabolites of products derived from *S. officinarum*. The positive health effects of cane honey and its derivatives are clear. It is evident the need to reformulate the NTC that determines the minimum parameters in the products derived from sugar cane, the above, not with the aim of generating another impediment to the productive chain, but quite the opposite, in order to generate an added value to the products, in terms of integral use of biological, nutraceutical and biofunctional properties of the metabolite set. These quantifications will generate added value to the products and give them enough nutritional relevance to negotiate better prices, as well as the option to think about new products for the market. This effort must be accompanied by a national and agreed characterization with the productive sector, which makes it possible to study the potential of the subregions of cultivation, for example, in the Hoya del Río Suarez that includes sectors of the Departments of Santander, Boyacá, and Cundinamarca or in the areas of Valle del Cauca or Antioquia. It is suggested, at a minimum, that the parameters of total phenol content, antioxidant capacity, and acrylamide, be added to the NTC 1311:2009 (Icontec, 2009), and the study of the possible incorporation into the other group of standards of characterization of products derived from *S. officinarum* as described in Table 2 and 3 is initiated, or to create a new group of NTCs that standardize their measurement using the standards available for sugars or similar products, derived from entities such as ISO, ICUMSA or the International Sugar Organization.

## 6. Acknowledgements

The authors hereby express their gratitude to the National Coordination of Sennova for funding the SGPS 6383 project, which allowed the assembly of the infrastructure for the technological services laboratory of the Agrotourism Center of San Gil. They also appreciate the support of professionals Nelly Quiroga Sarmiento, deputy director (e); Tulio Rodríguez Bautista, deputy director (e) and Luz Marina Arenas Villar, missionary coordinator, for all their help, which enabled access to the resources and to carry out the execution to acquire the infrastructure for the technological services project, focused on the productive sector of panela and derivatives.

## Referencias

- Abbas, Syed; Ahmed, Sundus; Sabir, Syed; Shah, Asad; Awan, Shahid; Gohar, M.; Khan, M. F.; Rao, Aurangzeb. (2013). Antioxidant activity, repair and tolerance of oxidative DNA damage in different cultivars of Sugarcane (*Saccharum officinarum*) leaves. *Australian Journal of Crop Science*, 7, 40-45. R
- Abbas, Syed; Sabir Syed; Ahmad, Syed; Boligon, Aline; Athayde, Margareth (2014). Phenolic profile, antioxidant potential and DNA damage protecting activity of sugarcane (*Saccharum officinarum*). *Food Chemistry*, 15(147), 10-16.  
<https://doi.org/10.1016/j.foodchem.2013.09.113>
- Adom, Kafui; Liu, Rui. (2002). Antioxidant activity of grains. *Journal of Agricultural and Food Chemistry*, 50(21), 6182-6187.  
<https://doi.org/10.1021/jf0205099>
- Amer, Said; Na, Ki-Jeong; El-Abasy, Moshira; Motobu, Maki; Koyama, Yukari; Koge, Kenji; Hirota, Yoshikazu. (2004). Immunostimulating effects of sugar cane extract on X-ray radiation induced immunosuppression in the chicken. *International Immunopharmacology*, 4(1), 71-77.  
<https://doi.org/10.1016/j.intimp.2003.10.006>
- Andrews, Jennifer. (2001). Determination of minimum inhibitory concentrations. *Journal of Antimicrobial Chemotherapy*, 48(1), 5-16,  
<https://doi.org/10.1093/jac/48.suppl.1.5>
- Arcanjo, Francisco; Amancio, Olga; Braga, Josefina. (2013). Evaporated sugarcane extract as a food fortificant. In V. Preedy, R. Srirajaskanthan, y V. B. Patel (Eds.), *Handbook of Food Fortification and Health* (pp. 105-111). Nueva York: Springer.
- Arcanjo, Francisco; Pinto, Vicente; Arcanjo, María; Amancio, Olga (2009). Effect of a beverage fortified with evaporated sugarcane extract on hemoglobin levels in preschool children. *Revista Panameña de Salud Pública*, 26, 350-354.
- Benzie, Iris; Strain, J. J. (1996). The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. *Analytical Biochemistry*, 239(1), 70-76.  
<https://doi.org/10.1006/abio.1996.0292>
- Castro, Felipe; Arboleda, Óscar; Balcázar, Alvaro; Estupiñán, Fernando. (2013). *Evaluación institucional y de resultados del Subsistema Nacional de la Calidad*. Informe final. Bogotá: Fedesarrollo.
- Cheung, Min-Yu; Oh, Deok-Kun; Lee, Ki Won. (2012). Hypoglycemic health benefits of D-psicose. *Journal of Agricultural and Food Chemistry*, 60(4), 863-869.  
