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Classification Standard and Shelf Life of Mascavo Sugar: An Ontological Approach[1]

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ABSTRACT - In Brazil, agricultural food products, whether domestic or imported, are regulated by the Ministry of Agriculture, Livestock and Food Supply using an official classification standard, based on Law No. 9,972:2000. Normative Instruction No. 47:2018, which classified crystal and liquid sugars, but did not include mascavo sugar, considered a natural or gourmet product with high economic potential for family farming. The aim of this study was to develop a technical foundation for an official classification standard, defining classes and types of mascavo sugar, using qualitative bibliographic research, an ontological approach and multivariate statistical analysis. The raw material was defined as sugarcane juice, considering both industrial and artisanal production processes, with direct consumption as the intended use. The proposed quality parameters were a minimum polarisation of 84.0 °Z, maximum moisture content of 5.0%, maximum conductimetric ashes of 2.5% and maximum reducing sugars of 8.0%. Studying the safety factor and water activity enabled the formulation of a method to establish the shelf life of the product. As a result, a proposal was put forward to include a separate category for granulated and amorphous mascavo sugar in the legislation. This proposal was evaluated by market agents involved in the research, production and marketing of the product. The approach used in the classification of mascavo sugar has the potential to directly influence public policy, improve traceability and ensure greater food safety.

Keywords: Mascavo sugar. Non-centrifugal sugar. Family farming. Plant classification. Product of plant origin.

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INTRODUCTION

Agricultural products intended for human consumption or supplied to public authorities may be included in the list of official classification standards maintained by the Ministry of Agriculture, Livestock and Food Supply (MAPA). In Brazil, the classification system has been evolving since the time of the monarchy (Sousa, 2001); in 2018, sugarcane-derived products became regulated by Normative Instruction No. 47 (NI47) (Brazil, 2018), later updated by Normative Instruction No. 60 (NI60) (Brazil, 2019). However, mascavo sugar, a valuable derivative of sugarcane with the potential for generating significant income for family farmers, was not included, allowing for indiscriminate commercial exploitation.

Mascavo sugar has physicochemical characteristics that are similar to those of white crystal and raw sugar. Its composition imparts a golden colour to food when heated due to the Maillard reactions (Friedman, 1996), making it highly valued in culinary applications. However, artisanal production preserves the nutrients and flavours of the sugarcane juice, unlike industrial processing, which removes them (Jerônimo *et al*., 2020). Including mascavo sugar in the official classification system is essential to protect small producers, ensure quality, and promote traceability and food safety (Andrade; Medeiros; Borges, 2018).

According to Piedade (1983), classification involves dividing objects into groups or classes based on their similarities and differences. For Abbagnano (2018), it is a process that describes, organises and predicts recognisable objects. Pombo (1988) identifies four main approaches to classification: ontological (entities), gnosiological (sciences), biblioteconomic (books) and informational (information). Classifying involves choosing between possible classifications and seeking sufficient reasons for that choice. Carvalho and Souza (2013) point out that categorising entities into groups for specific purposes has been a key task since Ancient Greece.

Ontology, which investigates the nature of being and its fundamental structure (Blackburn, 1997; Chaui, 2010), dates back to Aristotle. His categories, such as quantity, quality and relationship, help an understanding of reality (Japiassú; Marcondes, 2001). Although related to taxonomy, which classifies objects based on common characteristics, ontology seeks to understand the essence of a being (Bonisson, 2014). Specific differences among objects pose challenges to the creation of universal classification standards, as can be seen in the classification of sugar (Chitarra; Chitarra, 2005). Ontological analysis of NI47 identifies the four Aristotelian causes for sugars. According to Aristotle, defining something involves determining its essence by combining its genus and specific differences (Chaui, 2010). The sugar classified under NI47 is defined as a product derived from sugarcane that is organised into groups (direct consumption or industrial use) and classes (white crystal or raw sugar) of different types, based on production processes and physicochemical parameters.

The aim of this study was to develop a technical basis for an official classification standard for mascavo sugar, using ontological methodology to characterise it into classes and types, and to define parameters of identity and quality. This requires an analysis of the relevant legislation, including Law No. 9,972 (Brazil, 2000a), Decree No. 5,741 (Brazil, 2006), Decree No. 6,268 (Brazil, 2007) and Ordinance No. 381 (Brazil, 2009), which aim to ensure quality, food safety and protection against fraud. NI47 and NI60 establish technical standards for sugar, including classification, quality, sampling, presentation and labelling.

MATERIALS AND METHODS

The research subject is mascavo sugar, a product derived from sugarcane juice, together with its manufacturing process, intended use and physicochemical characteristics. The study was structured in four stages to meet the general and specific objectives, and to answer the research question: what are the technological requirements of identity and quality for mascavo sugar that characterise and differentiate this product from other, regulated sugars? The following sources were used: CAPES Journal Platform, Google Scholar and the National Library of Brazil.

For the first stage, a search was conducted for scientific articles and definitions related to Aristotelian metaphysics and ontology and their application in agriculture, data science and classification systems. A search was made for articles and official documents describing the classification of plant-based products throughout history, with the aim of identifying the responsibilities of regulatory bodies. The requirements of NI47 were analysed from the perspective of Aristotle's theory of the four causes, as an aid in the development of the official classification standard for mascavo sugar.

During the second stage, a qualitative narrative literature review was conducted, with the aim of presenting and discussing the available literature from the perspective of the authors, without applying formal criteria for ranking scientific evidence (Gil, 2017). This approach was intended to provide an interpretative summary of the information rather than a quantitative classification of the studies. Articles on manufacturing methods were searched using the keywords 'mascavo sugar,' 'non-centrifugal sugar', '*panela*', '*rapadura*', 'sugar mill', and their Portuguese variants. In addition, technical books detailing the operational stages of production helped define the identity of mascavo sugar. The legislation in force from 1875 to 2018 regulating the manufacture and classification of sugars was reviewed, and articles addressing the history of sugarcane cultivation in Brazil were also analysed, covering the emergence, development and decline of sugar mills, as well as their replacement by industrial plants (factories) as a result of the Industrial Revolution.

