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MASCAVO SUGAR QUALITY: EXPLORING THE LINK BETWEEN MINERAL COMPOSITION AND COLOR

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Abstract: The lack of standardization in the classification of mascavo sugar compromises its commercialization and use as an ingredient in the food industry. This study aimed at investigating the correlation between the mineral composition and the instrumental color of mascavo sugars obtained both from factories and from markets. Seventeen samples were analyzed, 8 of which obtained from markets and 9 from processing plants. The sugar samples were analyzed by inductively coupled plasma-optical emission spectrometry and subsequent colorimetric analysis in the CIELAB system for the assessment of the variables L* (lightness) and hue angle (hue). The results demonstrated variations in the mineral contents between samples, with values often higher than a national reference table. Multivariate statistical analyses presented five main factors which explain data variability, with the lack of a direct correlation between the parameters of color (L* and hue) and the mineral contents analyzed.

Keywords: Mineral composition; Colorimetry; Principal component analysis.

QUALIDADE DO AÇÚCAR MASCAVO: EXPLORANDO A RELAÇÃO ENTRE A COMPOSIÇÃO MINERAL E A COR

Resumo: A falta de padronização na classificação do açúcar mascavo compromete sua comercialização e o uso como ingrediente na indústria alimentícia. O estudo teve como objetivo investigar a correlação entre a composição mineral e cor instrumental de açúcares mascavos obtidas tanto em usinas quanto no comércio varejista. Foram analisadas 17 amostras sendo que 8 foram obtidas de comércio e 9 de uma usina. Os açúcares foram analisados por meio de Espectroscopia de Emissão ótica por Plasma Acoplado Indutivamente e posteriormente análise colorimétrica no sistema CIELAB para avaliação das variáveis L* (luminosidade) e ângulo de tonalidade (hue). Os resultados mostraram variações nos teores de minerais entre as amostras, com valores frequentemente superiores a uma tabela nacional de referência. Análises estatísticas multivariadas apresentaram cinco fatores principais que explicam a variabilidade dos dados, sendo que os parâmetros de cor (L* e hue) não apresentaram correlação direta com os teores de minerais analisados.

Palavras-chave: Composição mineral; Colorimetria; Análise de componentes principais.

1. Introduction

The color of mascavo sugar is influenced by a combination of raw material composition, processing conditions, chemical reactions, and storage factors (Alves et al., 2024, Riffer, 1988), which affect its composition and sensory characteristics (Verruma-Bernardi et al., 2010; Durán et al., 2012). The color of Mascavo sugar is critical for both consumer perception and industrial processing performance.

Therefore, sectors that use this sugar as an ingredient in products such as cereal bars, confectionery, cookies, and bakery products need to standardize color and granulometry so that their final products will not affect consumer acceptance.

Given the importance of color, precise and objective methods are essential for its characterization, as well as the factors that can influence it, like mineral composition. Optical methods are widely used because they are non-destructive, often rapid, and can provide quantitative data.

This research aimed to evaluate the mineral composition by Inductively Coupled Plasma Optical Emission Spectrometry and its relationship with the instrumental color of Mascavo brown sugar.

2. Materials and Methods

2.1. Acquisition of the mascavo sugar samples

Seventeen samples of mascavo sugar were used, 8 of them purchased from markets and 9 obtained directly from processing plants.

2.2. Analysis of minerals

To determine the minerals, 0.5 to 1.2 g of the sample were digested in nitric-percloric acid (Oliveira et al., 2005). After digestion, the samples were swelled to 25 mL with deionized water and stored in plastic tubes at room temperature. Mineral composition was assessed by inductively coupled plasma-optical emission spectrometry (ICP-OES) with a dichroic spectral combiner for simultaneous data collection in the radial and axial visualization mode (VistaRL CCD-Simultaneous ICP-OES, Varian).

2.3. Instrumental color analysis

For the instrumental color analysis, sugar samples were placed in Petri dishes (60x15mm) and the readings were obtained at three positions using a Minolta Chroma Meter - model CM-25d, CR10, to determine parameters from the CIELAB color space system, L*= lightness, 0 (black) to 100 (white), and hue = hue angle (Konica Minolta, 2017).

2.4. Statistical analysis

For data analysis, multivariate statistical techniques were employed and analyzed with a significance level of $p \leq 0.05$.

3. Results and Discussion

The results obtained for the mineral contents are presented in Table 1. It was verified that the results obtained are superior to those of TACO (2011), a broad database that gathers information on the nutritional composition of the most consumed foods in Brazil.

Sugar mineral composition may vary depending on plant pigments, processing, and other factors, such as weather conditions, soil, and sugarcane variety, interfering in the color of mascavo sugar (Jaffé, 2015).

