Original Article
Food Science and Technology

ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)

DOI: https://doi.org/10.5327/fst.00263

Mineral levels in sugarcane syrup

Carolina Medeiros VICENTINI-POLETTE[1], Anderson de Souza GALLO[2*], João Henrique do Nascimento e SILVA[3], Alberto Carlos de Campos BERNARDI[4], Maria Teresa Mendes Ribeiro BORGES[3], Marta Regina VERRUMA-BERNARDI[3]

Abstract

Sugarcane syrup derived from evaporating sugarcane juice serves as both a self-consumed product and a dietary supplement. It retains nutrients in sugarcane juice, especially minerals and nutritional compounds resistant to cooking processes. This study evaluated the mineral content of Brazilian sugarcane syrup by using inductively coupled plasma optical emission spectrometry. The syrup was found to have high concentrations of potassium, magnesium, calcium, and phosphorus (340, 57, 49, and 48 mg 100 g^{-1}, respectively). Although the qualitative mineral composition of the evaluated products was relevant and consistent, there was considerable quantitative variation; therefore, standardization based on a narrow range of acceptable values is not recommended. It would take 243–1,157 g of syrup to replace 200 g of whole cow's milk. Nonetheless, sugarcane syrup contains essential minerals with proven health benefits. Potassium had the highest average concentration (up to 781.53 mg 100 g^{-1}), followed by magnesium (10.82–94.69 mg 100 g^{-1}), with iron ranking fifth (8.82 mg 100 g^{-1}). Despite the quantitative variation, the qualitative mineral composition remained relevant. Therefore, a narrow standardization based on a limited range of values is not recommended. Nonetheless, sugarcane syrups with lower mineral levels can be considered nutritionally adequate.

Keywords: food composition; food safety; nutrient composition; *Saccharum officinarum.*

Practical Application: Sugarcane syrup is an energy-rich and nutritious food that preserves nutrients and minerals in sugarcane juice.

1 INTRODUCTION

Around 1.5 billion people worldwide are affected by micronutrient deficiency due to the inability to afford adequate quantities of red meat, chicken, fish, fruits, and vegetables that meet their nutritional needs (Wang et al., 2016); children, mothers, nursing mothers, and senior citizens are the primary victims of malnutrition. Micronutrient deficiencies such as iron, zinc, and vitamin A may compromise children's physical and intellectual development and may even lead to premature death. Iron deficiency can also cause anemia in women of reproductive age, both well-nourished and overweight (Jennings Aburto et al., 2013).

Energy-rich diets can still be low in micronutrients due to limited access to fresh and nutritious food, which tends to be expensive. Consequently, individuals with limited resources often opt for cheaper, calorie-dense food with minimal diversity and low nutrient and fiber levels.

Current strategies to combat malnutrition in developing countries have focused on providing vitamin and mineral supplements and food fortification. Although these strategies have yielded positive results (Bouis & Saltzman, 2017), there are limitations in the fortification and availability of commercial supplements.

According to NEPA and UNICAMP (2011), 100 g of sugarcane syrup contains 1242.65 kJ (297 kcal), 22.1% moisture, 76.6 g carbohydrate, and 1.3 g ash, but no dietary fiber and cholesterol. The protein, lipid, and fiber contents were insignificant.

Sugarcane syrup has the potential to serve as an alternative food source for supplying energy and minerals. It is obtained by concentrating sugarcane juice (*Saccharum officinarum*) or rapadura through appropriate processes such as cooking and evaporation (Brasil, 1978; 2005). Unlike some organic compounds, most minerals are not destroyed during cooking, and their concentrations may increase in the final product (Nogueira et al., 2009).

The physical properties of sugarcane syrup vary, but literature reports an average specific gravity of 4.266, ash content ranging from 0.3 to 3.9%, sugar content of 57.25 g 100 g^{-1}, soluble solid content ranging from 72.3 to 82.9% per 100 g, acidity levels of 0.3% (glycolic acid) and 0.4% to 1.0% (aconitic acid), and pH values of 3.9 to 5.7 (Khalili et al., 2022; Vicentini-Polette et al., 2019).

