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Ideal concentration of turmeric to be added to artisanal cassava flour according to consumer preference

Virgínia de Souza ÁLVARES[1*], Ronielli Cardoso REIS[2], Joana Maria Leite de SOUZA[1], Daniel Moreira LAMBERTUCCI[1], Antônio Clebson Cameli SANTIAGO[3]

Abstract

In the artisanal manufacture of yellow cassava flour, in the North region of Brazil, it is common to add turmeric. However, there are no recommendations on this process considering the preference of consumers. The present study proposes to determine this ideal concentration of turmeric that should be added to cassava flour based on consumers' preference. Samples were produced with 0, 0.05, 0.10, 0.15, and 0.20% concentrations of turmeric in the flour. The flours were evaluated for moisture, ash, ether extract, fiber, protein, acidity, pH, aw, and instrumental color. Sensory evaluation was analyzed in the cities of Rio Branco and Cruzeiro do Sul, state of Acre, Brazil. The addition of turmeric promoted an increase in acidity and a reduction in moisture and water activity of the flours. The intensity of the yellow color increased as higher concentrations of turmeric were added. Sensory tests using the hedonic, ideal, and purchase intention scales and internal preference mapping revealed differences between the two municipalities in terms of preference of consumers. In Rio Branco, there was a preference for flours with intermediate concentrations of turmeric, from 0.05 to 0.15%, while Cruzeiro do Sul recommended a concentration of 0.05% of turmeric.

Keywords: *Curcuma longa*; *Manihot esculenta;* internal preference mapping; sensory evaluation; saffron.

Practical Application: Determining the ideal concentration of turmeric to be added to cassava flour will enable greater uniformity in the color of yellow cassava flour produced in the North region of Brazil. This recommendation, based on strategic improvement in the market study, brings greater security to family producers in the region, with the availability of this step in the technical recommendations within a consolidated artisanal production process and with recognition of geographical indication, in addition to encouraging increased competitiveness in the cassava production chain in the state.

1 INTRODUCTION

Cassava flour is a staple food of great importance throughout Brazil. It is a product that can be found in varying colors, from white to different shades of yellow. The yellow flours are predominantly found in the North and Northeast regions of Brazil and can be obtained by adding chemical, natural, or synthetic additives which are not allowed legally. Although illegal, the incorporation of additives to flour is a reality, by adding either the dye chemically extracted from turmeric (INS 100i) or the artificial dye tartrazine yellow (INS 102), which can cause adverse reactions to human health, such as allergies (Oliveira et al., 2021). The additive "turmeric" (INS 100i) has the same name as the spice "turmeric," but they are different. In the additive, the colored compounds are chemically extracted and concentrated, and their addition is a health violation (Brasil, 2018).

As an alternative to additives, producers in the North and Northeast regions use the spice turmeric, also known as saffron. This practice is allowed by the National Health Surveillance Agency when the spice is obtained by dehydrating and grinding the rhizomes of the plant species *Curcuma longa* L. and *C. domestica* Valenton (Brasil, 2023). However, there is no recommendation on the concentration of turmeric that should be added during the manufacture of cassava flour. When handmade, care must be taken so as not to alter the final quality of cassava flour (Álvares et al., 2015; Sena et al., 2021).

From a technological point of view, there is a concern of the Ministry of Agriculture, Livestock and Supply (MAPA) in relation to this practice regarding possible changes in the characteristics of the flour, mainly in relation to the ash content, whose maximum value allowed by legislation is 1.4% (Brasil, 2011). Álvares et al. (2015) evaluated the effect of adding different concentrations of natural turmeric on the centesimal composition of traditional cassava flour. These authors noted that the increase in the concentration of turmeric affected the

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[1]*Empresa Brasileira de Pesquisa Agropecuária, Rio Branco, Acre, Brazil.*
[2]*Empresa Brasileira de Pesquisa Agropecuária, Embrapa Mandioca e Fruticultura, Cruz das Almas, Bahia, Brazil.*
[3]*Secretaria de Estado de Agricultura, Cruzeiro do Sul, Acre, Brazil.*
*Corresponding author: virginia.alvares@embrapa.br
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ash content of handmade cassava flour and concentrations starting from 0.03% caused a significant increase in the intensity of the yellow color. However, in this study sensory preferences were not investigated.