<https://doi.org/10.1021/jf204050w>
- Consejo Nacional de Política Económica y Social [Conpes]. (2016). *Conpes 3866. Política nacional de desarrollo productivo*. Bogotá: Departamento Nacional de Planeación.
- Departamento Administrativo Nacional de Estadística. (2013). *Encuesta de Desarrollo e Innovación Tecnológica EDIT, 2005-2012*. Recuperado de  
<https://www.dane.gov.co/index.php/estadisticas-por-tema/tecnologia-e-innovacion/encuesta-de-desarrollo-e-innovacion-tecnologica-edit>

- Departamento Administrativo Nacional de Estadística. (2020). *Encuesta de Desarrollo e Innovación Tecnológica EDIT, 2018-2019*. Recuperado de <https://www.dane.gov.co/index.php/estadisticas-por-tema/tecnologia-e-innovacion/encuesta-de-desarrollo-e-innovacion-tecnologica-edit>
- Duarte-Almeida, Joaquim; Novoa, Alexis; Linares, Adyary; Lajolo, Franco; Genovese, María. (2006). Antioxidant activity of phenolic compounds from sugarcane extract. *Plant Foods for Human Nutrition*, 61, 187-192. <https://doi.org/10.1007/s11130-006-0032-6>
- Dybing, Erik; Farmer, P. B.; Anderson, Melvin; Fennell, Timothy; Lallje, Sam; Müller, D. J. G.; Olin, S.; Petersen, B. J.; Schlatter, J.; Scholz, Gabriele; Scimeca, Joseph; Slimani, Nadia; Tornqvist, Margareta; Tuijelaars, S.; Verger, Philippe. (2005). Human exposure and internal dose assessments of acrylamide in Food. *Food Chemical Toxicology*, 43(3), 365-410. <https://doi.org/10.1016/j.fct.2004.11.004>
- El-Abasy, Moshira; Motobu, Maki; Nakamura, Kikuyasu; Koge, Kenji; Onodera, Takashi; Vainio, Olli; Toivanen, Paavo; Hirota, Yoshikazu. (2004). Preventive and therapeutic effects of sugar cane extract on cyclophosphamide-induced immunosuppression in chickens. *International Immunopharmacology*, 4(8), 983-990. <https://doi.org/10.1016/j.intimp.2004.01.019>
- European Food Safety Agency. (2014). Scientific opinion on the substantiation of a health claim related to iron and contribution to normal formation of hemoglobin and red blood cells pursuant to Article 14 of regulation (EC) No 1924/2006. *EFSA Journal*, 12(1), 3355. <https://doi.org/10.2903/j.efsa.2014.3515>
- Food and Agriculture Organization (2019). *Codex Alimentarius. Recommended methods of analysis and sampling, adopted by the 42nd Session of the Codex Alimentarius Commission in 2019*. Recuperado de [http://www.fao.org/fileadmin/user\\_upload/agns/pdf/CXS\\_234e.pdf](http://www.fao.org/fileadmin/user_upload/agns/pdf/CXS_234e.pdf)
- Food and Agriculture Organization of the United Nations. (2014). *Producción de panela como estrategia de diversificación en la generación de ingresos en áreas rurales de América Latina*. Recuperado de [http://www.fao.org/fileadmin/user\\_upload/ags/publications/AGSF\\_WD6s.pdf](http://www.fao.org/fileadmin/user_upload/ags/publications/AGSF_WD6s.pdf)
- Galvez, Lena; Kwon, Young-In; Genovese, María; Lajolo, Franco; Shetty, Kalidas. (2008). Antidiabetes and antihypertension potential of commonly consumed carbohydrate sweeteners using in-vitro models. *Journal of Medicinal Food*, 11(2), 337-348. <http://doi.org/10.1089/jmf.2007.689>
- Glyad, V. M. (2002). Determination of monosaccharides, disaccharides, and oligosaccharides in the same plant sample by High-Performance Liquid Chromatography. *Russian Journal of Plant Physiology*, 49(2), 277-282. <https://doi.org/10.1023/A:1014870011027>
- Gómez-Narváez, F; Mesías, Marta; Delgado-Andrade, Cristina; Contreras-Calderón, José; Ubillús, Fabiola; Cruz, Gastón; Morales, Francisco. (2019). Occurrence of acrylamide and other heat-induced compounds in panela: Relationship with physicochemical and antioxidant parameters. *Food Chemistry*, 301, 125-256. <http://doi.org/10.1016/j.foodchem.2019.125256>

- Guerra, María; Mujica, Virginia. (2010). Physical and chemical properties of granulated cane sugar "panelas". *Ciencia e Tecnología de Alimentos*, 30(1), 250-257.  