Received 18 Jan., 2024.
Accepted 03 Mar., 2024.
[1]*Universidade Federal de São Carlos, Center of Agricultural Sciences, MSc Program in Agroecology and Rural Development, Department of Agroindustrial Technology and Rural Socio-Economics, Araras, São Paulo, Brazil.*
[2]*Universidade Federal de São Carlos, Center of Agricultural Sciences, Department of Rural Development, Araras, São Paulo, Brazil.*
[3]*Universidade Federal de São Carlos, Center of Agricultural Sciences, Department of Agroindustrial Technology and Rural Socio-Economics, Araras, São Paulo, Brazil.*
[4]*Brazilian Agricultural Research Corporation, Embrapa Cattle Southeast, Department of Plant Production, Soil Fertility, São Carlos, São Paulo, Brazil.*
*Corresponding author: andersondsgallo@hotmail.com

Sugarcane syrup provides essential nutrition in several regions of Brazil, serving as both an independent dietary item and a versatile additive. Recognized for its richness in energy and nutrients, 100 g of sugarcane syrup provides 1,242.65 kJ (297 kcal) (Jeronimo, 2018). Moreover, it is mainly produced through family-based operations, thus fulfilling its roles in self-consumption and income generation. Furthermore, it holds vital cultural solid significance; it is sought after in natural food markets and preserves nutrients from sugarcane juice, including high concentrations of essential minerals, such as iron, calcium, potassium, sodium, phosphorus, magnesium, and chlorine (Amorim et al., 2009). Notably, in contrast to certain organic compounds, minerals withstand the cooking process without degradation (Nogueira et al., 2009).

The nutritional composition of sugarcane syrup depends on the characteristics of sugarcane juice, which is influenced by several factors, including variety, soil type, climatic conditions, fertilization, cane maturity level, harvest method, the duration between harvest and processing, and quantity of leaves and straws present (Basso et al., 2011).

The recommended daily iron intake for an individual on a diet is approximately 8,368 kJ (2,000 kcal) of 14 mg. Therefore, 100 g of the product corresponded to 39% of the recommended value (Brasil, 2003). Calcium intake regulates body temperature, thermogenesis, and other metabolic processes, including hormonal regulation (Zemel et al., 2004). Zinc plays a role in growth, immunity, and cognition (Macedo et al., 2019). Therefore, sugarcane syrup is a promising source of essential minerals for nutrition.

Understanding the mineral composition of sugarcane syrup is crucial for several reasons: syrup is extensively used as a food product and for income generation. In addition, by examining its mineral content, we can also assess its nutritional value and potential health benefits for consumers. Second, investigating the mineral content of sugarcane syrup could provide insights into the nutrient profiles and potential bioavailability of these minerals. Furthermore, it is culturally and economically significant, particularly in the syrup production regions. Ensuring the production of high-quality syrup while preserving its cultural impact is of utmost importance. Overall, exploring the mineral content of sugarcane syrup contributes to our understanding of its nutritional value and potential health benefits and emphasizes its cultural significance, thus providing valuable insight into the sugarcane industry for both consumers and producers.

This study aimed to analyze the mineral composition of sugarcane syrup produced in different regions of Brazil and to assess its potential as a source of minerals in the human diet.

2 MATERIALS AND METHODS

In total, 15 commercial brands of sugarcane syrup were purchased from different Brazilian regions, including the product designation (name), manufacturer's name and address, net weight, ingredients, and expiration date. In addition, only syrups with expiration dates longer than the experimental duration were selected. Fifteen samples were obtained from the following Brazilian states: São Paulo (3), Paraná (3), Rio Grande do Sul (3), Santa Catarina (3), Mato Grosso do Sul (2), and Rio de Janeiro (1).

Calcium (Ca), copper (Cu), iron (Fe), phosphorus (P), magnesium (Mg), manganese (Mn), potassium (K), and zinc (Zn) were determined by mixing 0.5 to 1.2 g of each sample in nitric-perchloric acid (7 mL), following the study of Oliveira et al. (2005). Afterward, each sample was diluted with 25 mL of deionized water and stored in plastic tubes at room temperature. Mineral composition analysis was performed using inductively coupled plasma optical emission spectrometry (ICP-OES; VistaRL CCD-Simultaneous ICP-OES, Varian) with a dichroic spectral combiner for data collection in radial visualization mode, a V-groove nebulizer, and a Sturman–Masters fogging chamber. The experimental conditions for ICP-OES were as follows: plasma power, 1.3 kW; gas flow, 15.0 L min^{-1}; auxiliary flow, 1.5 L min^{-1}; nebulizer flow, 1.4 L min^{-1}; and nebulization rate, 4.0 L min^{-1}.