From a sensory point of view, the amount to be added must be sufficient to attract consumers, but at the same time it cannot change the characteristic flavor of cassava flour. Therefore, it is important to consider the sensory traits of the flour, as the quality of the product must also be defined in the consumer's perception. Sensory tests are essential to obtain information about which turmeric concentration is the most accepted by consumers.

Therefore, the present study proposes to evaluate the influence of turmeric concentration on physicochemical and sensory characteristics of artisanal cassava flours.

2 MATERIALS AND METHODS

The cassava flours were produced at a rural family agribusiness in the municipality of Mâncio Lima, Acre (AC), Brazil, in September 2021. The roots used to manufacture the flour were of local variety, at 12 months of age. The production process followed the traditional method adopted in the region, described by Álvares et al. (2015), only changing the turmeric concentrations. In this case, the flours were prepared with the following turmeric concentrations: 0, 0.05, 0.10, 0.15, and 0.20%. This spice was added in the form of powder upon grinding dehydrated rhizomes of *C. longa* L.

Samples were collected and sent to Embrapa Acre for the following analyses: moisture, by drying in an air-oven (Lucadema®, Modelo Luca-80/150, Brazil) at 105°C/8 h; ash, by combustion in a muffle furnace (Quimis®, Q318m, Brazil) at 540°C; ether extract, by Soxhlet extraction (Marconi®, MA044/850, Brazil); total crude protein, by the micro-Kjeldahl method (Gerhardt®, Vapodest 20s, Germany); total crude fiber, by digestion in H_2SO_4 in a fiber determination apparatus (Ankom® A200, USA) (AOAC, 2012); energy value, calculated as per Brasil (2020b); starch content, by polarimetry (Kruss P1000-LED, Brazil) (EC, 1999); and titratable acidity, pH (Mettler-Toledo AG, Easy Pro, Switzerland) (Instituto Adolfo Lutz, 2008), and water activity, by direct reading in a benchtop analyzer (Meter Group, AquaLab® Series 4TE, Washington, USA). Instrumental color analysis was carried out using a colorimeter (Konica Minolta®, model CR5, Tokyo, Japan) operating in the CIE Lab color scale (L*, a*, b*) and calculating chroma (C*), according to Equation 1, and the hue angle or color saturation (hue or H°), according to Equation 2:

$$\text{Chroma} = [(a^*)^2 + (b^*)^2]^{0,5} \quad (1)$$

$$\text{Hue} = (\tan b^*/a^* \times 180/\pi) \quad (2)$$

For the execution of the sensory tests, the study was previously approved by the Research Ethics Committee and registered under CAAE no. 37396620.6.0000.5010.

The sensory tests were carried out at the João Silvério Sobrinho commercial center, in Cruzeiro do Sul, AC, and at the Elias Mansour municipal market, in Rio Branco, AC. A total of 89 and 109 untrained tasters of both sexes (51% women and 49% men) participated in the tests in their respective municipalities. Samples were served in individual booths and under white light, coded with three-digit random numbers, and presented in a balanced order, in a randomized block design. Each consumer received 5 g of cassava flour in a monadic and sequential manner, totaling five samples. The sensory attributes of color, aroma, flavor, and overall acceptability were assessed using the nine-point hedonic scale proposed by Meilgaard et al. (1999). The product's acceptability index (AI) was calculated using Equation 3, where X is the average score obtained for the product, considering N is the maximum score, for each sample, given by the tasters in the overall acceptability. Flours with an AI ≥ 80% were considered to have good sensory acceptability.

$$\text{Al}\ (\%) = X/N * 100 \quad (3)$$

The attributes of color, aroma, and flavor were also evaluated using the ideal scale, structured with five points (Ferreira et al., 2000). The hypothetical intention to purchase the product by the consumer was assessed using a five-point scale ranging from 1 ("would definitely not buy") to 5 ("would definitely buy").

Data from the sensory and physicochemical tests were evaluated separately for each municipality and subjected to ANOVA. In the case of significance by the F-test, the Scott–Knott test was performed at 5% significance. The acceptability data of each attribute were subjected to principal component analysis (PCA) from the covariance matrix, which generated an internal preference map for each attribute. The ideal scale and purchase intent data were presented in frequency plots. All analyses were performed using the Statistica statistical software.