Sugar color is a mixture of natural compounds in the sugar cane that darken at the beginning of the process and substances formed by chemical reactions (Maillard and caramelization reaction and degradation) during processing (Riffer, 1988).

The results for L* varied between 57.43 (lighter sample) and 27.21 (darker sample), and for the variable hue, the variation ranged from 75.30 to 54.44 (Table 1), and the higher the value, the more brownish the sample.

Table 1. Results obtained for the mineral contents and instrumental color (L* and hue) of the 17 mascavo sugar samples obtained from processing plants and the market.

Sugar		**Ca**	**Mg**	**P**	**K**	**S**	**Na**	**Cu**	**Fe**	**Mn**	**Zn**	**Color**	
Factory					**(mg/100g)**							**L***	**Hue**
	1	166	79	76	641	0.44	34	1.7	7.8	2.0	0.9	56.2	71.82
	2	162	93	75	659	0.64	34	1.7	30.0	2.0	0.9	52.97	68.62
	3	164	89	83	651	0.66	36	1.7	30.8	2.3	0.9	51.32	66.35
	4	170	91	79	729	0.65	38	1.4	30.4	2.3	0.7	48.33	64.83
	5	148	110	81	694	0.73	37	1.6	20.6	2.3	0.7	43.05	63.08
	6	159	98	75	712	0.69	97	1.5	22.1	2.3	0.7	45.11	64.25
	7	162	104	67	798	0.71	96	3.4	21.3	2.3	0.6	48.38	64.96
	8	153	116	71	711	0.80	96	7.9	7.5	2.3	0.6	49.21	62.96
	9	157	115	70	754	0.71	27	5.6	7.0	1.8	0.6	44.97	62.55
# Commercial	10	141	75	70	589	0.30	64	1.4	57.0	0.9	0.2	57.43	75.30
	11	106	69	96	456	0.43	53	1.4	26.5	3.8	1.1	52.19	72.32
	12	134	111	91	196	0.99	99	2.3	7.8	2.1	0.9	50.92	67.39
	13	166	86	76	435	0.45	34	1.7	30.4	2.3	0.7	46.20	66.76
	14	116	79	75	529	0.65	37	1.5	21.3	2.3	0.7	41.36	69.05
	15	164	91	81	492	0.71	96	5.6	7.3	1.8	0.7	39.07	61.36
	16	159	104	71	789	0.75	24	1.2	17.8	1.4	0.4	31.93	57.27
	17	157	116	68	536	0.51	19	1.1	16.6	1.1	0.4	27.21	54.44
TACO (2011)		127	80	38	522	-	25	0.7	8.3	2.03	0.5	-	-

#data obtained from Xavier et al. (2024) converted to mg/100g.

Figure 1 shows the loading of the variables in terms of correlation, forming the 5 factors cited. Factors 2 (P, Mn and Zn), 3 (L* and hue) and 4 (Ca and K) present the highest factorial loads and indicate that there are no correlations between the coloration features, represented by variables L* and hue, with the concentration of metals in the samples from different origins.

According to the results presented in Table 2, there are at least three factors that can represent the grouping of the variables with the greatest impact on variability and correlation. Factor 1 grouped the variables Mg, S, Cu and Fe; factor 2, variables P, Mn and Zn; factor 3, variables L* and hue; factor 4, variables Ca and K, and factor 5 grouped Na. Nevertheless, the first 3 factors explain 59.2% of data variance.

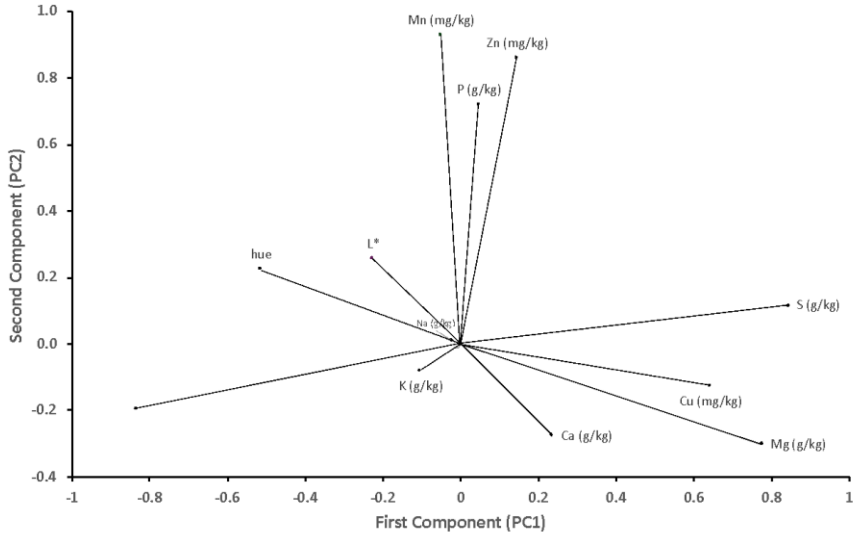

Figure 1. Results of the loadings of the principal components analyzed.