The data obtained were evaluated with analysis of variance using JASP software (version 0.11.1.0), considering significant differences between means in the Tukey test ($p \leq 0.05$) to be significant.

3 RESULTS AND DISCUSSION

Vicentini-Polette et al. (2019) determined that among the 15 brands analyzed, sugarcane syrup has a pH ranging from 3.93 to 5.67, acidity of 0.44–0.97%, viscosity of 9.00–314.33 St, soluble solids of 72.27–82.87 °Brix, reducing sugar content of 9.00–61.51%, and moisture of 9.01–26.12% (NEPA & UNICAMP, 2011).

The permitted ash content for sugarcane syrup was up to 6% (Brasil, 1978), and all analyzed samples adhered to this recommendation. However, current Brazilian legislation does not specify the ash content of the product (Brasil, 2005). Table 1 presents studies on the ash content of sugarcane syrup.

Furthermore, the ash content of a product directly correlates with its total mineral and metal content. Sugarcane syrups exhibit significant physical and chemical variations influencing consumer preferences (Vicentini-Polette et al., 2019). In addition, the lack of standardization negatively affects food quality, as dirt is found in 93% of Brazilian sugarcane syrups (Belé et al., 2019).

There was a variation of 1.21 and 1.84% in sugarcane syrups produced through different methods that utilized the same raw

Table 1. Average ash content in sugarcane syrup according to relevant literature.

Literature	Ash content (%)
Brasil (1978)	< 6
Brasil (2005)	Not determined
Saska and Chou (2002)	0.68–5.8
NEPA and UNICAMP (2011)	1.3
Barreto et al. (2015)	1.2–2.1
Vilela (2016)	0.23–1.60
Vicentini-Polette et al. (2019)	0.3–3.8

material and 2.08% in a commercial sample (Barreto et al., 2015); these findings suggest that processing methods do not significantly affect the final ash content when raw ingredients are identical. However, the elevated ash content in sugars needs to be controlled, as the high levels stop crystallization and also contribute to an undesirable taste (Lopes & Borges, 2004).

Sugarcane syrup naturally contains specific minerals, such as iron, calcium, magnesium, and potassium. Owing to its distinct flavor and thickness, this syrup can be widely used as a flavoring agent in various food products, including baked goods, sauces, and marinades. Furthermore, it contains precise amounts of essential minerals, including approximately 0.9 mg of iron; 146 mg of calcium; 242 mg each of iron, calcium, and magnesium; and 1,464 mg of potassium per 100 g of sugarcane syrup, respectively. Trace minerals enhance the taste of culinary creations and provide potential health benefits to individuals (Codex Alimentarius, 2019).

Nogueira et al. (2009) reported the following ranges of mineral variation in commercial sugarcane syrups (mg 100 g^{-1}): 1.2 to 7.5 iron, 62 to 699 potassium, 4.6 to 155 phosphorus; 4.6 to 57 sodium; 0.04 to 2.4 copper; 18 to 139 magnesium; 0.31 to 1.59 zinc; 0.39 to 2.8 manganese; and 22 to 50 calcium. The vast range of mineral nutrients in commercial sugarcane syrup hinders its nutritional characterization.

Furthermore, commercial sugarcane syrups showed significantly higher levels of iron, phosphorus, sodium, and manganese than artisanal syrups produced using stainless steel mills. These high metal levels may be attributed to contamination during manufacturing, especially when using copper pots (Nogueira et al., 2009). Finally, significant variation was found in the mineral content of the different sugarcane syrup samples, with potassium having the highest average of 340 mg 100 g^{-1}.

Minerals are essential nutrients for human health and are primarily obtained from food. Iron is crucial for preventing iron deficiency anemia, the most prevalent type in the Brazilian population; moreover, this type of anemia is diagnosed in 95% of cases (Brasil, 2002).

