Artículo Original/ Original Article

Effect of different hydration temperatures on the sensory, nutritional, and instrumental profile of black beans

Efecto de diferentes temperaturas de hidratación en el perfil sensorial, nutricional e instrumental de los frijoles negros

ABSTRACT

The objective of this study was to evaluate the effect of temperature using different hydration methods on the sensory profile, nutritional value, instrumental color, hardness, and rupture of the tegument, viscosity, and total soluble solids in the broth of common black beans. The black bean, Guapo Brillante (*Phaseolus vulgaris*), was analyzed after treatment with different hydration temperatures. The physico-chemical analysis showed that the treatments did not affect the hydration on protein and fiber content. The evaluation of the sensory profile was performed using the Optimized Descriptive Profile test with 16 evaluators. The evaluators recognized differences in the color, rupture, and viscosity attributes; however, a difference was detected in the hardness only in the sample of cooked beans hydrated at 90°C, which was not consistent with instrumental texturometric analysis. When hydration treatments were conducted the soluble solid content of the broth increased and grains were less hard and chewy. In the optimized descriptive profile, the disposal of the water, it was what differentiated sensorial the samples being that the evaluators perceived colors lighter, and with the lower viscosity of the broth. However, the sensory attributes relating to the instruments on the whole, there was a difference between treatments, and correlations for all variables.

Keywords: Optimized Descriptive Profile; Beans, Texture; viscosity; Temperature.

RESUMEN

El objetivo de la presente investigación fue evaluar el efecto de diferentes temperaturas de hidratación en el perfil sensorial, valor nutricional, color instrumental, dureza, ruptura del tegumento, viscosidad y sólidos solubles totales en el caldo del frijol negro común. *La cultivar* "Guapo Brillante", del frijol negro (*Phaseolus vulgaris*) fue analizada después de desarrollar el tratamiento con diferentes temperaturas de hidratación. El análisis físico-químico mostró que los tratamientos de hidratación no afectaron el contenido de proteína y fibra. La evaluación del perfil sensorial se realizó mediante la prueba del perfil descriptivo optimizado con dieciséis evaluadores. Los evaluadores reconocieron las

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diferencias de los atributos de color, ruptura y viscosidad. Se detectó diferencia para el atributo "dureza" en la muestra de frijol cocido con el agua de hidratación a 90°C, lo cual no concuerda con el análisis texturométricas. Cuando se realizaron tratamientos de hidratación, los contenidos de sólidos solubles del caldo aumentaron, así como los granos se mostraron más indulgentes en relación con la dureza y la masticabilidad. En el perfil descriptivo optimizado, la eliminación del agua fue lo que diferenció sensorialmente a las muestras, ya que los evaluadores percibieron los colores más claros y con la menor viscosidad del caldo. Sin embargo, relacionando los atributos sensoriales con los instrumentales en la totalidad, se verificó una diferenciación entre los tratamientos, y con correlaciones en todas las variables.

Palabras clave: Perfil descriptivo optimizado; Frijoles; Textura; Viscosidad; Temperatura.

INTRODUCTION

The common bean is an important source of protein, dietary fiber, iron, complex carbohydrates, minerals, and vitamins for millions of people in developing and developed nations¹.

Beans account for almost half of all legumes consumed worldwide, and are the second most important legume after soybeans, and are a staple food in Africa, India, and Latin America²⁻⁴. Given their health and nutritional benefits, health professionals should encourage greater bean consumption⁵.

Vegetables and legumes are excellent sources of several phytochemicals with proposed health-related benefits⁶. Phytochemicals are natural bioactive compounds found in vegetables and fruits used for combating free radicals and reducing the oxidative damage responsible by chronic diseases⁷.

Since the early part of the twentieth century many studies have been conducted to investigate the impact of preparation and cooking methods on the stability of nutrients in food. The results of these studies vary widely, leading the consumer to question the best ways of preparing and cooking foods in order to maintain the nutritional qualities, especially in legumes and vegetables. Many other researchers have shown that growth conditions of vegetables and legumes also have a significant impact on nutrient content⁸⁻¹¹.

Studies agree that hydration before cooking beans reduces the anti-nutritional and flatulent components of the grain¹².

