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Proceeding Paper

Effect of Cricket (*Acheta domesticus*) Flour Added to Mixture Powder to Obtain a Traditional Beverage (Chucula) on Its Physicochemical Characteristics †

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Abstract: The aim of this study was to add cricket (*Acheta domesticus*) flour to dried mixtures of chucula to obtain a mixture with higher protein content without altering the typical properties of the traditional product. An experimental design with three factors (cricket flour, cacao and other flours) was performed. From this, 27 experiments were carried out. The water and protein content, particle size, water solubility and water absorption index, and color of samples were determined. All samples presented water content values less than or equal to 3%, typical of this type of product. Crude protein content increased significantly with increasing cricket flour content. The particle size of the samples with lower cocoa contents were higher, however those with lower cricket flour contents were lower. The water absorption and solubility indices were not affected by the factors in the ranges studied. The sample with lower content of the generic flours presented lower luminosity values, that is, they were darker. The sample with the highest cocoa content in its formulation showed more orange-reddish tones compared to the rest. The addition of cricket flour could be an alternative to increase the protein content in powdered chucula without altering its traditional characteristics. According to results, 7% of cricket flour, 25% of cacao and 68% of general flour was recommended to improve the final product.

Keywords: Colombia; chucula; cricket; protein

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1. Introduction

At present, some traditional dishes and drinks from Cundinamarca are at risk of disappearing due to the lack of generational transmission and due to changes in sociocultural dynamics. The chucula may constitute an attempt to rescue traditional knowledge, while also promoting a healthy diet in contexts where there is malnutrition [1]. This food is one of the most issued preparations throughout the territory of Cundinamarca [2] and results from ground cocoa with beans, barley, oats, wheat, corn, chickpeas, cocoa, cinnamon, cloves and lentils added over the years, whose traditional presentation is a ball form [1].

Entomophagy is the consumption of insects by humans and constitutes a good food alternative, as confirmed by different investigations on edible insects due to their biogeographic aspects, their biodiversity in the world, their sustainability, their importance in the feeding of rural nucleus, to their nutritional value, having been shown to be a good source of protein, coupled with their protein quality since they are highly digestible [3].

The main purpose of this research was to obtain a product from the chucula with a higher protein content by adding cricket flour. It is intended to make this a complete food without losing its original characteristics, thus being equally accepted by the population.

2. Materials and Methods

2.1. Raw Materials and Sample Preparation

The raw materials were cricket flour supplied by the company ArthroFood S.A.S. (Bogota, Colombia); pure defatted cocoa powder obtained through Chocolates Valor S.A. (Alicante, Spain); powdered panela and grains of wheat, chickpeas, peas, barley, lentils and corn, which were acquired in a local market in Bogotá. Twenty-seven chucula samples (Table 1) were made from the experimental design obtained using Minitab 18 statistical software (Minitab Inc., State College, PA, USA). Three factors were considered: cricket flour, cocoa powder and total flour (which includes wheat, chickpea, pea, barley, lentil, corn and ground cinnamon flours). Finally, the chucula were made following the industrial method.

Table 1. Percentage (%) of cricket flour (CF), cocoa and flour used in chuculas. Mean values ± standard deviation of the % of humidity, crude protein (CP), absorption index (WAI) and solubility index (WSI) of each sample. Superscript letters within columns indicate homogeneous groups according to ANOVA ($p < 0.05$).