Table 2 shows the mineral composition of sugarcane syrup. According to Amorim et al. (2009), the mineral composition per 100 g of sugarcane syrup was 30–70 mg phosphorus, 190–540 mg potassium, 60–120 mg calcium, and 40–110 mg magnesium.

The varying ranges in mineral content were similar to those published by NEPA and UNICAMP (2011). However, there were exceptions for sodium and calcium, which had higher and lower concentrations than in the analyzed sugarcane syrup, respectively. Additionally, most samples had lower levels of minerals such as iron, manganese, copper, and phosphorus than those reported by NEPA and UNICAMP (2011). According to NEPA and UNICAMP (2011), sugarcane syrup contains the following per 100 g of product: 5.4 mg iron, 395 mg potassium, 74 mg phosphorus, 4.0 mg sodium, 0.85 mg copper, 115 mg magnesium, 0.3 mg zinc, 2.6 mg manganese, and 102 mg calcium. These values are the averages of the analytical results obtained from at least three to five samples of the leading commercial brands collected from different regions of Brazil.

In Brazil, a law was established wherein food products may be considered a source of vitamins and minerals if they contain

Table 2. Average mineral levels in sugarcane syrup and related laws.

Samples	Ca	Mg	P	K	Cu	Fe	Mn	Zn
				(mg 100 g^{-1})				
A	77.49^{ab}	94.69^{a}	44.83^{fg}	73.49^{ghi}	0.16^{a}	6.86^{bcd}	1.71^{c}	0.63^{abc}
B	42.60^{def}	69.39^{c}	53.87^{def}	95.43^{de}	0.23^{a}	34.35^{a}	3.03^{b}	0.79^{abc}
C	72.30^{bc}	60.36^{cd}	84.22^{b}	28.58^{cd}	0.17^{a}	1.22^{d}	1.01^{de}	0.41^{bc}
D	101.07^{a}	63.17^{cd}	98.49^{a}	04.88^{de}	1.61^{a}	3.62^{bcd}	1.42^{cd}	0.53^{bc}
E	22.02^{fg}	14.60^{f}	15.99^{h}	24.99^{hij}	0.93^{a}	2.48^{cd}	0.60^{e}	0.50^{bc}
F	25.64^{fg}	50.68^{de}	79.51^{bc}	781.53^{a}	0.45^{a}	3.40^{cd}	0.56^{e}	0.60^{bc}
G	65.95^{bcd}	87.52^{ab}	66.95^{cd}	542.04^{b}	0.30^{a}	39.52^{a}	2.54^{b}	1.50^{a}
H	3.56^{bcde}	98.51^{a}	46.22^{efg}	75.79^{de}	0.54^{a}	9.33^{bc}	2.95^{b}	0.95^{abc}
I	25.14^{fg}	10.82^{f}	9.72^{h}	111.07^{ij}	4.18^{a}	3.52^{bcd}	0.91^{de}	0.71^{abc}
J	21.32^{fg}	18.97^{f}	36.99^{g}	83.52^{de}	0.96^{a}	0.89^{d}	0.47^{e}	0.57^{bc}
K	76.02^{b}	93.57^{a}	62.95^{d}	18.13^{bc}	0.39^{a}	10.99^{b}	4.03^{a}	0.74^{abc}
L	44.32^{def}	73.43^{bc}	9.39^{h}	258.01^{fg}	0.09^{a}	7.41^{bcd}	0.73^{e}	0.35^{bc}
M	50.38^{cde}	53.59^{de}	54.73^{def}	311.69^{ef}	0.16^{a}	0.90^{d}	2.78^{b}	0.17^{c}
N	39.59^{efg}	43.24^{e}	59.12^{de}	32.23^{fgh}	0.52^{a}	4.97^{bcd}	0.80^{e}	1.19^{ab}
O	15.80^{g}	19.33^{f}	5.58^{h}	64.65^{j}	0.96^{a}	2.85^{cd}	0.53^{e}	1.05^{abc}
Average	49.55	56.79	48.57	340.4	0.77	8.82	1.6	0.71
SD	6.09	3.95	3.4	27.11	1.62	1.87	0.15	0.22
				(mg day^{-1})				
NEPA and UNICAMP (2011)	102	115	74	395	0.84	5.4	2.62	0.3
FAO (2001)	1.000-1.300	220-260	-	-	-	9-59	-	-
FDA (2016)	1.300	420	1,250	4.700	0.9	18	2.3	11
EFSA (s.d.)	750-860	300-350	550	3.500	1.3-1.6	6-7	3	6.2-12.7