The increase in water temperature during the steeping of grains or beans is carried out to accelerate the absorption of water and to facilitate the cooking of the product due to the grain softening. It has been observed that soaking beans with the addition of boiling water increases the loss of soluble solids from the beans¹³. The practice of hydration with hot water¹⁴, also called forced steeping, has been used previously; however, some authors¹⁵⁻¹⁷ consider this practice inadequate because it inhibits enzymes involved in the degradation of polyphenols, the hydrolysis of starch, and can also affect the nutritional quality after prolonged exposure to heat. There is considerable interest in identifying sensory attributes and nutritional value as a result of hydration at different temperature. Considering the fact that much of the population prepares food at home, the knowledge of how these foods are prepared and how different preparation methods affect the nutritional and sensory quality of the food is extremely relevant for today's consumer¹⁸.

The optimized descriptive profile (ODP) is a sensory test that has been described as the quickest method that provides quantitative information about the characteristics of the studied product¹⁹. This method aims to eliminate the training stages and final selection of evaluators²⁰.

It is believed that when beans are cooked using different hydration methods, this physically and nutritionally affects the

beans, and the beans have different sensory characteristics that will be perceived by the evaluators.

The objective of this study was to evaluate the effect of temperature, using different hydration methods, on the sensory profile, nutritional value, and instrumental color, hardness, rupture of the tegument, viscosity, and total soluble solids in the broth of black beans.

MATERIAL AND METHODS

The common bean crop, Guapo Brillhante (*P. vulgaris* L., black group), was produced and acquired in the municipality of Cangucu in Rio Grande do Sul (RS), Brazil. The grains were stored at 17±1 °C in a room in the Post-harvest, Industrialization, and Grain Quality Laboratory in Capao do Leao, RS, Brazil, where the analysis was also conducted. Hydration and Cooking

To determine cooking parameters, chemical and sensory analysis were performed for the following treatments: beans were hydrated in distilled water (1:5) at room temperature (25±2 °C) for 12 hours. The hydration water was then disposed before cooking the first sample (FSA25). For the second sample, hydration water was retained for cooking (FCA25).

The third sample was soaked in distilled water (1:5) at an initial temperature of 90±5 °C for 5 hours and cooked after discarding the hydration water (FSA90). The fourth sample was soaked under the same conditions and cooked with the hydration water (FCA90). In addition to these, a control sample with no prior hydration performed was also cooked (FCSH).

Cooking was done in a pressure cooker (2 atm). To verify that the beans were cooked and ready to eat, the tactile method²¹ was used to carry out the evaluation of the cooking time. Analysis of nutritional and colorimetric composition was conducted with raw and cooked beans. For the texturometric analysis, soluble solids in the broth were used and sensorial analysis was only conducted with the cooked grain.

Proximate composition

Raw and cooked beans were analyzed for their chemical composition: moisture, proteins, lipids, and carbohydrates content, total energy value (TEV), fibers, and ash content, according to AOAC²².

Colorimetric analysis

The colorimetric parameters L^* , a^* and b^* were determined according to Lawless²³, using a Minolta colorimeter (CR-300 Model Konica Minolta, Japan). The HUE angle and chroma were determined using equations 1 and 2 respectively²⁴.

$$^{\circ}\text{HUE} = \arctg \frac{b^*}{a^*} \quad (\text{Eq. 1})$$

$$C^2 = (a^2 + b^2) \quad (\text{Eq. 2})$$

Total soluble solids of the broth and Texturometric analysis

The total soluble solids in the bean broth was determined based on the methodology described by Skowronski²⁵.

Texturometric characterization was performed using a single grain and by performing a validation using 15 replicates using the Stable Micro Systems Texture Analyzer (TA.XT plus model, England)²⁶. The parameters analyzed included hardness, cohesiveness, and chewiness; these were chosen because of their relationship with sensory parameters.

Sensory Analysis

Sensory analysis was performed at the Center for Chemical Sciences, Pharmaceutical, and Food of the Federal University of Pelotas, Campus Capao de Leao, under the approval of the UFPel Research Ethics Committee and the protocol CAAE 49200415.2.0000.5316.

To evaluate the color, hardness, broth viscosity, and seed coat rupture, the ODP test¹⁹ was performed with unstructured scale of 9 cm. Sixteen evaluators, of both sexes, with previous experience in sensory evaluation, were individually asked to perform the test. They participated in a familiarization session of descriptive terms with the extreme of sensory attributes evaluated, as well as their respective reference materials. After this stage, they were asked to sign a consent form. The samples (approximately 15 grams) were served after cooking in porcelain pots at a temperature of 50-55 °C.