During the third stage, articles addressing the quality of different types of sugar were reviewed, covering the period from colonial Brazil to 2023. This review gathered information on the terms and quality parameters used to characterise sugar, including polarisation (pol), colour, moisture, ash content (sulphated or conductimetric) and reducing sugars (RS). Based on this survey, a secondary database containing 1,676 samples was built, categorised a priori into five groups: (1) white crystal sugar, (2) VHP or VVHP raw sugar, (3) demerara sugar, (4) mascavo sugar and (5) *rapadura*, as per the Official Classification Standard (OCS) for regulated sugars.

A multivariate statistical analysis was conducted with two objectives: (i) to identify the physicochemical parameters that distinguish mascavo sugar from the other types of sugar, and (ii) to select the factors that contribute to its deterioration during storage, associated with relative humidity (RH), the safety factor (SF) and water activity (a_w). The relationship between SF and a_w was established statistically, allowing limits for pol, moisture, ash and reducing sugars (RS) to be defined. Before applying discriminant analysis, Principal Component Analysis (PCA) was carried out to reduce the dimensionality of the dataset and identify the most relevant variables for differentiating mascavo sugar. The database that was used contained records obtained from the CAPES Journal Platform, Google Scholar, the National Library of Brazil and collections of technical books published between 1673 and 2010, based on searches using keywords in both Portuguese and English: ‘white sugar’, ‘raw sugar’, ‘mascavo sugar’, ‘non-centrifugal sugar’, ‘*rapadura*’, as well as expressions associated with ‘quality parameters’ and ‘sugar deterioration.’ The initial variables submitted to PCA included polarisation (°Z), ICUMSA colour, moisture (%), ash (%), reducing sugars (%), insoluble residue, water activity (a_w), CIELAB colour, sucrose concentration and safety factor (SF). The analysis was carried out using the Minitab17® software, adopting Bartlett’s test of sphericity and the KMO measure of sampling adequacy to confirm the applicability of the method, and retaining the principal components with eigenvalues greater than 1 (Kaiser criterion). Interpretation of the factor loadings made it possible to select four variables with the greatest discriminatory power—polarisation, moisture, conductimetric ash and reducing sugars—which were used as input variables in the subsequent stage. Linear discriminant analysis, also carried out using Minitab17®, was applied to evaluate the effectiveness of these variables in differentiating mascavo sugar from the other regulated types. The sample set was maintained in the same five a priori categories, and classification performance was measured by the rate of accuracy and agreement between the predicted and original classifications. These results provided robust quantitative evidence to support the proposal for including mascavo sugar in the official classification standard.

For the fourth stage, a draft revision of NI47 was prepared, proposing an Official Classification Standard (OCS) for mascavo sugar from the perspective of Aristotelian theory, encompassing the material, efficient and final causes, as well as the quality parameters corresponding to the formal cause. To evaluate the proposal, an opinion survey was conducted involving three groups of social agents represented by industrial producers, family farmers, support organisations, government agencies and teaching and research institutions. Participants were selected based on their established experience in the production chain of mascavo sugar and other sugars derived from sugarcane. The inclusion criteria adopted were: (i) direct involvement in the industrial or artisanal production of mascavo sugar; (ii) participation in activities related to the marketing, inspection or regulation of sugars; or (iii) academic or outreach experience in research and technical training related to the product. End consumers with no technical connection to the sector were excluded since the evaluation was restricted to technological and regulatory factors. The sample covered a wide range of segments, ensuring validation of the proposal was representative and technically comprehensive. The questionnaire, structured based on the five-point Likert scale (Likert, 1932), was applied to measure the level of agreement of the participants regarding the elements of the draft, in accordance with the methodological approach described by Silva Júnior and Costa (2014). The responses were analysed statistically using Mood’s median nonparametric test (Mood; Graybill; Boes, 1974), adopting a significance level of 5%, in order to verify whether there was consensus regarding the validity of the proposal, and treating the lack of any difference between the medians of the agreeing and disagreeing groups as a null hypothesis.

RESULTS AND DISCUSSION

Stage 1: The history of sugar classification systems

Brazil has a long history of sugar regulation and classification dating back to the colonial period. Initially, in 1751, the Inspection Boards for Tobacco and Sugar were established by Portugal in order to prevent fraud, followed by regulation of customs houses and revenue boards (Portugal, 1751). The nineteenth century witnessed significant changes in the classification process, such as the introduction of central mills, which modernised the sugar industry and increased its international competitiveness (Meira, 2009). Between 1824 and 1891, there was a focus on modernisation and production incentives (Niederle; Wesz Jr., 2018), while the creation of the Sugar and Alcohol Institute (IAA) in 1933 consolidated the standardisation and classification of sugar (Brazil, 1933).

From 1934 to 1967, regulations were tightened to ensure the quality and safety of agricultural products, increasing attention on sanitary surveillance and food safety, as reflected in the creation of specialised agencies and adherence to international agreements (Niederle; Wesz Jr., 2018). The promulgation of the 1988 Federal Constitution marked a decisive period of legislative evolution, with the creation of the Unified System for Agricultural Health Care (SUASA), the dissolution of the Sugar and Alcohol Institute (IAA) (Brazil, 1989), and the implementation of the Southern Common Market (MERCOSUR) (Brazil, 1991). Legislation continued to adapt to new demands, expanding the variety of agricultural products and reinforcing the importance of food safety and compliance throughout the production chain (Brazil, 1997).

Stage 2: Manufacturing (efficient cause) and quality parameters (formal cause)

The introduction of sugarcane cultivation into colonial Brazil in the sixteenth century was driven by the need for colonisation and defence of the land against European corsairs (Shikida; Bacha, 1994), as well as by the commercial value of sugar on the global market, especially in Europe. King Manuel I encouraged the establishment of sugar mills by providing resources and technical support (Pombo, 1956). Although the exact date of the introduction of sugarcane is uncertain (Schwartz, 1988), sugar production began to consolidate after 1530, with the founding of São Vicente (Andreatta, 1999) and the establishment of mills in the northeast of the country, particularly in Pernambuco. Duarte Coelho played a crucial role in the development of the sugar industry in Pernambuco by establishing sugar mills and promoting sugarcane cultivation. By the mid-sixteenth century, Pernambuco was already an important production centre, with dozens of mills in operation, and became the main producer in Brazil during the 1580s (Schwartz, 1988).