3 RESULTS AND DISCUSSION

In accordance with the Brazilian Legislation, the coarse cassava flour had moisture, ash, and total crude fiber contents at maximum values of 13, 1.4, and 4%, respectively, and starch at a minimum value of 80% (Brasil, 2011; 2020a). There were no differences between the flours for the lipid (ether extract), protein, or fiber contents. Ash contents were higher in the flours with the turmeric concentrations of 0, 0.05, and 0.20%. This result differed from that observed by Álvares et al. (2015), who described increasing ash contents with increasing turmeric concentration. Sena et al. (2021), however, did not observe a pattern in the variation of physicochemical composition of the flours as a function of the turmeric concentration used.

Higher concentrations of turmeric led to an increase in acidity in the flours (Table 1).

This finding disagrees with that described by Álvares et al. (2015), who stated that acidity did not vary between flours with different concentrations of the same ingredient. Flours with up to 0.15% turmeric concentration showed low acidity, according to

Table 1. Physicochemical characteristics and color of cassava flours with different concentrations of turmeric (*Curcuma longa*).

C (%)	Titratable acidity (%)*	pH*	Aw*	Color parameter				
				L$^{n.s.}$	a*	b*	c*	Hue*
0	1.65d	4.58a	0.13a	95.31a	-1.28a	23.84c	23.88c	93.09b
0.05	2.12c	3.89b	0.15a	93.98a	-5.31b	52.34b	52.61b	95.80a
0.10	2.85b	3.79b	0.15a	93.44a	-6.04c	58.29a	58.60a	95.91a
0.15	2.98b	3.73b	0.09b	92.83a	-6.15c	59.23a	59.55a	95.93a
0.20	3.56a	3.96b	0.10b	92.30a	-6.16c	59.62a	59.95a	95.90a
Mean	2.63	3.99	0.13	93.57	-4.99	50.66	50.92	95.33
CV (%)	11.33	3.79	29.94	1.69	9.31	1.90	1.89	0.71

Means followed by the same lowercase letters in the column do not differ from each other at the 5% probability level by the Scott–Knott test; C: turmeric concentration; aw: water activity; L: lightness; a: color coordinate a*; b: color coordinate b*; C: chroma; Hue: hue color or saturation angle; CV: coefficient of variation; *significant at the 5% level by the t-test; $^{n.s.}$not significant at the 5% level by the t-test.

Brasil (2011), with values lower than 3%, which was expected for flours of the dry group. Nonetheless, the flour with 0.2% turmeric concentration was classified as highly acidic (> 3%), which may be related to the high acidity of turmeric rhizomes (Leonel & Cereda, 2002). Sena et al. (2021) did not identify a relationship between turmeric concentration and increased acidity in the flour.

The flours did not differ as to lightness, and all showed a hue angle within the yellow region (Table 1). The highest turmeric concentrations provided lower a* color coordinate values and higher b* and chroma values, indicating that these flours have a more intense yellow color than the others.

Sensory acceptability means ranged between 7.08 and 8.52, i.e., from "Like moderately" to "Like very much," for consumers in Rio Branco (Table 2) and between 5.91 and 8.15, considered between the terms "Like slightly" and "Like very much," for consumers in Cruzeiro do Sul (Table 3).

Considering the attributes of color and aroma, consumers in Rio Branco attributed the highest scores to the flours with the turmeric concentrations of 0.05 and 0.10%. These samples also obtained the highest acceptability indices, which were greater than 92% (Table 2). For flavor, the flour with 0.05% turmeric concentration had the highest score. In contrast, both the white flour and the flour with 0.15 and 0.20% turmeric concentrations (intense yellow color) obtained lower scores and acceptability indices.

Consumers in Cruzeiro do Sul showed a different acceptance profile because they attributed the highest scores to white flour (0%) and light yellow flour (0.05%) for all evaluated attributes. For taste, these concentrations did not differ significantly from 0.15% turmeric concentration in their mean values (Table 3).

The flour with an intense yellow color (0.20%) had the lowest color and flavor scores, in addition to an AI lower than 80% (Table 3). According to Naghetini (2006), turmeric has a strong, penetrating, spicy smell and a slightly bitter taste, which may underlie the lower consumer acceptance of this flour regarding this attribute. Additionally, the flour with the highest concentration of turmeric had higher acidity (Table 2), a characteristic that may have contributed to its lower acceptance.