At each session, evaluators, in individual booths, received the coded sample number consisting of three random digits, along with the scale. They were also presented samples and references materials that limit the extreme of each attribute so that the evaluators could refer to them throughout the evaluation.

The attributes evaluated were defined using a scale ranging from 0 to 9 as follows: grain color (0= light, 9= dark), hardness (0= hard, 9= soft), broth viscosity (0= little, 9= too much), and rupture of the tegument (0= too much, 9= little).

Statistical Analysis

A completely randomized design in a bifactorial scheme with three replications was used. We used the F-test to evaluate analysis of variance. Hydration effects were compared using the Duncan test and comparisons to the control were conducted using the Dunnett test. All tests were performed at 5% probability.

A principal component analysis (PCA) was conducted using a correlation matrix of groups of instrumental and sensory variables. Thus, the information contained in the original variables was designed for a smaller number of underlying principal component calls. We used the criteria for variable elimination recommended by Jolliffe²⁷. According to this criterion a number of principal components should be retained that explain at least 70 to 90% of the total variation. After selecting the number of components, their respective eigenvalues were obtained with their corresponding eigenvectors. The adopted graphic procedure was the biplot generated from the scores and the loads of selected principal components.

RESULTS

Effect of hydration in the proximal composition

The proximal composition, energy, and soluble protein are shown in Table 1. The raw beans had 22.3% protein content. Corroborating this result, Oliveira et al.²⁸ found 22.5% protein in raw beans (Guapo Brilhante). The protein composition of samples undergoing subsequent hydration

Table 1.

Effect of hydration on the proximal composition of raw and cooked Guapo Brilhante black bean. FAEM/UFPel, Pelotas-2015

Treatments	Humidity (%)	Proteins (%)	Soluble protein (%)	Lipids (%)	Carbohydrates (%)	Energy (kcal/100g)	Total (%)	Ash fiber (%)
Raw bean	13.4±0.15	22.3±0.11	65.9±2.73	1.8±0.01	54.6±0.47	334±1.53	3.6±0.19	4.3±0.07
FCSH	7.0±0.18	20.6±0.42	69.9±5.64	1.6±0.10	62.5±0.56	347±1.50	4.1±0.09	3.9±0.06
FCA25	6.4±0.23 ^b _α	20.3±0.33 ^{ns}	67.8±2.59 ^b	1.2±0.30 ^{abα}	63.5±0.50 ^b	344±3.63 ^b	4.7±0.14 ^{ns}	3.9±0.03 ^{ab}
FCA90	10.2±0.08 ^a _α	19.6±0.56 ^{ns}	77.3±7.39 ^a	0.9±0.05 ^{bα}	60.6±1.23 ^c	328±2.00 ^{cα}	4.2±0.10 ^{ns}	4.1±0.21 ^{aα}
FSA25	5.9±0.06 ^c _α	19.4±0.51 ^{ns}	71.9±2.04 ^b	1.4±0.05 ^a	65.2±0.61 ^b	351±2.40 ^{ab}	4.4±0.46 ^{ns}	3.6±0.25 ^b
FSA90	4.4±0.2d ^α	18.9±1.85 ^{ns}	73.9±4.38 ^{ab}	1.3±0.05 ^a	68.0±2.19 ^{aα}	359±7.72 ^{aα}	4.5±0.44 ^{ns}	2.8±0.05 ^{cα}

1/Means of three repetitions ± standard deviation accompanied by the same letter in the column do not differ by Duncan test ($p \leq 0.05$).

^αSignificant when compared to control FCSH (beans cooked without hydration) by Dunnett test ($p \leq 0.05$). Means followed by ns in the column were not significant by F-test ($p \leq 0.05$). FCA25 and FSA25 refer, respectively, to cooked beans with and without previous hydration water starting at temperature 25 °C; FCA90 and FSA90 refer respectively to cooked beans with and without previous hydration water at initial temperature of 90 °C.

and cooking was not statistically different ($p = \text{NS}$) in relation to FCSH.

In the analysis of total soluble protein content, the influence of temperature was observed. The grains hydrated at 90°C showed higher levels of soluble protein content, indicating that the increase of temperature promotes availability of these compounds, which is an important finding as it has direct action on the thickening broth.

The content of carbohydrate found in raw beans (54.6%) was different with the results observed by Barros²⁹ who found higher values in beans varieties varying between 69.89 (Pérola) to 72.47 (carioca) 100g⁻¹ of sample As for TEV, the FSA90 beans had a higher value in comparison to other treatments, which can be justified due to the difference in carbohydrate content.