Sample	CF	Cocoa	Flour	Humidity (%)	CP (%)	WAI	WSI (%)
1	1.13	26.25	72.62	2.962 ± 0.004^{b}	16.55 ± 0.16^{ihg}	2.37 ± 0.18^{dcb}	13.3 ± 0.4^{abcde}
2	0.00	30.00	70.00	2.96 ± 0.04^{b}	16.4 ± 0.2^{ih}	2.51 ± 0.07^{cba}	12.7 ± 0.9^{efg}
3	2.13	28.75	69.12	2.888 ± 0.002^{bcd}	17.4 ± 0.2^{fe}	2.7 ± 0.4^{a}	13.4 ± 0.5^{abc}
4	2.25	27.50	70.25	2.70 ± 0.03^{fg}	17.23 ± 0.07^{gfe}	2.25 ± 0.03^{a}	13.3 ± 0.2^{abcde}
5	7.00	25.00	68.00	2.43 ± 0.02^{k}	19.6 ± 0.7^{a}	2.31 ± 0.03^{dcb}	13.17 ± 0.08^{abcdef}
6	0.00	25.00	75.00	2.288 ± 0.003^{lm}	17.9 ± 0.3^{ed}	2.206 ± 0.006^{d}	13.29 ± 0.13^{abcde}
7	4.62	26.25	69.12	2.316 ± 0.106^{l}	16.110 ± 0.014^{i}	2.520 ± 0.006^{ba}	12.72 ± 0.05^{defg}
8	0.00	25.00	75.00	2.21 ± 0.02^{m}	15.94 ± 0.12^{i}	2.485 ± 0.015^{cba}	12.554 ± 0.004^{fg}
9	0.00	25.00	75.00	2.21 ± 0.02^{m}	15.9 ± 0.4^{i}	2.2 ± 0.2^{d}	12.4 ± 0.5^{g}
10	7.00	25.00	68.00	2.62 ± 0.02^{h}	19.7 ± 0.3^{a}	2.26 ± 0.03^{d}	13.04 ± 0.13^{bcdef}
11	2.25	27.50	70.25	2.8709 ± 0.0003^{cd}	17.5 ± 0.3^{fe}	2.292 ± 0.015^{dc}	13.3 ± 0.3^{abcde}
12	1.13	28.75	70.12	2.719 ± 0.017^{f}	16.3 ± 0.7^{ih}	2.33 ± 0.03^{dcb}	12.9 ± 0.2^{bcdefg}
13	0.00	30.00	70.00	2.861 ± 0.017^{cd}	16.9 ± 0.3^{hgf}	2.42 ± 0.03^{dcb}	12.9 ± 0.4^{cdefg}
14	1.13	28.75	70.12	2.53 ± 0.05^{ij}	16.943 ± 0.019^{hgf}	2.2612 ± 0.0105^{d}	13.25 ± 0.09^{abcde}
15	2.13	28.75	69.12	2.61 ± 0.06^{hi}	17.36 ± 0.05^{fe}	2.30 ± 0.05^{dcb}	$13.011 \pm 0.118^{bcdefg}$
16	2.13	28.75	69.12	2.83 ± 0.05^{de}	17.34 ± 0.06^{fe}	2.34 ± 0.05^{dcb}	13.56 ± 0.07^{ab}
17	4.62	26.25	69.12	2.51 ± 0.03^{jk}	17.462 ± 0.002^{fe}	2.36 ± 0.18^{dcb}	13.1 ± 0.7^{abcdef}
18	2.25	27.50	70.25	2.64 ± 0.02^{gh}	17.5 ± 0.3^{fe}	2.31 ± 0.07^{dcb}	13.1 ± 0.3^{bcdef}
19	1.13	26.25	72.62	2.74 ± 0.06^{f}	17.72 ± 0.14^{ed}	2.29 ± 0.09^{dc}	13.10 ± 0.18^{bcdef}
20	1.13	28.75	70.12	2.87 ± 0.07^{cd}	17.6 ± 0.2^{fed}	2.331 ± 0.019^{dcb}	13.41 ± 0.06^{abc}
21	2.00	30.00	68.00	2.82 ± 0.05^{de}	17.544 ± 0.119^{fe}	2.32 ± 0.05^{dcb}	13.38 ± 0.04^{abcd}
22	1.13	26.25	72.62	2.761 ± 0.013^{ef}	16.5 ± 0.5^{ih}	2.213 ± 0.006^{d}	13.77 ± 0.04^{a}
23	2.00	30.00	68.00	2.96 ± 0.02^{b}	17.6 ± 0.6^{fed}	2.41 ± 0.02^{dcb}	12.95 ± 0.19^{bcdefg}
24	0.00	30.00	70.00	3.043 ± 0.019^{a}	16.5 ± 0.4^{ih}	2.34 ± 0.07^{dcb}	12.9 ± 0.9^{bcdefg}
25	7.00	25.00	68.00	2.938 ± 0.015^{bc}	19.5 ± 0.2^{ba}	2.31 ± 0.06^{dcb}	13.2 ± 0.9^{abcdef}
26	2.00	30.00	68.00	1.33 ± 0.05^{n}	18.3 ± 0.9^{dc}	2.35 ± 0.03^{dcb}	12.8 ± 0.2^{cdefg}
27	4.62	26.25	69.12	0.941 ± 0.003^{ñ}	18.74 ± 0.14^{cb}	2.32 ± 0.02^{dcb}	12.7 ± 0.2^{efg}