Álvares et al. (2015) mentioned that the turmeric concentration of 0.033% was the average used by producers in the region of Cruzeiro do Sul, due to the preference for a lighter yellow product, which corroborate the results of this study.

Table 2. Mean values of acceptability of sensory attributes of cassava flour with different concentrations of turmeric (*Curcuma longa*), as determined by untrained judges in Rio Branco, AC, Brazil.

C (%)	Color*	Aroma*	Flavor*	Overall acceptability*	AI (%)
0	7.08 c	7.69 b	7.84 b	7.91 b	87.87
0.05	8.27 a	8.21 a	8.40 a	8.52 a	94.70
0.10	8.10 a	8.00 a	8.02 b	8.33 a	92.56
0.15	7.96 a	7.76 b	7.73 b	7.89 b	87.67
0.20	7.56 b	7.65 b	7.56 b	7.91 b	87.87
Mean	7.80	7.86	7.91	8.11	-
CV (%)	21.01	21.12	20.74	16.00	-

Means followed by the same lowercase letters in the column do not differ from each other at the 5% probability level by the Scott–Knott test; C: turmeric concentration; CV: coefficient of variation; *significant at the 5% level by the t-test.

Table 3. Mean values of acceptability of sensory attributes of cassava flour with different concentrations of turmeric (*Curcuma longa*), as determined by untrained consumers in Cruzeiro do Sul, AC, Brazil.

C (%)	Color*	Aroma*	Flavor*	Overall acceptability*	AI (%)
0	7.68 a	7.54 a	7.63 a	8.15 a	90.51
0.05	7.68 a	7.57 a	7.83 a	7.94 a	88.26
0.10	6.82 b	6.82 b	6.98 b	7.38 b	82.02
0.15	6.41 b	6.98 b	7.34 a	7.84 a	87.14
0.20	5.91 c	6.07 c	6.48 b	7.08 b	78.78
Mean	6.90	6.99	7.25	7.68	-
CV (%)	30.67	26.92	27.79	21.55	-

Means followed by the same lowercase letters in the column do not differ from each other at the 5% probability level by the Scott–Knott test; C: turmeric concentration; CV: coefficient of variation; *Significant at the 5% level by the t-test.

By comparing the acceptance results of the two municipalities, we find that consumers in Rio Branco (Table 2) attributed higher scores than consumers in Cruzeiro do Sul (Table 3). This fact may be due to a greater tradition and notoriety of artisanal cassava flour manufacture in the Juruá region, which even enhanced the recognition of the geographical indication of "Cruzeiro do Sul." As a consequence, consumers in Cruzeiro do Sul may have acquired a more discerning habit regarding this product. However, there was no rejection (score £ 4) of any of the samples presented for any of the evaluated parameters.

For both municipalities, the lowest scores were assigned to the color attribute. The lowest score in Rio Branco was assigned to white flour (Table 2), while in Cruzeiro do Sul, the flour with 0.20% turmeric concentration had the lowest score (Table 3), which clearly shows the different acceptance profiles of these two municipalities.

Sousa and Piraux (2015) found that color is a sensory trait that is associated with the quality of cassava flour and observed different preferences regarding its color when comparing two municipalities in the state Pará. In Mocajuba, the preference is for white or cream flour, whereas people in Tailândia prefer yellow color.

To consider individual preferences, internal preference mapping was generated for each sensory attribute, for each municipality. In the municipality of Rio Branco, most consumers are situated close to flours B, C, and D with the turmeric concentrations of 0.05, 0.10, and 0.15%, respectively, regarding the attributes of color and aroma (Figure 1). This result is in line with the information given in Table 2, reinforcing that the population of the state capital has a preference for yellow flours, but with an intermediate shade. Very intense white or yellow flours can be considered less competitive, because the color of this product is a decisive parameter for the preference of consumers in the region.

As for flavor, consumers in Rio Branco also preferred white flour (A) (0%) and flour (B) with 0.05% turmeric concentration (Figure 1). These findings are similar to the results displayed in Table 3, which shows that flour (B) had the highest mean acceptability score.

The overall acceptability of the flours (Figure 1) was very homogeneously distributed among consumers, meaning that there is no greater predilection for a certain flour based on this attribute.

As regards the attributes of color and aroma, most consumers in Cruzeiro do Sul are close to white flour (A) and flour (B) with 0.05% turmeric concentration, indicating a greater preference for lighter-colored flours (Figure 2).