<http://doi.org/10.1590/S0101-20612010005000012>
- Harish Nayaka, M. A.; Sathisha, U. V.; Manohar, M. P.; Chandrashekar, K. B.; Dharmesh, Shylaja. (2009). Cytoprotective and antioxidant activity studies of jaggery sugar. *Food Chemistry*, 115(1), 113-118.  
<https://doi.org/10.1016/j.foodchem.2008.11.067>
- Hoenicke, K.; Gatermann, R. (2005). Studies on the stability of acrylamide in food during storage. *Journal of AOAC International*, 88(1), 268-273.
- Ho-Soo, Lim; Sung-Kwan, Park; So-Hee, Kim; Sung-Bong, Song; Su-Jin, Jang; Meehye, Kim. (2014). Comparison of four different methods for the determination of sulfites in foods marketed in South Korea. *Food Additives & Contaminants: Part A*, 31(2), 187-196.  
<https://doi.org/10.1080/19440049.2013.857048>
- Indyk, H. E., Lawrence, Broda. (1993). The micronutrient content of bovine whole milk powder: influence of pasture feeding and season. *Food Chemistry*, 46(4), 389-396.  
[https://doi.org/10.1016/0308-8146\(93\)90010-D](https://doi.org/10.1016/0308-8146(93)90010-D)
- Instituto Colombiano de Bienestar Familiar. (2014). *Tabla de composición de alimentos colombianos*. Recuperado de [http://alimentoscolombianos.icbf.gov.co/alimentos colombianos/consulta alimento.asp](http://alimentoscolombianos.icbf.gov.co/alimentos%20colombianos/consulta%20alimento.asp)
- Instituto Colombiano de Normas Técnicas y Certificación. (2021). *Icontec*.  
<https://www.icontec.org/>
- Instituto Colombiano de Normas Técnicas y Certificación. (2009). *Norma Técnica Colombiana, NTC-ISO 3951-1, 2, 3, 4 y 5: Procedimientos de muestreo para la inspección por variables*. Recuperado de <https://www.icontec.org/rules/procedimientos-de-muestreo-para-la-inspeccion-por-variables-parte-2-especificacion-general-para-los-planes-de-muestreo-simples-tabulados-segun-el-nivel-aceptable-de-calidad-nac-para-la-inspeccion/>
- Instituto Colombiano de Normas Técnicas y Certificación. (1994a). *Norma Técnica Colombiana, NTC 587:1994. Industrias alimentarias e industrias de bebidas. melaza de caña*. Recuperado de <https://tienda.icontec.org/gp-industrias-alimentarias-e-industrias-de-bebidas-melaza-de-cana-ntc587-1994.html>
- Instituto Colombiano de Normas Técnicas y Certificación (1994b). *Norma Técnica Colombiana, NTC 2369:1994. Industrias alimentarias. Floculantes derivados de la acrilamida utilizados en la clarificación del agua potable y de los jugos y jarabes de la caña de azúcar*. Recuperado de <https://tienda.icontec.org/gp-industrias-alimentarias-floculantes-derivados-de-la-acrilamida-utilizados-en-la-clarificacion-del-agua-potable-y-de-los-jugos-y-jarabes-de-la-cana-de-azucar-ntc2369-1994.html>
- Instituto Colombiano de Normas Técnicas y Certificación. (1999). *Norma Técnica Colombiana, NTC 410:1999. Bebidas alcohólicas. aguardiente de caña. Caña, cachaza o branquiña*. Recuperado de <https://tienda.icontec.org/gp-bebidas-alcoholicas-aguardiente-de-cana-cana-cachaza-o-branquiña-ntc410-1999.html>

- Instituto Colombiano de Normas Técnicas y Certificación. (2002). *Norma Técnica Colombiana, NTC-ISO 2859-1:2002. Procedimientos de muestreo para inspección por atributos. parte 1: planes de muestreo determinados por el nivel aceptable de calidad -nac- para inspección lote a lote*. Recuperado de <https://tienda.icontec.org/gp-procedimientos-de-muestreo-para-inspeccion-por-atributos-parte-1-planes-de-muestreo-determinados-por-el-nivel-aceptable-de-calidad--nac--para-inspeccion-lote-a-lote-ntc-iso2859-1-2002.html>
- Instituto Colombiano de Normas Técnicas y Certificación. (2009). *Norma Técnica Colombiana, NTC 1311:2009. Productos agrícolas. Panela*. Recuperado de <https://tienda.icontec.org/gp-productos-agricolas-panela-ntc1311-2009.html>
- Instituto Colombiano de Normas Técnicas y Certificación. (2010). *Norma Técnica Colombiana, NTC 1856:2010. Bebidas alcohólicas. Miel de caña. determinación del dióxido de azufre*. Recuperado de <https://tienda.icontec.org/gp-bebidas-alcoholicas-miel-de-cana-determinacion-del-dioxido-de-azufre-ntc1856-2010.html>