The Jesuit priest André João Antonil gave a detailed account of the sugar production process in seventeenth-century sugar mills (Gama, 1983), including the royal mills, which had extensive sugarcane plantations and water-powered milling systems that distinguished them from smaller mills. He emphasised the structure of these mills as complex engineering works, with a clear division of labour between enslaved and free workers, the former being responsible for key tasks in the process, carried out in a simple, repetitive manner, generally under inhumane conditions. Antonil (1837) described in detail the sequence of production stages, from the extraction of sugarcane juice to the production of various end products, including white sugar and mascavo sugar.

The history of sugar exports in Brazil, from the colonial period to independence, is marked by significant changes. Initially, the country exported a variety of products, the main one being sugar, surpassing even gold in value (Amaral, 1958). In 1875, a financial crisis deeply affected the agricultural sector (Meira, 2007), and, in response, Decree No. 2,687 (Brazil, 1875) authorised the creation of mortgage banks and central mills, with the aim of separating the agricultural and industrial phases of sugar production and implementing technical mechanisms to reduce costs and improve sugar quality. This division was seen as beneficial for improving both the plantations and the factories. Government support was crucial for obtaining the necessary capital, and the central mills were conceived as modernised industrial sectors, adopting machines and processes developed during the Industrial Revolution, which led to the replacement of enslaved labour. Modernising the old sugar mills, particularly in the Northeast, was essential, since their architecture and techniques were outdated compared to the technologies used in global industrial centres (Milet, 1881). The types of sugar being produced were therefore diversified and standardised to expand and revitalise the market and meet consumer demand (IAA, 1942). The IAA established product categories based on the production process and characteristics (Pereira, 1944) that reflected the drive for modernisation and efficiency in sugar production in Brazil and ensured competitiveness on the international market.

Subsequently, sugar production in Brazil became concentrated in the states of the Center-South, resulting in a significant shift in geographical distribution (Szmrecsányi, 1979). During the Second World War, sugar mills in the Northeast faced difficulties of maintenance and modernisation, whereas those in São Paulo benefitted from the support of the metallurgical industry (Andrade, 1994). The post-war period brought economic challenges, leading the IAA to implement measures to address balance-of-payments deficits and a shortage of foreign exchange reserves, while encouraging the production of anhydrous alcohol (Szmrecsányi, 1979). Thus, the era of the *engenhos banguês*, known for the artisanal production of mascavo sugar and *rapadura*, came to an end with the transition to a more industrialised model and the production of white sugar and raw crystal sugar

(Rodrigues; Ross, 2020). According to Godoy (2013), the history of the sugar industry can be divided into four periods: up to 1930, sugar mills predominated, although modernisation was already underway and industrial plants were expanding more rapidly; from 1930 to 1950, there was a reversal, with sugar mills accounting for less than 20% of domestic production; from 1950 to 1970, sugar mills underwent a final expansion before entering a phase of decline that accelerated towards the end of the twentieth century.

Over the centuries, defining and characterising the types of sugar intended for human consumption has been a constant concern (Coutinho, 1975). This dates back to 1751, when a decree issued by King Joseph I of Portugal established regulations governing the export of sugar from Brazil (Portugal, 1751), and included later proposals for the use of the photoelectric colorimetry method suggested by Mattos (1938) and Decree No. 10,395 (São Paulo, 1939), which classified sugars based on their physicochemical characteristics. These regulations classified sugars based on polarisation and purity into categories such as 'first-run, 'second-run', and 'third run'. In addition, they established criteria for refined sugars, distinguishing between first and second grades, as well as standards for lower-grade sugars such as mascavo and the lighter '*mascavinho*', including limits for moisture and fixed mineral residue. Other initiatives, such as the Public Food Regulation of 1946 (São Paulo, 1946), sought to classify sugar into such categories as crystal, ordinary, demerara and mascavo, with the aim of improving the product and ensuring fair prices for higher-quality sugars. The IAA proposal of 1949 defined such categories as 'raw sugars' and 'refined sugars,' with subcategories based on the manufacturing process and specific characteristics (IAA, 1949). In 1953, mascavo sugar was referred to as colonial sugar, with 84 degrees of polarisation (IAA, 1953), and in 1978, the National Commission on Food Standards and Norms (CNNPA) of the Ministry of Health established identity and quality standards for foods, including sugar, setting limits for such parameters as polarisation and moisture (Brazil, 1978). More recently, in 2018, NI47 defined the raw material and established two groups of products (for direct consumption and industrial use) and production processes; it was later amended in 2019 by NI60, which updated parameters such as pol, ICUMSA colour, moisture, ash, black specks, magnetic particles and reducing sugars. Meanwhile, aspects related to heavy metal concentration, foreign matter and microbiological contamination, which affect the preservation of sugar, are regulated by Anvisa (Anvisa, 2022).