2.2. Analytical Determinations

2.2.1. Humidity

For the determination of humidity (x_w) the official method 20.013 (AOAC, 1980) was used. This method is based on the determination of the weight loss of a previously homogenized sample (Ultraturrax T25, Janke and Kunkel, Germany) when placed in a vacuum oven (50 mmHg) at a constant temperature of 70 °C, until reaching a constant weight.

2.2.2. Water Absorption Index and Water Solubility Index

The absorption index (WAI) and the solubility index (WSI) were determined according to the Singh and Smith method [4].

2.2.3. Crude Protein

To determine the nitrogen content, the Dumas method was used through a LECO CN628 elemental analyzer (Leco Corporation, St. Joseph, MI, USA), according to the official method 990.03 (AOAC, 2002). The conversion factor used was 5.83 [5].

2.2.4. Optical Properties

To determine the color, four measurements were made on each of the samples, using a spectrocolorimeter (Minolta, CM 3600D, Tokio, Japan). The equipment was previously calibrated and the reflection spectrum of the homogenized samples was measured using the CIEL*a*b color space under the conditions of illumination D65 and observer 10°.

2.2.5. Particle Size Distribution

The particle size of the formulated chuculas was determined by the laser diffraction method and the Mie theory. For this, the ISO 13320 standard was followed and a particle size analyzer Mastersizer 2000 (Malvern Instruments Ltd., Malvern, UK) equipped with a dispersion unit for dry samples was used. Six repetitions were carried out per sample.

2.3. Statical Analysis

A three-component mixture design was carried out through an axial design that generated 27 examples. For this, Minitab 18 Statistical Software (Minitab Inc., USA) was used. Analysis of variance (ANOVA), with a confidence level of 95% ($p < 0.05$), was applied to evaluate the differences among samples, using Statgraphics Centurion XVII Software, version 17.2.04.

3. Results and Discussion

Table 1 shows that there is a significant difference ($p < 0.05$) in the water content between the different chuculas, samples number 26 and 27 present a lower percentage of humidity, however sample 24 is the only one that exceeds 3% humidity. The water content does not seem to be related to the amount of insect flour added to the samples, but a decrease in water content can be seen in those samples that contained a lower amount of cocoa powder. Results are similar to those reported by other studies carried out on cocoa powder [6]. On the other hand, samples with high concentration of cricket flour, such as samples number 5 and 10, marked a significant ($p < 0.05$) crude protein increase while samples with a low concentration of cricket flour presented a significant ($p < 0.05$) crude protein decrease. These values coincide with other studies where it was determined that the protein content in cricket flour is approximately 60%, but in other kinds of vegetable flour, such as corn or pea, the protein values are less than 20% [7–9].

Furthermore, Table 1 shows that the content of cricket flour, cocoa and grain flour is not related to the difference in the WSI values of each sample. On the other hand, although no significant changes ($p < 0.05$) were observed in WAI values, on analyzing the data, a slight decrease in WAI values could be seen as the cocoa powder content of the chucula samples decreased. Moreover, the WAI index and WSI index were satisfactory because most of the solid elements of the powder obtained under the experimental conditions were easily soluble in water. Similar results were observed in other studies, where the WAI and WSI values obtained were 2.87 ± 0.05 for flours [10] and 16.00 ± 0.07 for cocoa powder [11].

The particle size distribution curves show a very similar trend (Figure 1), which represents that they are mixtures with a distribution of practically equal sizes. However, it can be seen how the distribution curve of sample number 5 has a slight shift to the left, which indicates that it has smaller particle sizes. The opposite case occurs in sample 25, which shows a slight shift to the right, indicating that the particle sizes have increased. This heterogeneity of particle distribution between the samples could depend on the nature of the raw materials, and, as a traditional product, the ingredients were mixed and hand-made.