When evaluating the fiber content, it was observed that there was no statistical difference between treatments. The fiber content in cooked beans varied between 4.4 and 4.7%. This data presents technological significance, indicating that even after different processes commonly used in households, the Guapo Brilhante beans kept their fiber content, ensuring functionality of the grain.

The ash content found for the beans evaluated was 4.3% (Table 1), which was similar to the results found in the study by³⁰ and the study by³¹, who found a content of 4.22 cultivars Diamante Negro and 4.91% cultivars BRS Pontal, respectively.

Effect of hydration on the colorimetric analysis

Table 2 summarizes the results of the colorimetric parameters. Regarding color analysis, it was found that the raw beans showed the highest value in relationship to the brightness parameter. The black beans grouped with L*

values within the range of 20 to 22 units can be considered suitable³². Silva, Rocha & Canniatti-Brazaca³¹ found a value of 18.13 for the BRS supreme black bean. Regarding the samples that had undergone hydration, the greatest value was 25°C.

A similar pattern was observed with a a^* ; beans that were soaked had higher values indicating a reddened color. This may have occurred due to the leaching of pigments during the hydration treatments. The b^* value was not different between the cooking treatments.

The chroma values increased after cooking, indicating that this process removed the pigment agents responsible for the grain's grayish tone. There was no significant difference between grains that received hydration treatment before cooking. Another study found a chroma value of 4.05 ± 1.0 for BRS Supremo, which was lower than the one found in this study³¹.

There was a decrease in the hue value with the hydration and cooking of the grains, however, did not present statistical difference between the hydration and cooking treatment. The results for this colorimetric parameter indicate a red tone in the grain after cooking, since the values were close to 0 °Hue.

Effect of hydration on soluble solids in the broth

In the analysis of total soluble solids in the broth (Table 3), results showed that the non-hydrated beans (3.2%) showed a lower amount of solids compared with the hydrated samples. Among the treatments with hydration and later cooking, results were similar, ranging from 7 to 7.4% except for the FSA90 (6.2%), where a thinner broth was obtained. This indicates that both the non-hydration as well as the temperature of the hydration water allowed the reduction of soluble solids in the beans.

Table 2.
Effect of hydration on the colorimetric parameters L*, a*, b*, chroma (purity or color intensity), and °Hue of raw and cooked Guapo Brilhante black bean. DCTA/UFPEL, Pelotas - 2015.

Treatments	L*	a*	b*	Chroma	°Hue
Raw bean	28.7±0.83	3.5±0.25	2.3±0.29	4.2±0.31	33.3±3.10
FCSH	25.1±0.73	6.9±0.54	1.6±0.47	7.1±0.46	13.0±4.42
FCA25	25.7±1.10 ^a	8.2±0.72 ^{nsα}	0.9±0.56 ^{ns}	8.3±0.68 ^{nsα}	6.4±4.24 ^{nsα}
FCA90	23.9±0.38 ^{bc}	8.7±0.72 ^{nsα}	1.3±0.37 ^{ns}	8.4±1.13 ^{nsα}	8.3±4.26 ^{ns}
FSA25	25.0±1.21 ^{ab}	8.7±1.03 ^{nsα}	1.4±0.36 ^{ns}	8.8±0.66 ^{nsα}	8.8±3.17 ^{ns}
FSA90	23.2±1.22 ^{cα}	8.8±0.58 ^{nsα}	1.4±0.23 ^{ns}	8.9±0.54 ^{nsα}	8.9±1.99 ^{ns}

1/ Means of five repetitions ± standard deviation accompanied by the same letter in the column do not differ by Duncan test ($p \leq 0.05$).
αSignificant when compared to control FCSH (beans cooked without hydration) by Dunnett test ($p \leq 0.05$). Means followed by ns in the column were not significant by F-test ($p \leq 0.05$). FCA25 and FSA25 refer, respectively, to cooked beans with and without previous hydration water starting at temperature 25 °C; FCA90 and FSA90 refer, respectively, to cooked beans with and without previous hydration water at initial temperature of 90 °C.

Table 3.

Effect of hydration on the soluble solids in the broth of cooked Guapo Brillhante black bean. DCTA/UFPEL, Pelotas -2015.