Color is a very divergent attribute in the opinion of consumers. Some studies have evaluated this topic in different regions of Brazil, e.g., Borges (2015) and Santana et al. (2017), who found a preference for white flour by consumers in the state of Bahia, and Cereda and Vilpoux (2010), with yellow flour in Maranhão.

The preference of Cruzeiro do Sul consumers regarding flavor and overall acceptability grew toward flours A (white), B (0.05% turmeric concentration), and D (0.15% turmeric concentration), as also shown by the mean test (Table 3). In both municipalities, the flour with the highest concentration of this spice, 0.20%, was the least preferred by consumers.

For consumers in Rio Branco, the flour with 0.05% turmeric concentration (B) was considered "ideal" in terms of color, aroma, and flavor by 84%, 86%, and 89% of respondents, respectively (Figure 3).

As for color, the flour with the turmeric concentration of 0.10% (C) was considered "ideal" by 84% of consumers in Rio Branco, whereas the product without turmeric (A) was considered "much lighter than ideal" by 32% of the judges. Flour with 0.20% turmeric concentration (E) was deemed "much darker than ideal" by 20.4% of consumers. For this last flour, the attributes of aroma and flavor were considered "ideal" for a smaller percentage of consumers: 71 and 68%, respectively.

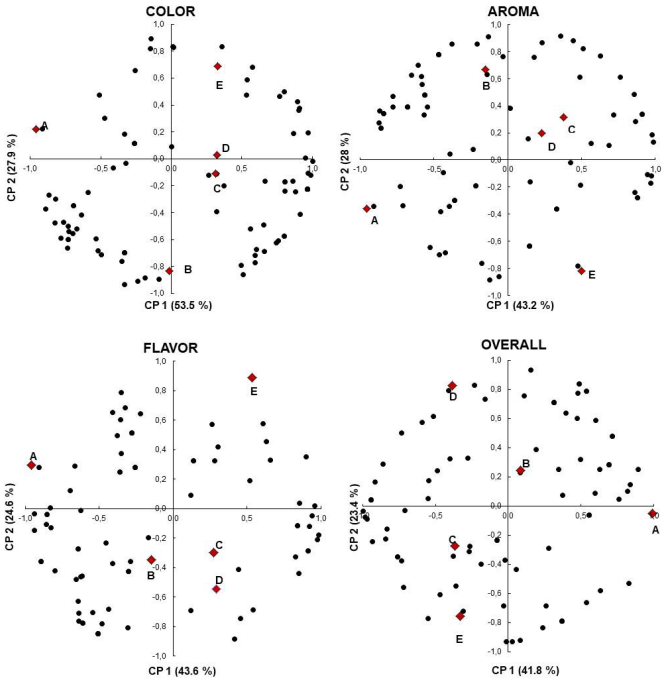

Figure 1. Internal preference mapping of cassava flour with different turmeric concentrations. Rio Branco, AC, Brazil. Treatments (samples): (A) 0%; (B) 0.05%; (C) 0.10%; (D) 0.15%; (E) 0.20% turmeric concentration.