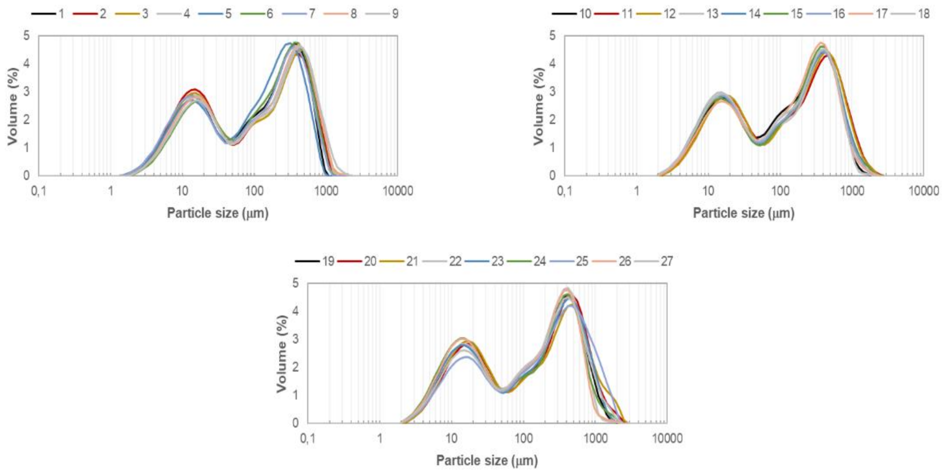

Figure 1. Volume particle size distribution (representative curves) of chuculas studied.

In Table 2, the values of D [4.3] showed that when the concentration of cocoa powder in the samples decreased, the particle size increased significantly ($p < 0.05$), obtaining the smallest particle sizes for sample 5, which has a higher cocoa content. A similar situation appears in the samples with low concentrations in cricket flour, which present the lowest D [4.3] values, thus obtaining smaller particle sizes. The percentile d (0.9) is significantly ($p < 0.05$) different among all the samples; 90% of the particles of the chucula samples that did not contain insect flour, such as samples 6 and 24, presented a particle size smaller than 530.35 µm and 575.83 µm, respectively. The results are like those reported by other studies where cricket flour was added to a traditional product [7].

Table 2. Mean values ± standard deviation of the volumetric mean diameter (µm) D [4.3] and the standard percentiles (µm) d (0.01), d (0.05) and d (0.09) of each of the samples obtained. Superscript letters within columns indicate homogeneous groups according to ANOVA ($p < 0.05$).

Sample	D (4.3)	d (0.1)	d (0.5)	d (0.9)
1	209 ± 8^{fghij}	8.32 ± 0.09^{ef}	119 ± 8^{efgh}	552 ± 22^{fghi}
2	200 ± 13^{hij}	7.58 ± 0.16^{jk}	105 ± 9^{h}	543 ± 37^{fghi}
3	220 ± 27^{defghij}	7.8 ± 0.4^{ijk}	117 ± 21^{efgh}	593 ± 69^{cdefgh}
4	220 ± 20^{defghij}	8.24 ± 0.17^{efg}	124 ± 18^{cdefgh}	584 ± 47^{cdefgh}
5	195.7 ± 10.2^{i}	8.8 ± 0.4^{c}	127 ± 17^{bcdefg}	500 ± 20^{i}
6	207 ± 14^{efghij}	9.2 ± 0.4^{ab}	133.1 ± 11.3^{bcdef}	530 ± 36^{ghi}
7	219 ± 7^{defghij}	8.15 ± 0.13^{efgh}	126 ± 6^{bcdefgh}	578 ± 21^{defghi}
8	223 ± 17^{cdefghij}	8.4 ± 0.3^{de}	132 ± 16^{bcdef}	581 ± 39^{cdefgh}
9	243 ± 25^{bcd}	8.8 ± 0.3^{c}	146 ± 12^{bc}	628 ± 66^{bcde}
10	208 ± 32^{efghij}	8.8 ± 0.5^{c}	119 ± 22^{defgh}	547 ± 81^{fghi}
11	230 ± 26^{bcdefgh}	8.4 ± 0.2^{ef}	124 ± 14^{cdefgh}	605 ± 69^{bcdefg}
12	228 ± 31^{bcdefghi}	8.4 ± 0.4^{de}	129 ± 22^{bcdefg}	591 ± 79^{cdefgh}
13	224 ± 32^{cdefghij}	8.0 ± 0.3^{fghi}	119 ± 28^{defgh}	593 ± 70^{cdefgh}
14	237 ± 13^{bcdef}	8.25 ± 0.13^{efg}	129 ± 7^{bcdefg}	614 ± 33^{bcdef}
15	236 ± 27^{bcdef}	8.4 ± 0.3^{de}	140 ± 19^{bcd}	601 ± 70^{bcdefg}
16	224 ± 29^{cdefghij}	8.2 ± 0.3^{efgh}	125 ± 29^{bcdefgh}	581 ± 75^{cdefgh}
17	222 ± 30^{defghij}	8.9 ± 0.5^{bc}	138 ± 25^{bcde}	558 ± 63^{efghi}
18	204 ± 28^{ghij}	8.3 ± 0.3^{efg}	114 ± 16^{fgh}	540 ± 70^{fghi}
19	230 ± 37^{bcdefg}	8.3 ± 0.2^{ef}	136 ± 24^{bcde}	600 ± 102^{bcdefg}