- Instituto Colombiano de Normas Técnicas y Certificación. (2011). *Norma Técnica Colombiana, NTC 3442:2011. Bebidas alcohólicas. Tafías de caña*. Recuperado de <https://tienda.icontec.org/gp-bebidas-alcoholicas-tafias-de-cana-ntc3442-2011.html>
- Instituto Colombiano de Normas Técnicas y Certificación. (2012a). *Norma Técnica Colombiana, NTC 570:2012. Azúcar, mieles, jarabes y jugos de caña. métodos de ensayo para determinar cenizas*. Recuperado de <https://tienda.icontec.org/gp-azucar-miel-jarabes-y-jugos-de-cana-metodos-de-ensayo-para-determinar-cenizas-ntc570-2012.html>
- Instituto Colombiano de Normas Técnicas y Certificación. (2012b). *Norma Técnica Colombiana, NTC 5970:2012. Azúcar, jugos y jarabes de caña. determinación de sulfito con el método colorimétrico de rosanilina*. Recuperado de <https://tienda.icontec.org/gp-azucar-jugos-y-jarabes-de-cana-determinacion-de-sulfito-con-el-metodo-colorimetrico-de-rosanilina-ntc5970-2012.html>
- Instituto Colombiano de Normas Técnicas y Certificación (2013). *Norma Técnica Colombiana, NTC 573:2013. Azúcar. Terminología*. Recuperado de <https://tienda.icontec.org/gp-azucar-terminologia-ntc573-2013.html>
- Instituto Colombiano de Normas Técnicas y Certificación. (2015). *Norma Técnica Colombiana, NTC 440:2015. Productos alimenticios. Métodos de ensayo*. Recuperado de <https://tienda.icontec.org/gp-productos-alimenticios-metodos-de-ensayo-ntc440-2015.html>
- Instituto Colombiano de Normas Técnicas y Certificación. (2017a). *Norma Técnica Colombiana, NTC 1779:2017. Meladura y mieles de caña. Método para determinar azúcares reductores totales en meladura y mieles de caña, después de hidrólisis por el procedimiento Lane & Eynon a volumen constante*. Recuperado de <https://tienda.icontec.org/gp-meladura-y-miel-de-cana-metodo-para-determinar-azucars-reductores-totales-en-meladura-y-miel-de-cana-despues-de-hidrolisis-por-el-procedimiento-lane-eynon-a-volumen-constante-ntc1779-2017.html>
- Instituto Colombiano de Normas Técnicas y Certificación. (2017b). *Norma Técnica Colombiana, NTC 3953:2017. Azúcar, jugos, meladuras y mieles de caña. Determinación de coliformes y Escherichia coli. técnica del número más probable (nmp)*. Recuperado de <https://tienda.icontec.org/gp-azucar-jugos-meladuras-y-miel-de-cana-determinacion-de-coliformes-y-escherichia-coli-tecnica-del-numero-mas-probable-nmp-ntc3953-2017.html>

- Instituto Colombiano de Normas Técnicas y Certificación. (2017c). *Norma Técnica Colombiana, NTC 3954:2017. Azúcar, jugos, jarabes y mieles de caña. determinación de mohos y levaduras. Método de recuento en placa.* Recuperado de <https://tienda.icontec.org/gp-azucar-jugos-jarabes-y-mieles-de-cana-determinacion-de-mohos-y-levaduras-metodo-de-recuento-en-placa-ntc3954-2017.html>
- Instituto Colombiano de Normas Técnicas y Certificación. (2017d). *Norma Técnica Colombiana, NTC 6086:2017. Azúcar, jugos, meladuras y mieles de caña. detección y recuento de coliformes o Escherichia coli o ambos. Método de recuento en placa.* Recuperado de <https://tienda.icontec.org/gp-azucar-jugos-meladuras-y-mieles-de-cana-deteccion-y-recuento-de-coliformes-o-escherichia-coli-o-ambos-metodo-de-recuento-en-placa-ntc6086-2017.html>
- Instituto Colombiano de Normas Técnicas y Certificación. (2017e). *Norma Técnica Colombiana, NTC 3908:2017. Azúcar, jugos, meladuras y mieles de caña. recuento de bacterias mesófilas aerobias. Método de recuento en placa.* Recuperado de <https://tienda.icontec.org/gp-azucar-jugos-meladuras-y-mieles-de-cana-recuento-de-bacterias-mesofilas-aerobias-metodo-de-recuento-en-placa-ntc3908-2017.html>
- Instituto Colombiano de Normas Técnicas y Certificación. (2020a). *Norma Técnica Colombiana, NTC 6385:2020. Azúcar. Determinación de almidón soluble en azúcar y materiales de proceso mediante el método rápido de almidón de spri.* Recuperado de <https://tienda.icontec.org/gp-azucar-determinacion-de-almidon-soluble-en-azucar-y-materiales-de-proceso-mediante-el-metodo-rapido-de-almidon-de-spri-ntc6385-2020.html>