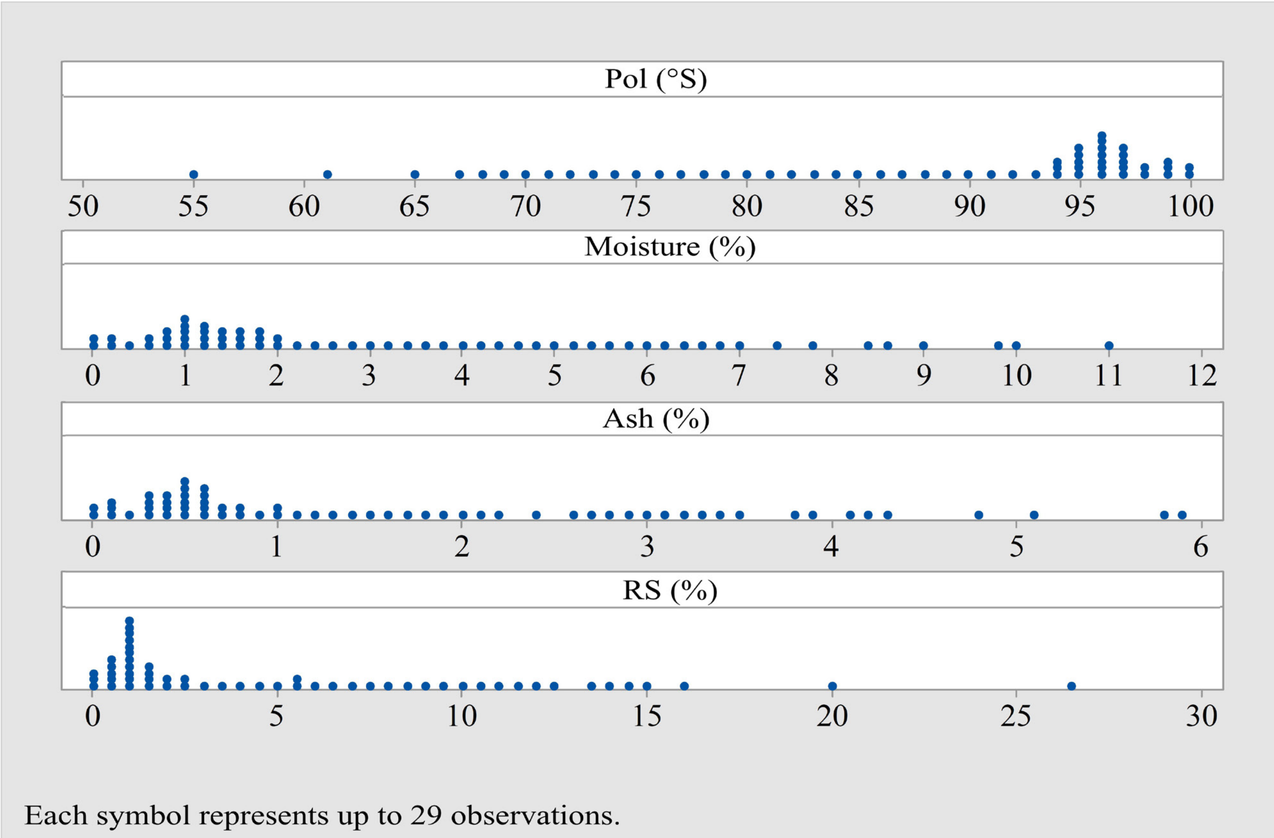
Stage 3: Definition of the quality parameters

To define the physicochemical quality parameters of mascavo sugar (formal cause), a survey of secondary data was carried out. Secondary data are understood as information previously collected by other researchers or institutions for original purposes different from those of the present investigation, but which may be reinterpreted or reanalysed to answer new research questions (Gil, 2017). A total of 1,676 records of sugar samples and their respective physicochemical parameters, such as pol, ash, moisture and reducing sugars (RS), were identified and are summarised in Figure 1. These data were obtained entirely from documentary sources, including scientific articles, technical books, laboratory reports, technical standards and legislation. The sources used included studies published in specialised journals, analytical reports from certified laboratories, and official documents from regulatory agencies. Each record corresponds to analytical results from individual samples of different types of sugar (mascavo, crystal, demerara, raw sugar, and *rapadura*). When selecting the records, the relevance of the type of sugar, the availability of the physicochemical variables of interest (polarisation, moisture, conductimetric ash, reducing sugars and, when applicable, ICUMSA colour), and the reliability of the source were all taken into account.

Additional records containing data on the safety factor (SF) and water activity (a_w) were also included in the database, since these indicators enable the physicochemical properties to be linked to the risk of the product deteriorating during storage. For the Principal Component Analysis (PCA), only samples with a complete set of values for pol, ash, moisture and RS were selected, resulting in 970 records. PCA was carried out using the Minitab 17® software, as per Mingoti (2020); the results are shown in Table 1. The first principal component (PC1) explained 78.8% of the variance and was considered significant according to the Kaiser criterion, showing that pol and moisture were the most influential variables. Ash and RS showed a stronger association with PC2, which explained 13.1% of the variance. Including SF and a_w values in the database then made it possible to interpret the parameters identified by the PCA in light of their relationship with the stability and shelf life of mascavo sugar, ensuring that the selection of quality indicators was in line with both the characterisation and safety of the product.

According to Stupiello and Joly (1968), the quality of the raw crystal sugar is of crucial importance for refineries, especially during irregular harvests. Problems arise due to variations in the raw materials and in the juice purification process (Joly; Stupiello, 1973). Conditions such as moisture and temperature affect microbiological contamination, leading to the conversion of sucrose into glucose and fructose by microorganisms present in the film of molasses (Geerligs, 1922; Moroz, 1963). These monosaccharides may originate from either the sugarcane juice or during processing. Stupiello and Joly (1972) emphasise the importance of moisture content in preserving sugar, both during storage and after centrifugation.

Figure 1 - Variation in physicochemical quality parameters reported for sugar samples published between 1869 and 2023: polarisation (Pol), moisture, conductimetric ash and reducing sugars (RS)



Source: Research data

Table 1 - PCA of the physicochemical classification parameters

Eigenanalysis (eigenvalues and eigenvectors) of the correlation matrix				
Eigenvalues	3.1501	0.5221	0.2286	0.0993
Proportion	0.788	0.131	0.057	0.025
Cumulative	0.788	0.918	0.975	1.000
Variable	PC1	PC2	PC3	PC4
Pol (°S)	-0.543	-0.059	0	-0.838
Ash (%)	0.448	-0.807	0.306	-0.234
Moisture (%)	0.518	0.092	-0.779	-0.342
RS (%)	0.486	0.581	0.548	-0.356