SD: Standard deviation. Different letters in the same column indicate significant differences ($P < 0.05$).

either a minimum of 15% of the recommended daily intake of the respective nutrients per 100 g for solid food or a minimum of 7.5% per 100 mL for liquids (Brasil, 1998). These limits consider food intake, with liquids generally consumed in larger quantities. However, the recommended amount of sugarcane syrup that can be ingested is smaller than for most solid foods at an estimated 20 g (Brasil, 2003).

Table 2 illustrates that potassium has the highest average concentration among all elements. In this study, potassium levels in the samples ranged from 4.88 mg to 781.53 mg. Fu thermore, the World Health Organization (WHO) recommends a minimum daily intake of 3,510 mg of potassium. Potassium is an essential cation that directly affects lean mass and cellular behavior (Grillo et al., 2020). It aids various functions of the body, including muscle movement and nerve impulse transmission. Imbalances in the intra- and extracellular concentrations may impair neural transmission, cell contraction, and vascular tone (Hack, 2012).

Potassium intake below the recommended level can cause fatigue, thirst, cardiac problems, and muscle fatigue (Pinheiro et al., 2005). Similar potassium levels have been reported in previous studies of sugarcane syrup (Lee et al., 2018; Shaheen et al., 2013; Singh et al., 2013).

Magnesium is essential for calcium fixation in the body (Brasil, 2002). In the present study, the values for magnesium were slightly lower than those reported by Amorim et al. (2009), ranging from 10.82 to 94.69 mg 100 g^{-1} for magnesium. The Food and Agriculture Organization (FAO, 2001) recommends a minimum daily intake of 220 mg for a balanced adult diet. Therefore, adults can consume from 4.92 to 44.78% magnesium in 100 g of sugarcane syrup (approximately 5 tablespoons). Among these minerals, calcium is crucial for bone maintenance, osteoporosis prevention, and blood pressure regulation. The study found slightly lower calcium values than those mentioned in the literature (Amorim et al., 2009; NEPA & UNICAMP, 2011), ranging from 15.80 to 101.07 mg 100 g^{-1}.

Although sugarcane syrup is not widely recognized for its calcium content, it is richer in calcium than whole cow's milk, which has a calcium content of 123 mg 100 g^{-1} (NEPA & UNICAMP, 2011). Therefore, it would take 243–1,157 g of sugarcane syrup to replace 200 g of whole cow's milk. Adults' recommended minimum daily calcium intake is 1,000 mg (FAO, 2001). Consequently, consuming 100 g of the syrups analyzed in this study would provide 0.36 to 10.11% of the daily calcium requirement.

In this study, iron ranked fifth in mineral content in sugarcane syrup, followed by calcium, magnesium, phosphorus, and potassium, which were the highest (Table 2). The average iron levels in sugarcane syrups ranged from 0.89 to 39.52 mg 100 g^{-1}. However, the amount of iron absorbed and available for metabolism is determined by its bioavailability. Bioavailability is influenced by several factors, such as speciation, molecular bonding, quantity ingested, food matrix, nutritional status, genetics, and interactions between minerals and vitamins (Cozzolino, 1997).

Iron contained in food of animal origin is better absorbed (up to 22%) than in food of plant origin (1 to 6%). Despite sugarcane syrup being a source of iron, it likely needs to be oxidized before consumption because of potential contamination and exposure to heat, resulting in less to no absorption (Nogueira et al., 2009; Silva & Williams, 1993).

In addition, the competition between calcium and iron in biological systems may also interfere with their absorption (Pereira et al., 2009). The same holds for interactions between iron, zinc, and other minerals and vitamins. Therefore, in addition to improving bioavailability, a balanced diet is necessary (Cozzolino, 1997).