- Instituto Colombiano de Normas Técnicas y Certificación. (2020b). *Norma Técnica Colombiana, NTC 1846:2020. Miel virgen de caña de azúcar.* Recuperado de <https://tienda.icontec.org/gp-miel-virgen-de-cana-de-azucar-ntc1846-2020.html>
- International Commission for Uniform Methods of Sugar Analysis. (1994). GS 1/3/4/7/8-13. *Determinación de cenizas conductimétricas en azúcar crudo, azúcar moreno, jugo, jarabe y melaza-Oficial.* Recuperado de <https://www.icumsa.org/index.php?id=931>
- International Commission for Uniform Methods of Sugar Analysis. (2000). GS3/4/7/8-11. *Determinación de cenizas sulfatadas en azúcar moreno, jugos, jarabes y melazas-Oficial.* Recuperado de <https://www.icumsa.org/index.php?id=1301>
- International Commission for Uniform Methods of Sugar Analysis. (2009a). GS 2/1/7-33. *Determinación de sulfito por el método colorimétrico de rosanilina en azúcar blanco-Oficial.* Recuperado de <https://www.icumsa.org/index.php?id=1067>
- International Commission for Uniform Methods of Sugar Analysis. (2009b). GS 1/2/3/4/7/8-23. *Determinación del pH por un método directo - en azúcar crudo, melaza, jugos y jarabes-Oficial.* Recuperado de <https://www.icumsa.org/index.php?id=935>
- International Commission for Uniform Methods of Sugar Analysis. (2011a). GS 4/3-7. *Determinación de azúcares reductores totales en melaza y jarabes refinados después de hidrólisis por el procedimiento Lane & Eynon contante-Oficial (de referencia).* Recuperado de <https://www.icumsa.org/index.php?id=1375>

- International Commission for Uniform Methods of Sugar Analysis. (2011b). GS 2/3/ 9-17. *Determinación de cenizas conductimétricas en productos de azúcar refinada y azúcar blanco de plantación-Oficial*. Recuperado de <https://www.icumsa.org/index.php?id=1058>
- International Commission for Uniform Methods of Sugar Analysis. (2011c). GS9/1/2/3-8. *Determinación del color de la solución de azúcar a pH 7,0 mediante el método tampón MOPS-Oficial*. Recuperado de <https://www.icumsa.org/index.php?id=1717>
- International Commission for Uniform Methods of Sugar Analysis. (2011d). GS9/1/2/3-8. *The Determination of Sugar Solution Colour at pH 7.0 by the MOPS Buffer Method-Official (Reference) Method*. Recuperado de <https://www.icumsa.org/index.php?id=1717>
- International Commission for Uniform Methods of Sugar Analysis. (2011e). GS 2/3-35. *Determinación de sulfito en productos de azúcar refinado con excepción del azúcar moreno por un método enzimático-Oficial. Determinación de sulfito en azúcares moreno*. Recuperado de <https://www.icumsa.org/index.php?id=1068>
- International Organization for Standardization. (1980a). ISO 1741:1980. *Dextrose. Determination of loss in mass on drying. Vacuum oven method*. Recuperado de <https://www.iso.org/standard/6362.html>
- International Organization for Standardization. (1980b). ISO 1742:1980. *Glucose syrups. Determination of dry matter. Vacuum oven metho*. Recuperado de <https://www.iso.org/standard/6363.html>
- International Organization for Standardization. (2013a). ISO 10504:2013. *Starch derivatives. Determination of the composition of glucose syrups, fructose syrups and hydrogenated glucose syrups. Method using high-performance liquid chromatography*. Recuperado de <https://www.iso.org/standard/50792.html>
- International Organization for Standardization. (2013b). ISO5379:2013. *Starches and derivedproduct. Determination of sulfur dioxide content. Acidimetric method and nephelometric method*. Recuperado de <https://www.iso.org/ru/standard/50791.html>
- Jaffé, Walter. (2012). Health Effects of Non-Centrifugal Sugar (NCS): A Review. *Sugar Tech*, 14(2), 87-94.
- Jaffé, Walter; Ochoa. A. E. (1949). El papelón como fuente de hierro en la dieta popular venezolana. *Revista de la Sociedad Venezolana de Química*, 21, 1-7.