Pol = polarisation; RS = reducing sugars; PC = principal component

Sterilisation and drying are used to prevent deterioration; however, their effectiveness depends on maintaining the sugar in a dry state, since molasses is hygroscopic (Joly; Stupiello, 1973). According to Bayma (1974), moisture and the concentration of non-sucrose compounds are crucial for preserving the product, especially sugars with a high level of purity. The SF (Equation 1), established by the Colonial Sugar Refining Company (Geerligs, 1922), helps determine the risk of deterioration, emphasising the importance of keeping moisture below half the amount of non-sucrose compounds so as to prevent microbial contamination. Delgado and Cesar (1977) pointed out that when the '100 − pol' fraction is greater, indicating lower polarisation, the moisture content of the sugar may also be higher.

$$SF = \frac{moisture}{100 - pol} \quad (1)$$

At the 12th ICUMSA Session in 1958 (Plews, 1997), the term Equilibrium Relative Humidity (ERH) was introduced as a result of studies on sugar crystallography. Bienenstock and Powers (1951) used the ERH to refer to the relative humidity of the atmosphere at which sugar is in equilibrium. According to Moroz (1963), ERH is the ratio between the vapour pressure of the solution (the molasses film in raw sugar) and the vapour pressure of the solvent (the water content of the film), similar to water activity (a_w), and defined as the ratio between the partial vapour pressure of water (P) and the saturated vapour pressure of water (P_0) at the same temperature (Equation 2). This concept is fundamental to predicting food safety and stability, particularly in relation to microbial growth (Celestino, 2010).

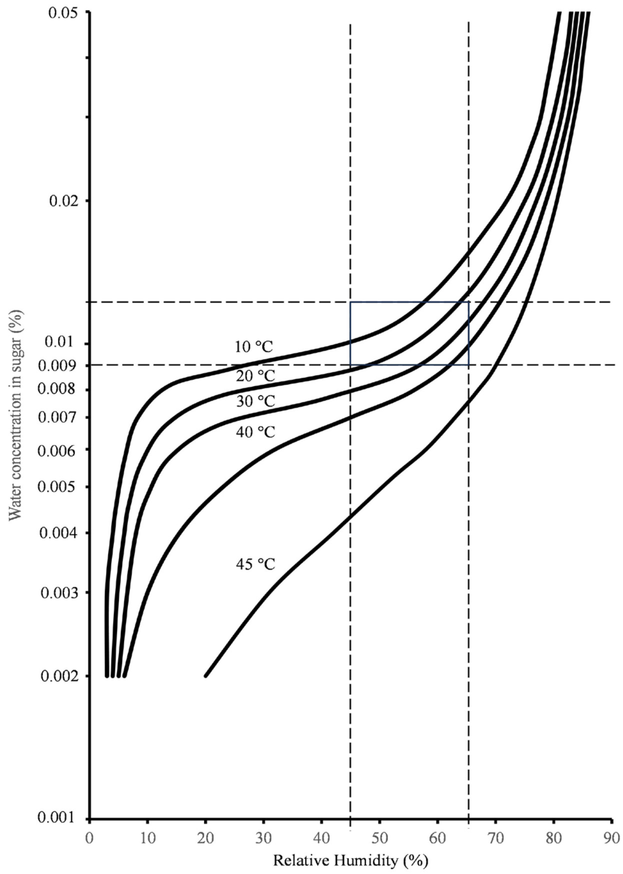
$$a_w = \frac{P}{P_0} = \frac{ERH}{100} \quad (2)$$

A knowledge of relative humidity (RH) affords answers to several problems associated with sugar storage, particularly caking. When sugar is exposed to an atmosphere of a given RH, it may lose or gain moisture depending on the RH and the ambient temperature (Lopes, 1981). It can be seen from the sorption isotherm of white crystal sugar (Figure 2) that, within a specific RH range and at room temperature, water absorption by the sugar decreases. This phenomenon can be exploited to stabilise the moisture content of the product.

Webster (1941) stated that the RS content, particularly levulose due to its high hygroscopicity, affects the ERH. Lopes (1976) found that, for a given SF, crystal sugar with higher polarisation presents a higher ERH, which can be explained by the purity of the molasses film on the crystals. Thus, a lower polarisation would indicate a molasses film of inferior quality, and since impurities tend to increase the hygroscopicity of the molasses film, its ERH tends to decrease. Therefore, low-polarisation sugars are generally highly hygroscopic and vulnerable to atmospheric moisture.

It is known that as the ERH of demerara sugar exceeds 65%, storage problems become increasingly likely (Figure 3). The IAA (1934) emphasised the importance of problems when storing sugar at ports, stating that the hygroscopicity of sugar, or of its solution, depends mainly on its concentration regardless of its composition. According to Behne (1940), storing the product under a relative humidity of more than 66% is crucial for preserving the sugar.