Thus, it can be observed that the mineral content is also dependent on various factors, and standardization based on a narrow range of acceptable values is not recommended. However, future studies may explore factors that enhance mineral content, suggesting a minimum or desirable range for mineral content. Incorporating sugarcane syrup as an additive into other food can also help balance the overall nutrition of an individual's diet. In addition to the benefits of minerals to human health, a healthy diet is known to influence the gut microbiome, suggesting the beneficial effects of bacteria on mineral bioaccessibility and bioavailability (Bielik & Kolisek, 2021).

Furthermore, since sugarcane syrup is a product of national significance, it is crucial to enforce efficient regulations that establish parameters for producing high-quality sugarcane syrup without compromising its cultural essence.

4 CONCLUSION

Besides sugarcane syrup's renowned flavor and thickness, it naturally contains essential minerals, such as iron, calcium, magnesium, and potassium, offering potential health benefits. Potassium has the highest average concentration of up to 781.53 mg among all other elements. Magnesium levels in the syrup varied from 10.82 to 94.69 mg 100 g^{-1}. Iron ranked fifth in mineral content (8.82 mg 100 g^{-1}), trailing behind calcium, magnesium, phosphorus, and potassium.

Due to its significant mineral content, sugarcane syrup has high nutritional value, making it a valuable addition to a balanced diet. Although considerable quantitative variation was observed, the qualitative mineral compositions of the evaluated products remained relevant and consistent. Therefore, establishing a narrow standardization based on a limited range of acceptable values is not recommended. Despite, sugarcane syrups with lower mineral levels can be considered nutritionally adequate.

ACKNOWLEDGMENTS

We wish to express our gratitude to the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the scholarships awarded. This study was partly funded by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Brazil (CAPES—Finance Code 001) and the Funding Authority for Studies and Projects (FINEP/CT—AGRO/FNDCT, Cooperation Agreement N. 01.22.0080.00, Ref. 1219/21).

REFERENCES

Amorim, H. V., Basso, L. C., & Lopes, M. L. (2009). Sugar cane juice and molasses, beet molasses and sweet sorghum: composition and usage. In W. M. Ingledew, G. D. Austin, D. R. Kelsall & C. Kluhspies (Eds.), *The alcohol textbook: a reference for the beverage, fuel, and industrial alcohol industries* (pp. 39-46). Nottingham University Press.

Barreto, P. P. P., Bettani, S. R., Borges, M. T. M. R., & Verruma-Bernardi, M. R. (2015). Avaliação físico-química e sensorial de diferentes melados. *Brazilian Journal of Agriculture*, *90*(3), 217-228. https://doi.org/10.37856/bja.v90i3.66

Basso, L. C., Basso, T. O., & Rocha, S. N. (2011). Ethanol production in Brazil: the industrial process and its impact on yeast fermentation. In M. A. S. Bernardes (Ed.), *Biofuel production-recent developments and prospects* (pp. 85-100). InTechOpen.

Belé, J. S. A., Vicentini-Polette, C. M., Ceccato-Antonini, S. R., Spoto, M. H. F., Belini, V. L., & Verruma-Bernardi, M. R. (2019). Microbiological and microscopic analysis of sugarcane syrup. *Journal of Agricultural Science*, *11*(17), 210-217. https://doi.org/10.5539/jas.v11n17p210

Bielik, V., & Kolisek, M. (2021). Bioaccessibility and bioavailability of minerals in relation to a healthy gut microbiome. *International Journal of Molecular Sciences*, *22*(13), 6803. https://doi.org/10.3390/ijms22136803

Bouis, H. E., & Saltzman, A. (2017). Improving nutrition through biofortification: a review of evidence from HarvestPlus, 2003 through 2016. *Global Food Security*, *12*, 49-58. https://doi.org/10.1016/j.gfs.2017.01.009

Brasil (1978). Comissão Nacional de Normas e Padrões para Alimentos. Aprova as normas técnicas especiais, do estado de São Paulo, revistas pela CNNPA, relativas a alimentos (e bebidas), para efeito em todo o território brasileiro (Resolução nº 12, de 24 de julho de 1978). *Diário Oficial da República Federativa do Brasil*.

Brasil (1998). Ministério da Saúde. Secretaria de Vigilância Sanitária. Aprova o Regulamento Técnico referente à Informação Nutricional Complementar (Portaria nº 27, de 13 de janeiro de 1998). *Diário Oficial da República Federativa do Brasil*.