- Jiang, Zhen-Yue; Hunt, James; Wolff, Simon. (1992). Ferrous ion oxidation in the presence of xylenol orange for detection of lipid hydroperoxide in low density lipoprotein. *Analytical Biochemistry*, 202(2), 384-389. [https://doi.org/10.1016/0003-2697\(92\)90122-N](https://doi.org/10.1016/0003-2697(92)90122-N)
- Mesias, Marta; Delgado-Andrade, Cristina; Gómez-Narváez, Faver; Contreras-Calderón, José; Morales, Francisco. (2020). Formation of Acrylamide and other Heat-Induced Compounds during Panela Production. *Foods (Basel, Swikerland)*, 9(4), 531. <https://doi.org/10.3390/foods9040531>
- Nakasone, Y.; Ikema, Y.; Kobayashi, A. (1990). Changes in the composition of amino acids during manufacturing process of non-centrifugal cane sugar (Kokuto). *The Science Bulletin of the College of Agriculture, University of Ryukyus*, 35, 35-39.

- Nedorostova, Lenka; Kloucek Pavel; Kokoska, Ladislav; Stolcova, Milusa; Pulkrabek, Josef. (2009). Antimicrobial properties of selected essential oils in vapour phase against food borne bacteria. *Food Control*, 20, 157-160.  
<https://doi.org/10.1016/j.foodcont.2008.03.007>
- Nimrouzi, Majid; Sadeghpour, Omid; Imanieh, Mohammad-Hadi; Shams-Ardekani, Mohammadreza; Zarshenas, Mohammad; Salehi, Alireza; Mohamad-Bagher, Minaei. (2014). Remedies for Children Constipation in Medieval Persia. *Journal of Evidence-Based Complementary and Alternative Medicine*, 19(2), 137-143.  
<https://doi.org/10.1177/2156587214524579>
- Nishad, Jyoti; Selvan, Cynthia; Mir, Shabir; Bosco, Sowriappan. (2017). Effect of spray drying on physical properties of sugarcane extract powder (*Saccharum officinarum* L.). *Journal of Food Science and Technology*, 54(3), 687-697.  
<https://doi.org/10.1007/s13197-017-2507-x>
- Nordic Committee on Food Analysis [NMKL]. (1990). NMKL 135. Sulphite. Enzymatic determination in foods. Recuperado de  
<https://www.nmkl.org/index.php/en/publications/item/sulfit-enzymatisk-bestamning-i-livsmedel-nmkl-135-1990>
- Novak, Ana; Gutiérrez-Zamora, Merce; Domenech, Lluís; Suñé-Negre, Josep; Miñarro, Montserrat; García-Montoya, Encarna; Llop, Josep; Ticó, Josep; Pérez-Lozano, Pilar. (2017). Development and validation of a simple high-performance liquid chromatography analytical method for simultaneous determination of phytosterols, cholesterol and squalene in parenteral lipid emulsions. *Biomedical Chromatography*, 32(2), e4084.  
<https://doi.org/10.1002/bmc.4084>
- Okabe, Takafumi; Toda, Takayoshi; Inafuku, Massashi; Wada, Koji; Iwasaki, Hironori; Oku, Hirosuke. (2008). Antiatherosclerotic function of Kokuto, Okinawan noncentrifugal cane sugar. *Journal of Agricultural and Food Chemistry*, 57(1), 69-75.  
<https://doi.org/10.1021/jf802796m>
- Olivares, Manuel; Pizarro, Fernando; Hertrampf, Eva; Fuenmayor, Guillermo; Estévez, Edmundo. (2007). Iron absorption from wheat flour: Effects of lemonade and chamomile infusion. *Nutrition*, 23, 296-300.  
<https://doi.org/10.1016/j.nut.2006.04.014>
- Paton, N. H.; Doung, M. (1992). Sugarcane phenolics and first expressed extract color. Part III. Role of chlorogenic acid and flavonoids in enzymic browning of cane extract. *Journal International Sugar*, 94, 170-176.
- Payet, Bertrand; Shum-Cheong-Sing, Alain; Smadja, Jacqueline. (2005). Assessment of antioxidant activity of cane Brown sugars by ABTS and DPPH radical scavenging Assays: determination of their polyphenolic and volatile constituents. *Journal of Agricultural and Food Chemistry*, 53, 10074-10079.  
<https://doi.org/10.1021/jf0517703>
- Penson, Peter; Banach, Maciej. (2021). Natural compounds as anti-atherogenic agents: Clinical evidence for improved cardiovascular outcomes. *Atherosclerosis*, 316, 58-65.  
<https://doi.org/10.1016/j.atherosclerosis.2020.11.015>

- Phillips, Katherine; Carlsen, Monica; Blomhoff, Rune. (2009). Total antioxidant content of alternatives to refined sugar. *Journal of the Academy of Nutrition and Dietetics*, 109, 64-71.  
<https://doi.org/10.1016/j.jada.2008.10.014>
- Rodríguez, Antonio; Segura, M. (2004). Panela granulada ecológica. *Antenor Orrego*, 15(22), 43-55.