Figure 2 - Sorption isotherm of white crystal sugar

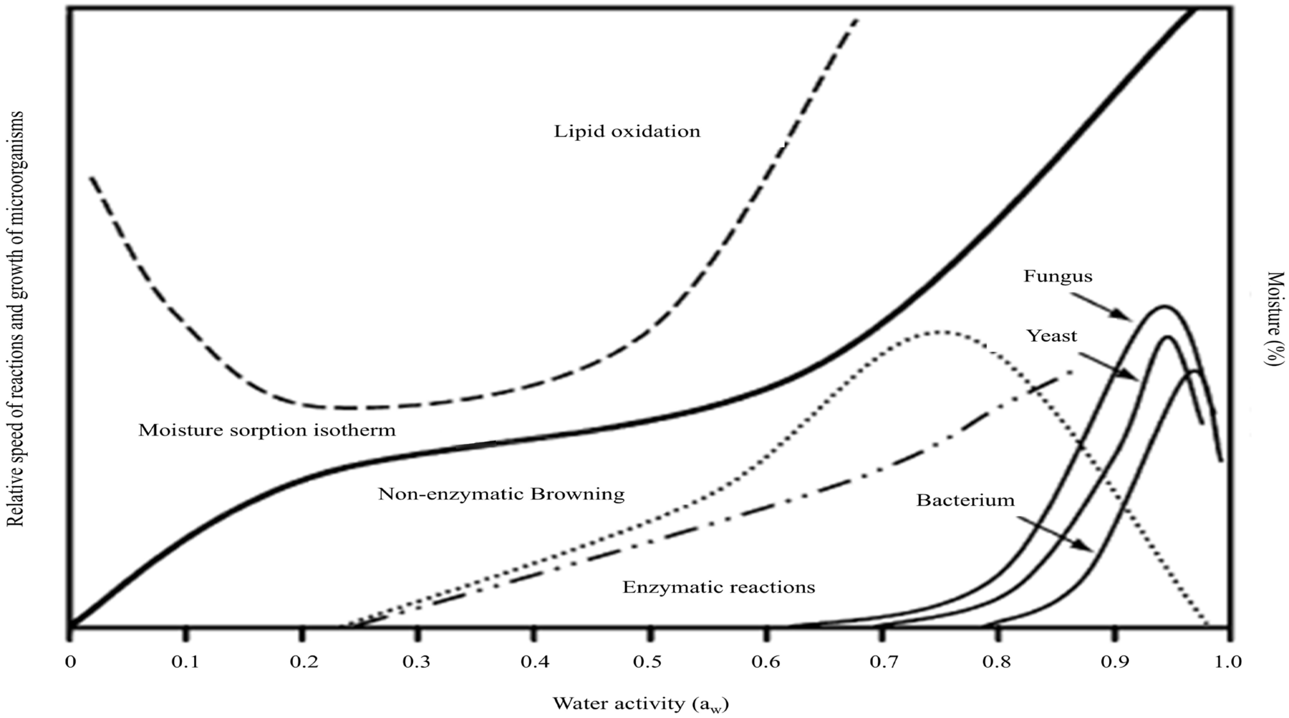


Source: Adapted from Schindler and Juncker (1993)

Although ERH may not be as reliable as SF for predicting the vulnerability of sugar to microbial attack, it is closely related to the osmotic pressure in the syrup, which affects microorganisms (Bienenstock; Powers, 1951). It is therefore possible to establish a maximum moisture limit for the product based on the sorption isotherm (Figure 2), using SF as a reference to determine a minimum value for polarisation. The correlation study between the SF and a_w indicators, based on secondary data obtained by Seguí *et al*. (2015) and Silva (2017), revealed a significant relationship, showing that for an SF of 0.3, the ERH was estimated to be approximately 65%. Another study conducted by Miller and Wright (1971) resulted in an estimated ERH of 63% for an SF of 0.28. The data from these studies were combined and are shown in Figure 4.

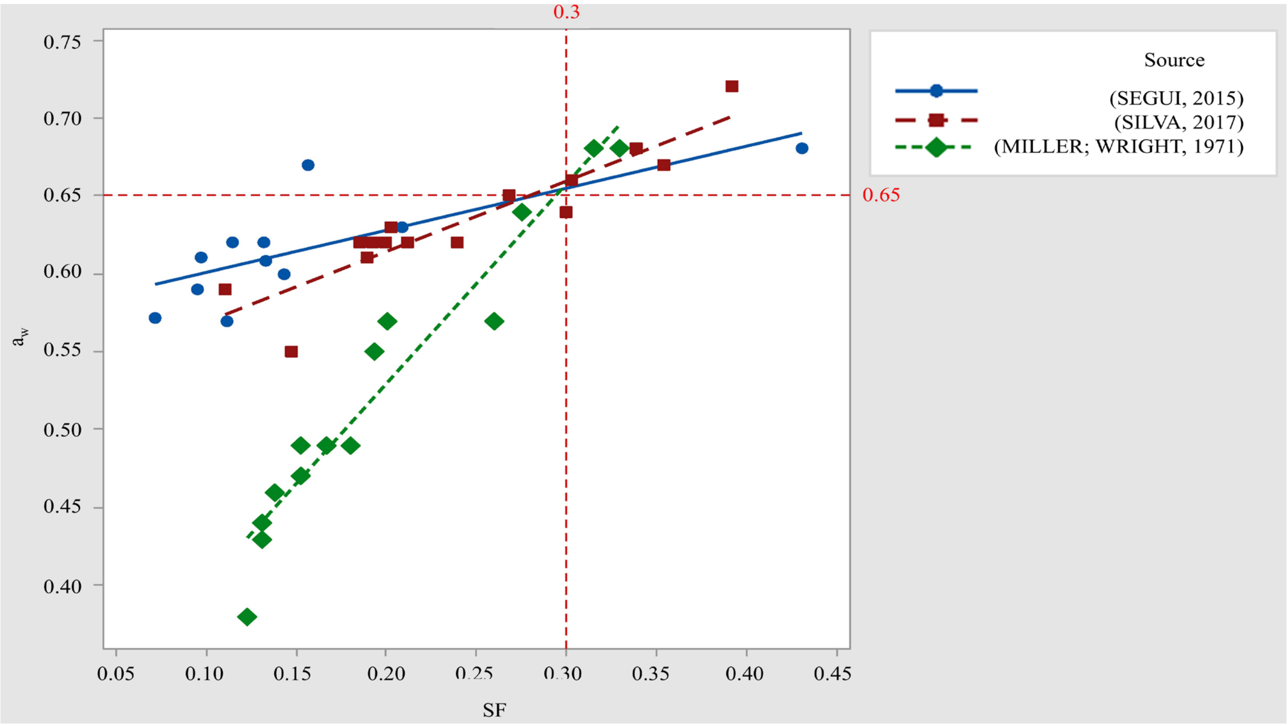
Since the appropriate SF value is related to the concentration at which microorganisms begin to act, and varies with the type of microorganism (Stupiello; Joly, 1968), Stupiello and Joly (1972) demonstrated that an SF close to 0.25 limits microbial growth after 360 days of storage. In addition, Abdo, Oliveira, and Mathlouthi (2019) suggested a minimum shelf life of 36 months.