Brasil (2002). Resolução de Diretoria Colegiada. Aprova o Regulamento Técnico para a Fortificação das Farinhas de Trigo e das Farinhas de Milho com Ferro e Ácido Fólico (Resolução RDC nº 344, de 13 de dezembro de 2002). *Diário Oficial da República Federativa do Brasil*.

Brasil (2003). Resolução de Diretoria Colegiada. *Aprova o Regulamento técnico sobre rotulagem nutricional de alimentos embalados* (Resolução RDC nº 360, de 23 de dezembro de 2003). *Diário Oficial da República Federativa do Brasil*.

Brasil (2005). Resolução de Diretoria Colegiada - RDC. Aprova o "Regulamento técnico para açúcares e produtos para adoçar", constante do Anexo desta Resolução (Resolução nº 271, de 22 de setembro de 2005). *Diário Oficial da República Federativa do Brasil*.

Codex Alimentarius (2019). *Standard for Sugars*: CXS 212-1999 [PDF]. Retrieved from https://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCXS%2B212-1999%252FCXS_212e.pdf

Cozzolino, S. M. F. (1997). Biodisponibilidade de minerais. *Revista de Nutrição*, *10*(2), 87-98. https://doi.org/10.1590/S1415-52731997000200001

European Food Safety Authority (EFSA) (s.d.). *Dietary References Values for the UE*. EFSA. Retrieved from https://www.efsa.europa.eu/en/topics/topic/dietary-reference-values

Food and Drug Administration (FDA) (2016). *Food Labeling: Revision of the Nutrition and Supplement Facts Labels*. FDA. Retrieved from https://s3.amazonaws.com/public-inspection.federalregister.gov/2016-11867.pdf

Food and Agriculture Organization of the United Nations (FAO) (2001). *Exigências de vitaminas e minerais humanos*. FAO. Retrieved from http://www.fao.org/3/a-y2809e.pdf

Grillo, A. D. C., Guedes, I. M. D. S., Nicolai, J. C., & Fernandez, W. S. (2020). Importância e atuação dos sais minerais no organismo. *Revista Científica Eletrônica de Enfermagem da FAEF*, *4*(3), 1-11. Retrieved from http://faef.revista.inf.br/imagens_arquivos/arquivos_destaque/BY50V66CJgicZcz_2020-7-7-8-45-37.pdf

Hack, J. A. S. (2012). *Atividades Interativas e de Pesquisa para Abordagem do Tema: Alimentação e Fome Oculta*. Secretaria da Educação do Estado do Paraná.

Jennings Aburto, N., Rogers, L., De-Regil, L. M., Kuruchittham, V., Rob, G., Arif, R., & Peña-Rosas, J. P. (2013). Evaluación de un sistema global de vigilancia nutricional sobre vitaminas y minerales. *Archivos Latinoamericanos de Nutrición*, *63*(2), 105-113.

Jeronimo, E. M. (2018). Produção de açúcar mascavo, rapadura e melado no âmbito da agricultura familiar e sua importância na alimentação humana. In S. M. Junior (Ed.). *Ciência alimentando o Brasil* (pp. 111-120). Centro Paula Souza.

Khalili, S., Sharifi, A., Hajiaghaei, M., & Mortazavi, S. A. (2022). Rheological properties of Babolsar sugarcane syrup. *Journal of Food and Bioprocess Engineering*, *5*(1), 60-66. https://doi.org/10.22059/JFABE.2022.339839.1111

Lee, J. S., Ramalingam, S., Jo, I. G., Kwon, Y. S., Bahuguna, A., Oh, Y. S., & Kim, M. (2018). Comparative study of the physicochemical, nutritional, and antioxidant properties of some commercial refined and non-centrifugal sugars. *Food Research International*, *109*, 614-625. https://doi.org/10.1016/j.foodres.2018.04.047

Lopes, C. H., & Borges, M. T. M. R. (2004). *Proposta de normas e especificações para açúcar mascavo, rapadura e melado de cana*. Universidade de São Carlos.