Table 2. *Cont.*

Sample	D (4.3)	d (0.1)	d (0.5)	d (0.9)
20	237 ± 36 bcde	8.05 ± 0.18 fghi	135 ± 12 bcdef	612 ± 98 bcdef
21	256 ± 23 b	7.9 ± 0.2 hij	126 ± 13 bcdefgh	672 ± 78 b
22	209 ± 23 efghij	8.1 ± 0.2 efgh	125 ± 17 cdefgh	542 ± 52 fghi
23	248 ± 39 bcd	8.0 ± 0.3 ghi	143 ± 31 bc	655 ± 100 bcd
24	219 ± 40 defghij	7.5 ± 0.2 k	109 ± 25 gh	576 ± 99 defghi
25	315 ± 34 a	9.5 ± 0.4 a	187 ± 32 a	833 ± 91 a
26	198 ± 27 ij	7.80 ± 0.14 ijk	109 ± 14 gh	519 ± 61 hi
27	253 ± 35 bc	8.7 ± 0.2 cd	147 ± 17 b	658 ± 103 bc

The samples with higher concentrations of total flour presented a significant ($p < 0.05$) luminosity increase and, therefore, resulted in a less dark appearance (Table 3). These values coincide with those reported by other studies, where corn flour was replaced by cricket flour [7]. Sample 3 showed a more orange and saturated color than the rest of the chucula. This was due to its high cocoa content, which gave it higher values for the coordinates a*, b* and Chroma (C^*_{ab}). The opposite case occurred with samples with a lower percentage of this ingredient, such as sample 1, which presented the lowest values for the coordinates a*, b* and Chroma (C^*_{ab}), creating a more bluish colored chucula and less saturated than sample 3. The Hue (h^*_{ab}) indicates the relative orientation of the color with respect to the 0° origin [12]. Chucula formulations with a lower content of cricket flour and higher values of cocoa presented significant ($p < 0.05$) lower tone values than those with a higher content of insect flour and lower content in cocoa.

Table 3. Mean ± and standard deviation of the color coordinates (L*, a*, b*, h^*_{ab} and C*ab) of each of the samples obtained. Superscript letters within columns indicate homogeneous groups according to ANOVA ($p < 0.05$).