It was possible to verify that the grouping of the variables into 5 factors demonstrated the similarity in variation between the sets of samples obtained from the market and processing plant. The samples originating from the processing plant are similar to each other and form a group (Figure 2).

Table 2. Results of the grouping of factors of the variables studied in the mascavo sugar samples obtained from the market and the processing plant.

Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Communality
Ca	0.236	-0.276	0.079	0.825	0.113	0.832
Mg	0.775	-0.3	-0.316	0.22	0.038	0.839
P	0.047	0.718	0.209	-0.501	0.241	0.869
K	-0.103	-0.08	-0.209	0.821	-0.338	0.848
S	0.842	0.116	-0.11	-0.01	0	0.734
Na	-0.02	0.01	0.063	0.131	-0.91	0.850
Cu	0.643	-0.126	0.165	0.024	-0.648	0.877
Fe	-0.834	-0.195	0.207	0.02	0.056	0.781
Mn	-0.051	0.928	0.055	-0.128	-0.217	0.931
Zn	0.145	0.858	0.355	-0.106	0.21	0.939
L*	-0.225	0.255	0.913	0.015	-0.113	0.962
hue	-0.514	0.223	0.748	-0.274	-0.063	0.953
Variance	2.8261	2.4679	1.8017	1.7739	1.547	10.4166
% Var	0.236	0.206	0.15	0.148	0.129	0.868
	Mg	P	L*	Ca	Na	
	S	Mn	hue	K		
	Cu	Zn				
	Fe					

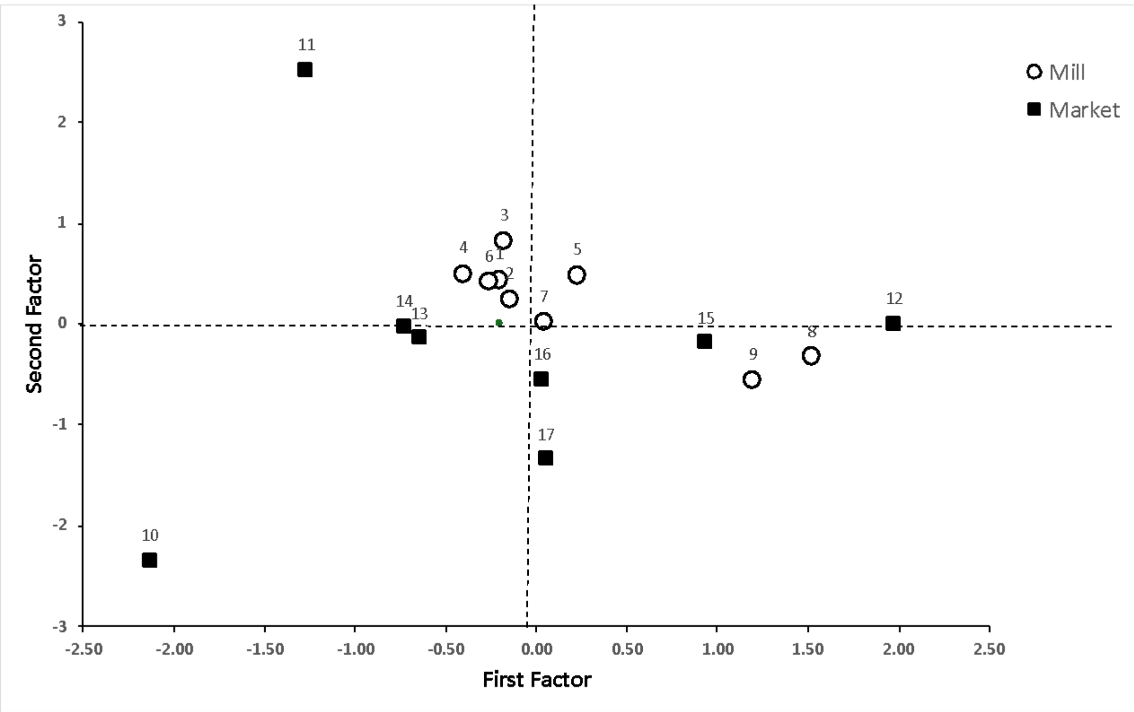

Figure 2. Correlation of the grouped factors according to sample origin.

4. Conclusions

- The use of colorimetry and ICP-AES methods allows consistent quality control, accurate grading, and precise formulation in various food industries that utilize Mascavo sugar, ensuring that the final product meets quality requirements.
- The mineral content of the analyzed samples exceeded values reported by the Brazilian Food Composition Table.
- The variables L* and hue are not correlated with the studied minerals, and the sugar samples obtained from the factory grouped more than those obtained from different market points.

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