Macedo, C. N. A. de, Feitosa, J. M., Moura Santos, M. R. de, De Sousa, A. F., & Santos Duarte, E. C. P. dos (2019). A importância dos micronutrientes no desenvolvimento neurocognitivo da gestação a infância. *Revista Uningá*, *56*(4), 145-155. https://doi.org/10.46311/2318-0579.56.eUJ2985

Nogueira, F. D. S., Ferreira, K. S., Carneiro Junior, J. D. B. & Passoni, L. C. (2009). Minerais em melados e em caldos de cana. *Food Science and Technology*, *29*(4), 727-731. https://doi.org/10.1590/S0101-20612009000400005

Núcleo de Estudos e Pesquisas em Alimentação (NEPA) & Universidade Estadual de Campinas (UNICAMP). (2011). *Tabela Brasileira de Composição de Alimentos - TACO* (4th ed.). Retrieved from https://www.cfn.org.br/wp-content/uploads/2017/03/taco_4_edicao_ampliada_e_revisada.pdf

Oliveira, A. S., Nogueira, A. R. A., Carmo, C. A. F. S., Almeida, D. G., Fernandes, F. D., Pitta, G. V. E., Carlos, G. M., Oliveira, H., Mamão, J. B., Armelin, M. J. A., Saldanha, M. F. C., Miyazawa, M., Scramin, S., Barreto, W. O., Ruffini, Y. A. (2005). Tecidos vegetais. In A. R. A. Nogueira & Souza, G. B. (Ed.). *Manual de laboratórios: solo, água, nutrição vegetal, nutrição animal e alimentos* (pp. 32-42). Embrapa Pecuária Sudeste.

Pereira, G. A., Genaro, P. S., Pinheiro, M. M., Szejnfeld, V. L., & Martini, L. A. (2009). Cálcio dietético: estratégias para otimizar o consumo.

Revista Brasileira de Reumatologia, *49*(2), 164-171. https://doi.org/10.1590/S0482-50042009000200008

Pinheiro, D. M., Andrade Porto, K. R. de, & Silva Menezes, M. E. da (2005). *A química dos alimentos: carboidratos, lipídeos, proteínas, vitaminas e minerais*. EDUFAL.

Saska, M., & Chou, C. C. (2002). Antioxidant properties of sugarcane extracts. In *Proceedings of First Biannual World Conference on Recent Developments in Sugar Technologies*. Retrieved from https://wholecane.com/wp-content/uploads/2019/08/05-2002-comparison-of-the-concentration-of-phenolic-constituents-in-cane-sugar-manufacturing-products-with-their-antioxidant.pdf

Shaheen, N., Abu Torab, M. A. R., Mohiduzzaman, Md., Banu, C. P., Latiful B. Md., Tukun, A. V., Mannan, M. A., Bhattacharjee, L., & Stadlmayr, B. (2013). *Food composition table for Bangladesh*. University of Dhaka.

Silva, J. J. R. F. da & Williams, R. J. P. (1993). *The biological chemistry of the elements: the inorganic chemistry of life*. Oxford University Press.

Singh, J., Solomon, S., & Kumar, D. (2013). Manufacturing jaggery, a product of sugarcane, as health food. *Agrotechnology*, *S11*, 007. https://doi.org/10.4172/2168-9881.S11-007

Vicentini-Polette, C. M., Belé, J. S. A. H., Borges, M. T. M. R., Spoto, M. H. F., & Verruma-Bernardi, M. R. (2019). Physicochemical and sensorial characterization of commercial sugarcane syrups. *Revista de Ciências Agrárias*, *42*(3), 808-816. https://doi.org/https://doi.org/10.19084/rca.17279

Vilela, D. C. (2016). *Avaliação da qualidade físico-química de amostras de melado* (Trabalho de Conclusão de Curso). Universidade Tecnológica Federal do Paraná.

Wang, H., Naghavi, M., Allen, C., Barber, R., Bhutta, Z., & Carter, A. (2016). A systematic analysis for the global burden of disease study 2015. *Lancet*, *388*(10053), 1459-1544. https://doi.org/10.1016/S0140-6736(16)31012-1

Zemel, M. B., Thompson, W., Milstead, A., Morris, K., & Campbell, P. (2004). Calcium and dairy acceleration of weight and fat loss during energy restriction in obese adults. *Obesity Research*, *12*(4), 582-590. https://doi.org/10.1038/oby.2004.67