Figure 3 - General map of food stability as a function of water activity (a_w)



Source: Adapted from Labuza (1975)

Figure 4 - SF and w_a for samples of mascavo sugar and *rapadura*



Source: Research data

Consequently, controlling the moisture as indicated by the SF, is essential for preserving sugar quality during storage. If the SF exceeds 0.3, sugar deteriorates rapidly; however, if it is equal to or lower than 0.3, deterioration is slower or non-existent. Based on these analyses, an SF limit of 0.30 was considered effective for preserving sugar under suitable storage conditions, together with a safe range for RH (between 45% and 65%) and the ambient temperature (between 20 °C and 40 °C), taking into account the sorption isotherm shown in Figure 2. Therefore, by adopting a maximum limit of 0.65 for the a_w indicator, it is possible to establish limits for polarisation and moisture and to suggest a minimum shelf life of 24 months for the sugar.

A subset of 1,573 samples that included moisture values was extracted from the secondary database, of which 662 samples of mascavo sugar showed a maximum moisture content of 5%. Based on these data, and considering an SF of 0.3, a preliminary polarisation limit of 84.0 °Z was estimated for mascavo sugar, which coincidentally is similar to the limit proposed by Brazil at the 1953 International Sugar Conference (IAA, 1953). For *rapadura*, a moisture content greater than 5% was considered acceptable, with a maximum of 9% being established, resulting in a minimum polarisation limit of 70 °Z, as set out by Carmo (IAA, 1972) in IAA Act No. 14/72. The ability of the ash parameter to distinguish mascavo sugar from other types of sugars was later examined, with most mascavo samples showing concentrations of less than 2.5%. For RS, a maximum concentration of 8% might be a useful indicator for differentiating mascavo sugar from *rapadura*.

The discriminant analysis (Mingoti, 2020) using the a priori classification (Table 2) indicated that the products had significant discriminatory power, with an overall accuracy rate of 74.4% (Table 3).

Table 2 - A priori physicochemical limits adopted for the discriminant analysis of sugar classes and types

Product	Order	Pol (°S) min	Moisture (%) max	Ash (%) max	RS max (%)	SF
Granulated	1	99.8	0.05	0.04	-	0.25
Crystal	1	99.5	0.10	0.1	-	0.20
Refined	1	99.0	0.30	0.2	-	0.30
VVHP	2	99.49	0.15	0.15	-	0.29
VHP	2	99.0	0.25	0.25	-	0.25
Demerara	3	96.0	1.2	0.5	2.0	0.30
Mascavo	4	84.0	5.0	2.5	8.0	0.31
Rapadura	5	70.0	9.0	5.0	15	0.30

Pol = polarisation; RS = reducing sugars; SF = safety factor

Table 3 - Discriminant analysis of the sugar classification parameters

Group	1	2	3	4	5
Frequency	43	31	260	508	128
			Classification summary		
Allocated to			Actual Group		
Group	1	2	3	4	5
1	38	0	0	0	0
2	5	31	43	0	0
3	0	0	217	175	0
4	0	0	0	311	3
5	0	0	0	22	125
Total N	43	31	260	508	128
Correct N	38	31	217	311	125
Proportion	0.884	1	0.835	0.612	0.977
N = 970 Correct N = 722 Correct Proportion = 0.744					

Source: Research data

According to Landis and Koch (1977), the calculated kappa index of 0.66 shows that adopting the proposed limits for the physicochemical parameters of sugars allows for a high degree of accuracy in classifying the products. However, the distinction between demerara sugar and mascavo sugar is less clear, highlighting the importance of considering not only the physicochemical quality parameters, but also those related to product identity (raw material and manufacturing processes).

Stage 4: Proposal of an OCS for mascavo sugar from an ontological perspective

The proposal to revise NI47 to include an Official Classification Standard (OCS) for mascavo sugar was developed from an ontological perspective, identifying the four Aristotelian causes for product characterisation. As the material cause, mascavo sugar is considered to be produced from the juice extracted from sugarcane, as described by Antonil (1837). The historical evolution of mascavo sugar production, which moved from artisanal methods to more productive industrial processes, highlights the importance of recognising different modes of production. Thus, with regard to the efficient cause, it is proposed that a separate class for mascavo sugar be included in NI47, subdivided into two types based on the manufacturing process, which include crystallisation or beating stages. For the final cause, classification is also based on the intended use of the product, which categorises it into two groups: intended for human consumption (sold directly to the end consumer) or intended for the food industry. The intended use of mascavo sugar was considered to be direct consumption. Finally, the proposal establishes physicochemical parameters for mascavo sugar, shown in Table 4, and suggests the items be included in the draft revision of the legislation.

Mascavo: That obtained by direct manufacture in sugar mills through a process of extraction and clarification of sugarcane juice by physicochemical treatments, followed by evaporation, crystallisation, centrifugation and drying of the end product; or that obtained by direct manufacture in industrial or artisanal processes through the extraction and clarification of sugarcane juice by manual or physicochemical treatments, followed by evaporation, beating, drying, cooling and sieving of the end product.

Granulated: Centrifugal sugar with a polarisation greater than 84.0 °Z (eighty-four degrees Zucker).

Amorphous: Non-centrifugal sugar with a polarisation greater than 84.0 °Z (eighty-four degrees Zucker).

It should be noted that the ICUMSA Colour parameter was not included in the proposal for mascavo sugar since this index is traditionally used to differentiate crystal-type sugars, which serve as the raw material for the production of refined sugar. In the case of mascavo sugar, whose final cause is direct consumption rather than refining, colour evaluation should be based on a visual colour scale, which is more suitable for representing the variations perceived by the consumer, and consistent with the artisanal or industrial nature of the product.