- Sautter, Christof; Gruissem, Wilhelm. (2010). *Iron biofortification of rice by targeted genetic engineering*. ISB. News Report. Recuperado de  
<https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.614.4228&rep=rep1&type=pdf>
- Scheid, Simone; Faria, Maria; Velásquez, Leonardo; do Valle, Juliana; Gongalves, Affonso; Dragunski, Douglas; Colauto, Nelson; Linde, Gianí. (2020). Iron biofortification and availability in the mycelial biomass of edible and medicinal basidiomycetes cultivated in sugarcane molasses. *Scientific Reports*, 10(1), 12875.  
<https://doi.org/10.1038/s41598-020-69699-0>
- Seguí, Lucía; Calabuig-Jiménez, Laura; Betoret, Noelia; Fito, Pedro. (2015). Physicochemical and antioxidant properties of non-refined sugarcane alternatives to white sugar. *International Journal of Food Science*, 50(12), 2579-2588.  
<https://doi.org/10.1111/ijfs.12926>
- Semwal, Pooja; Jai Singh, Ranjana; Kumar, Amit; Malik, Jitender. (2021). Pharmacognostical Exploration of *Saccharum officinarum*. *Scholars International Journal of Traditional and Complementary Medicine*, 4(4), 53-60.  
<https://doi.org/10.36348/sijtcm.2021.v04i04.003>
- Shaheen, Nazma; Rahim, Abu; Mohiduzzaman, Cadi; Bari, Latiful; Tukun, Avonti; Mannan, M. A.; Bhattacharjee, Lalita; Stadlmayr, Barbara. (2013). *Food composition table for Bangladesh*. Institute of Nutrition and Food Science, University of Dhaka, Bangladesh. Recuperado de  
[http://www.fao.org/fileadmin/templates/food\\_composition/documents/FCT\\_10\\_2\\_14\\_final\\_version.Pdf](http://www.fao.org/fileadmin/templates/food_composition/documents/FCT_10_2_14_final_version.Pdf)
- Shahidi, Fereidoon; Zhong, Ying. (2015). Measurement of antioxidant activity. *Journal of functional foods*, 18, 757-781.  
<https://doi.org/10.1016/j.jff.2015.01.047>
- Singh, Amandeep; Lal, Uma; Mukhtar, Hayat; Singh, Prabh; Shah, Gagan; Dhawan, Ravi (2015). Phytochemical profile of sugarcane and its potential health aspects. *Pharmacognosy reviews*, 9(17), 45-54.  
<https://doi.org/10.4103/0973-7847.156340>
- Stralfors, A. (1966). Inhibition of hamster caries by substances in brown sugar. *Archives of Oral Biology*, 11, 61-622.  
[https://doi.org/10.1016/0003-9969\(66\)90228-7](https://doi.org/10.1016/0003-9969(66)90228-7)
- Sumiyoshi, Maho; Hayashi, Teruaki; Kimura, Yoshiyuki. (2009). Effects of the non-sugar fraction of brown sugar on chronic ultraviolet B irradiation-induced photoaging in melanin-possessing hairless mice. *Journal of Natural Medicines*, 63, 130-136.  
<https://doi.org/10.1007/s11418-008-0301-9>
- Takara, Kensaku; Otsuka, Keiko; Wada, Koji; Iwasaki, Hironori; Yamashita, Masatsugu. (2007). 1,1-Diphenyl-2-picrylhydrazyl radical scavenging activity and tyrosinase inhibitory effects of constituents of sugar cane molasses. *Bioscience, Biotechnology, and Biochemistry*, 71, 183-191.  
<https://doi.org/10.1271/bbb.60432>

- Thaipong, Kriengsak; Boonprakoba, Unaroj; Crosby, Kevin; Cisneros-Zevallos, Luis; Hawkins, David. (2006). Comparison of ABTS, DPPH, FRAP, and ORAC assays for estimating antioxidant activity from guava fruit extracts. *Journal of Food Composition and Analysis*, 19, 669-675.  
<https://doi.org/10.1016/j.jfca.2006.01.003>
- Uchenna, Eneh; Adaeze, Okechukwu; Steve, Adindu. (2015). Phytochemical and antimicrobial properties of the aqueous ethanolic extract of *Saccharum officinarum* (sugarcane) bark. *Journal of Agricultural Science*, 7(10), 291.  
<https://doi.org/10.5539/jas.v7n10p291>
- Vargas, J. J; Talero, Y. V; Trujillo, F; Caballero, L. R. (2014). Acrylamide Determination in the Sugar cane extract Process by the Liquid Chromatography Technique. *Revista Ciencia en Desarrollo*, 5, 99-105.  