Sample	L*	a*	b*	h^*_{ab}	C^*_{ab}
1	50.375 ± 0.107 g	10.94 ± 0.04 mn	16.10 ± 0.03 q	55.80 ± 0.08 jkl	19.46 ± 0.04 p
2	48.3 ± 0.3 p	12.28 ± 0.16 b	17.91 ± 0.16 c	55.58 ± 0.12 n	21.71 ± 0.2 b
3	44.24 ± 0.15 o	13.47 ± 0.04 a	18.675 ± 0.017 a	54.20 ± 0.06 ñ	23.03 ± 0.04 a
4	50.65 ± 0.13 f	11.37 ± 0.04 i	17.32 ± 0.02 jk	56.72 ± 0.09 cd	20.72 ± 0.03 jk
5	49.97 ± 0.05 i	11.22 ± 0.04 jk	17.13 ± 0.08 m	56.77 ± 0.19 c	20.48 ± 0.05 m
6	50.793 ± 0.019 ef	11.348 ± 0.005 i	17.195 ± 0.010 lm	56.58 ± 0.02 e	20.602 ± 0.008 l
7	51.73 ± 0.07 b	11.01 ± 0.04 m	16.460 ± 0.016 p	56.23 ± 0.08 gh	19.80 ± 0.03 o
8	51.5 ± 0.4 c	10.88 ± 0.09 n	16.57 ± 0.14 o	56.71 ± 0.04 cde	19.83 ± 0.17 o
9	51.46 ± 0.04 c	11.080 ± 0.008 l	16.90 ± 0.05 ñ	56.74 ± 0.08 cd	20.20 ± 0.04 n
10	49.76 ± 0.03 jk	11.615 ± 0.013 h	17.643 ± 0.013 ef	56.64 ± 0.03 cde	21.122 ± 0.015 fg
11	49.95 ± 0.03 i	11.68 ± 0.02 gh	17.387 ± 0.006 ij	56.10 ± 0.05 hi	20.947 ± 0.009 i
12	49.62 ± 0.06 kl	11.820 ± 0.008 ef	17.31 ± 0.02 jk	55.68 ± 0.03 lmn	20.96 ± 0.02 hi
13	49.428 ± 0.013 m	11.9500 ± 0.0115 c	17.45 ± 0.08 i	55.60 ± 0.10 mn	21.15 ± 0.07 efg
14	49.588 ± 0.102 klm	11.958 ± 0.019 c	17.55 ± 0.04 gh	55.724 ± 0.018 klm	21.23 ± 0.04 cde
15	49.50 ± 0.10 lm	11.89 ± 0.04 cde	17.390 ± 0.010 ij	55.638 ± 0.112 mn	21.066 ± 0.017 gh
16	49.93 ± 0.05 ij	11.69 ± 0.07 gh	17.81 ± 0.04 d	56.728 ± 0.105 cd	21.30 ± 0.06 c
17	51.12 ± 0.15 d	11.17 ± 0.04 k	17.56 ± 0.03 fgh	57.55 ± 0.12 a	20.81 ± 0.02 i
18	50.19 ± 0.16 h	11.72 ± 0.07 g	17.62 ± 0.05 efgh	56.36 ± 0.08 fg	21.16 ± 0.08 efg
19	50.39 ± 0.02 g	11.795 ± 0.013 f	17.628 ± 0.017 efg	56.21 ± 0.03 hi	21.209 ± 0.019 cdef
20	50.42 ± 0.08 g	11.635 ± 0.018 h	17.17 ± 0.07 lm	55.88 ± 0.10 j	20.74 ± 0.06 jk
21	49.11 ± 0.05 n	11.89 ± 0.02 cd	17.54 ± 0.14 h	55.86 ± 0.25 jk	21.189 ± 0.104 def
22	50.82 ± 0.06 ef	11.37 ± 0.09 i	17.24 ± 0.07 kl	56.610 ± 0.115 de	20.651 ± 0.105 kl
23	49.76 ± 0.08 jk	11.95 ± 0.06 c	18.010 ± 0.014 b	56.44 ± 0.13 f	21.61 ± 0.04 b

Table 3. *Cont.*

Sample	L*	a*	b*	h^*_{ab}	C^*_{ab}
24	50.4000 ± 0.1003 ^{g}	11.870 ± 0.014 ^{de}	17.65 ± 0.04 ^{e}	56.08 ± 0.04 ^{i}	21.27 ± 0.04 ^{cd}
25	50.93 ± 0.08 ^{e}	11.24 ± 0.03 ^{i}	17.39 ± 0.03 ^{ij}	57.12 ± 0.07 ^{b}	20.70 ± 0.04 ^{kl}
26	50.258 ± 0.013 ^{gh}	11.325 ± 0.006 ^{i}	17 ± 0 ^{n}	56.360 ± 0.013 ^{fg}	20.443 ± 0.004 ^{m}
27	51.938 ± 0.010 ^{a}	10.768 ± 0.010 ^{p}	16.873 ± 0.005 ^{p}	57.455 ± 0.017 ^{a}	20.015 ± 0.009 ^{p}

As a conclusion of this work, the addition of cricket flour into mixture powder has shown adequate behavior to obtain a new product with a higher protein content. Therefore, we demonstrated that the addition of cricket flour in the chucula could have interesting applications in the food technology field because it generates new foods with a high nutritional value, with the consequent improvement of the nutritional status of populations.

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