External validation of the proposed OCS for mascavo sugar

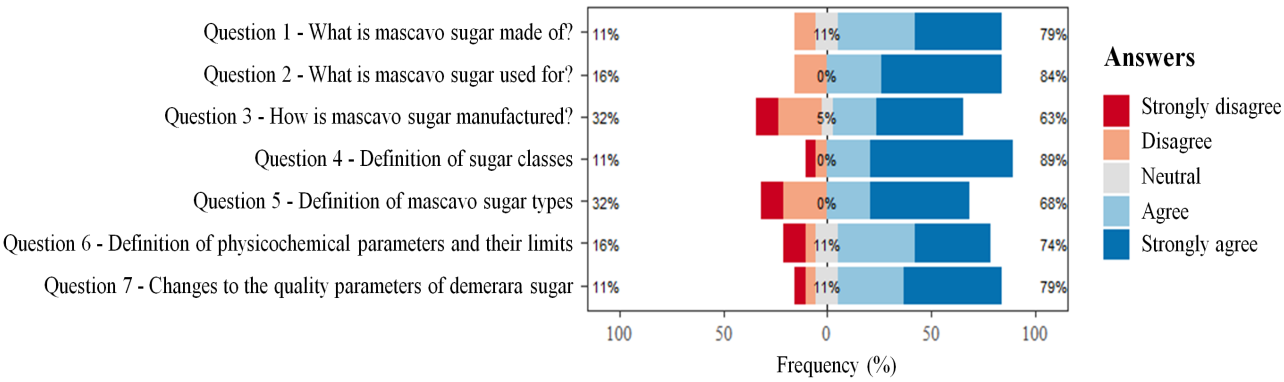
The proposed OCS for mascavo sugar was submitted to an opinion survey involving three groups of social agents. Data were collected virtually using a questionnaire with seven multiple-choice questions on a five-point Likert scale, and developed using Google Forms. The results, prepared using the R software (v 4.1.2), are summarised in Figure 5. The responses were grouped into two sets, Agreeing and Disagreeing, forming a contingency table that was submitted to the Pearson chi-square test, as per Cohen (2013), in order to verify the association between the frequencies observed in the Agreeing and Disagreeing groups and the three groups of social agents (Table 5).

Table 4 - Proposed physicochemical specification limits for sugar classes and types in the revision of Annex III of NI 60, including the proposed class mascavo sugar

		Parameters						
		Pol.	Moisture	ICUMSA Colour	Condut. Ash	Black specks	Magnetic particles	Reducing Sugars
Class	Type	(°Z min.)	(% max.)	(IU max.)	(% max.)	(n./100 g max.)	(mg/kg max.)	(%m/m max.)
White Crystal	Crystal	99.50	0.10	300	0.10	20	15	N/A
	Amorphous Refined or Refined	99.00	0.30	100	0.20	5	5	N/A
	Granulated Refined	99.80	0.05	60	0.04	5	5	N/A
	Confectioner	99.00	0.30	150	0.20	5	5	N/A
Raw Crystal	Demerara	96.00	1.20	5000	0.50	N/A	N/A	2.5
	VHP	99.00	0.25	2500	0.25	N/A	N/A	N/A
	VVHP	99.49	0.15	1000	0.15	N/A	N/A	N/A
Mascavo	Granulated	84.0	5.0	N/A	2.5	N/A	N/A	8.0
	Amorphous	84.0	5.0	N/A	2.5	N/A	N/A	8.0

Pol = polarisation; ICUMSA = International Commission for Uniform Methods of Sugar Analysis; Condut Ash = conductimetric ash; N/A = not applicable

Figure 5 - Agreement of stakeholder groups with the proposed revision of NI47 for mascavo sugar, assessed through seven Likert-scale questions



Source: Research data

Table 5 - Pearson chi-square test of independence between stakeholder group and agreement with the proposed revision of NI47 for mascavo sugar

		Mills	Ind & FF	Neutral	Total
Disagreeing	Observed	7	9	14	30
	Expected	9.32	9.55	11.14	
Agreeing	Observed	34	33	35	102
	Expected	31.68	32.45	37.86	
		41	42	49	132
Pearson chi-square = 1.740; df = 2; p-value = 0.419					

Source: Research data

Assuming the null hypothesis that the median values of the grouped responses to the seven questions did not differ between the three groups of social agents at a significance level of 5%, the observed p-value indicates that there is no statistical association between the groups of social agents and the position of agreement or disagreement with the proposals in the draft. Most participants agreed with the proposed items, indicating a strong consensus regarding the amendments to the legislation.

CONCLUSIONS

1. The study addressed the central research question by proposing an official classification standard for mascavo sugar based on historical documents and secondary quality data to serve as a basis for updating the legislation. The evolution of the classification of plant-based products in Brazil since Portuguese colonisation was outlined, highlighting the laws that regulated the export and import of food products. The literature review showed the transition from the artisanal sugar production process in sugar mills to industrial production in sugar plants, highlighting the variety of terms used and demonstrating that, over nearly 500 years, white crystal sugar, raw crystal sugar and mascavo sugar were produced in Brazil in both sugar mills and industrial plants;
2. Using an ontological approach and the Aristotelian method, the criteria of the legislation on the classification of plant-based products were interpreted and applied in the preparation of the proposed official classification standard for mascavo sugar, defining sugarcane juice as the raw material, industrial and artisanal manufacturing processes as the means of production, and direct consumption as the intended use of the product. The following quality parameters were proposed: minimum polarisation of 84.0 °Z, maximum moisture content of 5.0%, maximum conductimetric ash content of 2.5% and maximum reducing sugars content of 8.0%. A proposal was made to include in the legislation a separate class for mascavo sugar, comprising the granulated and amorphous types. This proposal was evaluated by means of a qualitative multiple-choice survey, which demonstrated acceptance by market agents involved in the research, production and marketing of the product;

3. The study clarified the historical and current role of Mapa and Anvisa in the food classification process, as well as the importance of the microbiological parameters defined by Anvisa in conjunction with the physicochemical parameters regulated by Mapa. Furthermore, the historical research and the use of secondary data made it possible to develop a procedure for determining the shelf life of stored sugars, recommending a minimum shelf life of 24 months, provided that the microbiological and physicochemical parameters comply with the legislation; this may be revalidated based on analyses of representative samples of the stored product.

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DATA AVAILABILITY STATEMENT

The research data is available in the repository (https://repositorio.ufscar.br/bitstreams/cf178747-8441-4706-a8e6-cc94438ffb42/download).

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