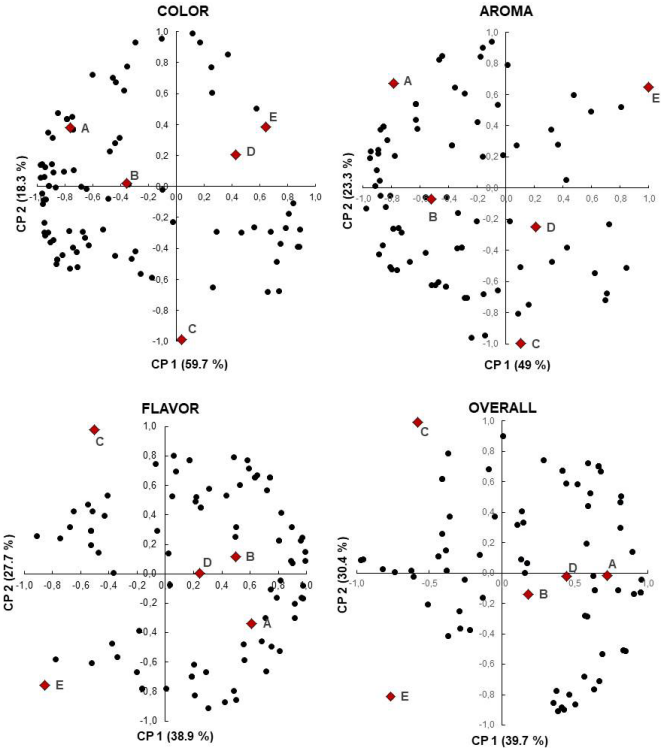

Figure 2. Internal preference mapping of cassava flour with different turmeric concentrations. Cruzeiro do Sul, AC, Brazil. Treatments (samples): (A) 0%; (B) 0.05%; (C) 0.10%; (D) 0.15%; (E) 0.20% turmeric concentration.

In Cruzeiro do Sul, the flour with 0.05% turmeric concentration (B) was considered "ideal" with respect to color, aroma, and flavor for 81, 80, and 87% of consumers, respectively (Figure 3). White flour (A) reached good positions in the color evaluation, with 74% of consumers considering it "ideal," 82% stated so for aroma, and 79% for flavor. The flour with 0.20% turmeric concentration (E) was described as "much darker than ideal" by a large portion of these consumers (58%), in addition to aroma and flavor being considered "much stronger than ideal" by 25% and 29% of these consumers, respectively.

The sensory traits of the flours reflect on consumers' purchase intent (Figure 4). In Rio Branco, 83% of consumers would certainly buy flour with 0.05% turmeric concentration (B), a