<https://doi.org/10.19053/01217488.3664>
- Vila, Fabiana; Colombo, Renata; de Lira, Tatiana; Yariwake, Janete. (2008). HPLC microfractionation of flavones and antioxidant (radical scavenging) activity of *Saccharum officinarum* L. *Journal of the Brazilian Chemical Society*, 19, 903-908.
- Waheed, Shahida; Ahmad, Shujaad. (2008). Instrumental neutron activation analysis of different products from the sugarcane industry in Pakistan - Part 1: essential elements for nutritional adequacy. *Journal of AOAC International*, 91(2), 392-399.
- Wang, Lifeng; Chen, Jingyi; Xie, Huihui; Ju, Xingrong; Liu, Rui. (2013). Phytochemical profiles and antioxidant activity of adlay varieties. *Journal of Agricultural and Food Chemistry*, 61(21), 5103-5113.  
<https://doi.org/10.1021/jf400556s>
- Wang, Sunan; Melnyk, John; Tsao, Rong; Marcone, Massimo. (2011). How natural dietary antioxidants in fruits, vegetables and legumes promote vascular health. *Food Research International*, 44(1), 14-22.  
<https://doi.org/10.1016/j.foodres.2010.09.028>
- Watanabe, Kenta; Nakabaru, Mai; Taira, Eizo; Ueno, Masami; Kawamitsu, Yoshinobu. (2016). Relationships between nutrients and sucrose concentrations in sugarcane extract and use of extract analysis for nutrient diagnosis in Japan. *Plant Production Science*, 19(2), 215-222.  
<https://doi.org/10.1080/1343943X.2015.1128106>
- Wen, Lingrong; Guo, Xingbo; Liu, Rui; You, Lijun; Abbasi, Arshad; Fu, Xiong. (2015). Phenolic contents and cellular antioxidant activity of Chinese hawthorn "*Crataegus pinnatifida*". *Food Chemistry*, 186, 54-62.  
<https://doi.org/10.1016/j.foodchem.2015.03.017>
- Wong, Kam; Aziz, Suraini; Mohamed, Suhaila. (2008). Sensory aroma from Maillard reaction of individual and combinations of amino acids with glucose in acidic conditions. *International Journal Food Science Technology*, 43(9), 1512-1519.  
<https://doi.org/10.1111/j.1365-2621.2006.01445.x>
- Wootton-Beard, Peter; Moran, Aisling; Ryan, Lisa. (2011). Stability of the total antioxidant capacity and total polyphenol content of 23 commercially available vegetable extracts before and after in vitro digestion measured by FRAP, DPPH, ABTS and Folin-Ciocalteu methods. *Food Research International*, 44(1), 217-224.  
<https://doi.org/10.1016/j.foodres.2010.10.033>

- World Health Organization. (2001). *Iron deficiency anaemia. Assessment, prevention and control. A Guide for programme managers*. WHO/NHD/01.3. Recuperado de [https://www.who.int/nutrition/publications/micronutrients/anaemia\\_iron\\_deficiency/WHO\\_NHD\\_01.3/en/](https://www.who.int/nutrition/publications/micronutrients/anaemia_iron_deficiency/WHO_NHD_01.3/en/)
- Yoshimoto, M.; Kurata, R.; Fujii, M.; Hou, D. X. (2008). In vitro and in vivo anticarcinogenesis of sugarcane-vinegar. XXVII International Horticultural Congress. *Acta Horticulturae*, 765, 17-22. <https://doi.org/10.17660/ActaHortic.2008.765.1>
- Zhao, Yi; Chen, Mingshun; Zhao, Zhenzhang; Yu, Shujuan. (2015). The antibiotic activity and mechanisms of sugarcane (*Saccharum officinarum* L.) bagasse extract against food-borne pathogens. *Food Chemistry*, 185, 112-118. <https://doi.org/10.1016/j.foodchem.2015.03.120>
- Zhao, Zhenzhang; Huaifeng, Yan; Rui, Zheng; Muhammad, Saeed; Xiong, Fu; Zi, Tao; Zhanying, Zhang. (2018). Anthocyanins characterization and antioxidant activities of sugarcane (*Saccharum officinarum* L.) rind-extracts. *Industrial Crops and Products*, 113, 38-45. <https://doi.org/10.1016/j.indcrop.2018.01.015>
- Zheng, Rui; Su, Shan; Zhou, Huifang; Yan, Huaifeng; Ye, Junhua; Zhao, Zhengang; You, Lijun; Fu, Xiong. (2017). Antioxidant/antihyperglycemic activity of phenolics from sugarcane (*Saccharum officinarum* L.) bagasse and identification by UHPLC-HR-TOFMS. *Industrial Crops and Products*, 101, 104-1147. <https://doi.org/10.1016/j.indcrop.2017.03.012>