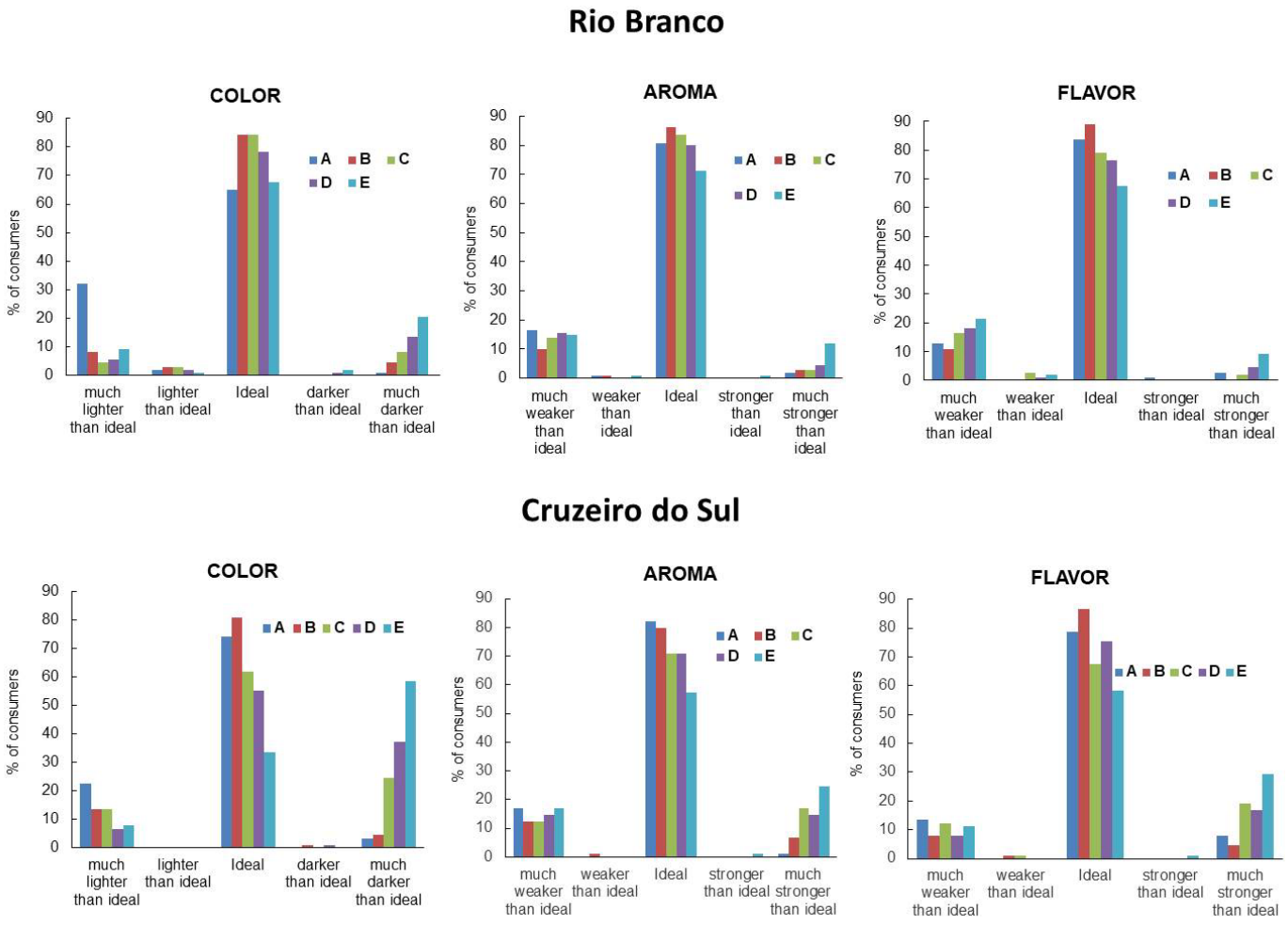

Figure 3. Evaluation of the attributes of color, aroma, and flavor of cassava flour with different concentrations of turmeric (*Curcuma longa*), using the ideal scale. Test carried out in Rio Branco and Cruzeiro do Sul, AC, Brazil. Treatments (samples): (A) 0%; (B) 0.05%; (C) 0.10%; (D) 0.15%; (E) 0.20% turmeric concentration.

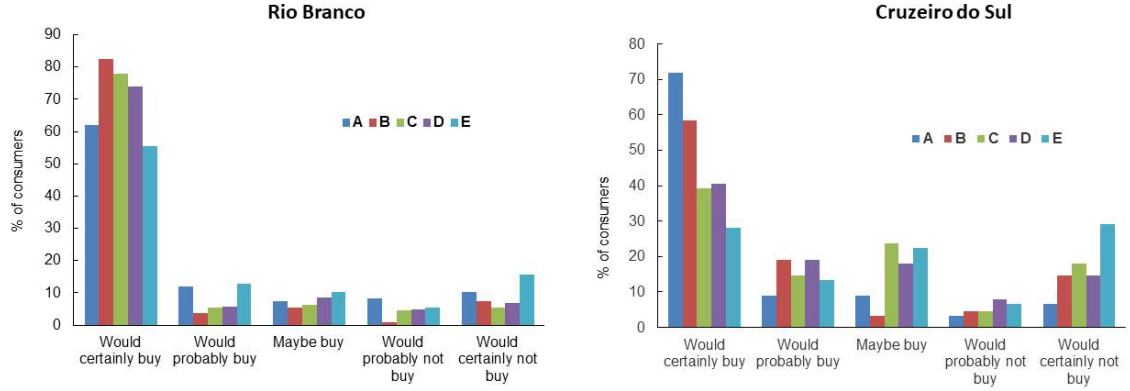

Figure 4. Purchase intent of consumers in Rio Branco regarding cassava flour with different concentrations of turmeric, produced in Mâncio Lima, AC, Brazil. Treatments (samples): (A) 0%; (B) 0.05%; (C) 0.10%; (D) 0.15%; (E) 0.20% turmeric concentration.

result that corroborates those observed in the acceptability test. The lowest purchase intents in this municipality were attributed to white flour (A) and the flours with 0.20% turmeric concentration (E): 62% and 55% of consumers, respectively.

In Cruzeiro do Sul, 72% of consumers would certainly buy white flour (A) and 58% would buy flour with 0.05% turmeric concentration (B). The lowest purchase intent was obtained by the flour with the highest concentration of turmeric (E), with 29% of consumers, indicating that they would not buy it. In this location, if we add categories "would certainly buy" with "would probably buy," 81% of consumers would buy white flour (A), 77% of consumers would buy flour with 0.05% turmeric concentration (B), and the smallest portion of consumers (41%) would buy the darkest flour (E).

4 CONCLUSION

The intensity of yellow in cassava flour increases as higher concentrations of turmeric are added to cassava flour.

Consumers in Rio Branco prefer cassava flours with intermediate concentrations of turmeric; therefore, concentrations from 0.05 to 0.15% are recommended.

Consumers in Cruzeiro do Sul prefer white cassava flour or cassava flours with low concentrations of turmeric, so 0.05% concentration is recommended.

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