Treatments	Soluble solids
FCSH	3.2±0.03
FCA25	7.0±0.59 ^{abα}
FCA90	7.2±0.48 ^{αα}
FSA25	7.4±0.28 ^{αα}
FSA90	6.2±0.15 ^{ba}

1/ Means of three repetitions ± standard deviation accompanied by the same letter in the column do not differ by Duncan test ($p \leq 0.05$). "Significant when compared to control FCSH (beans cooked without hydration) by Dunnett test ($p \leq 0.05$). Means followed by ns in the column were not significant by F-test ($p \leq 0.05$). FCA25 and FSA25 refer, respectively, to cooked beans with and without previous hydration water starting at temperature 25 °C; FCA90 and FSA90 refer, respectively, to cooked beans with and without previous hydration water at initial temperature of 90 °C.

Effect of hydration on texturometric analysis parameters

In Table 4, the instrumental parameters for the texture of cooked beans are presented. Regarding the hardness, it was observed that cooked beans with previous hydration had lower results indicating smoothness after cooking, with FSA25 presenting the lowest value (10.02 N). Hydration before cooking promotes the softening of the bean, thus the grain absorbs more water, which makes it soft.

Cohesiveness showed no difference between hydration treatments, but treatments with hydration at 25 °C were significantly different compared with FCSH.

The resistance to chewiness was higher in non-hydrated grains (1.16 Nmm⁻¹), with a significant difference compared to treatments where the water was discarded. The resistance to chewing was higher in non-hydrated grains (1.16 Nmm⁻¹), differing significantly from treatments in which water from grain hydration was discarded. The hydration treatments did not differ with respect to this parameter. It was observed that chewiness was similar to hardness, meaning that the harder grain had a higher resistance to chewiness.

Effect of hydration on sensory analysis

Sensory analysis was performed using the Optimized Descriptive Profile (ODP) method and measuring four attributes as shown in Figure 1. The starting point of the figure, represented by the zero on the scale, suggests that the intensity increases from the center to the edge and the sensory profile is shown for each treatment with dashed lines.

When analyzing the color parameter, the evaluators did not notice any difference between FCSH (3.1), FSA25

Table 4.

Effect of hydration on the texture profile of the Guapo Brillhante black bean. DCTA/UFPEL, Pelotas -2015.

Treatments	Hardness (N)	Cohesiveness	Chewiness (Nmm ⁻¹)
FCSH	16.5±1.49	0.14±0,01	1.16±0.23
FCA25	12.8±1.66 ^{αα}	0.16±0,0 ^{nsα}	0.74±0.23 ^{ns}
FCA90	13.0±1.47 ^{αα}	0.16±0,01 ^{ns}	0.88±0.55 ^{ns}
FSA25	10.0±1.43 ^{ba}	0.16±0,00 ^{nsα}	0.52±0.24 ^{nsα}
FSA90	11.9±1.13a ^{ba}	0.14±0,01 ^{ns}	0.41±0.11 ^{nsα}

1/ Means of five repetitions ± standard deviation accompanied by the same letter in the column do not differ by Duncan test ($p \leq 0.05$). "Significant when compared to control FCSH (beans cooked without hydration) by Dunnett test ($p \leq 0.05$). Means followed by ns in the column were not significant by F-test ($p \leq 0.05$). FCA25 and FSA25 refer, respectively, to cooked beans with and without previous hydration water starting at temperature 25 °C; FCA90 and FSA90 refer, respectively, to cooked beans with and without previous hydration water at initial temperature of 90 °C.

Figure 1. Sensory profile of five different types of treated beans for the attributes: color (0 = light, 9 = dark); hardness (0 = hard, 9 = soft); viscosity (0 = little, 9 = too much); rupture (0 = too much, 9 = too little).

(1.9), and FSA90 (2.5), but noted that the beans cooked without hydration water were lighter than those cooked with hydration water.

The average hardness ranged from 6.2 to 7.8 corresponding to the term "soft," indicating that all beans were suitable for consumption, with the only statistically significant difference observed between the FCA90 sample (6.2) versus the others.

Regarding the broth viscosity attribute, the beans cooked with hydration water had a higher value, indicating higher viscosity according to the evaluators. This shows that hydration followed by the use of water favored broth thickening.

According to the sensory evaluation, FCA90 (6.4) showed little bean rupture. The lowest rates were observed

for the FSA25 beans (2.3) and FCSH (3.5) that had similar sensory behavior, being close to the term “too much” on the unstructured scale.

In order to validate the sensory attributes (color, hardness, broth viscosity, and bean rupture) a correlation was conducted with the instrumental parameters (texturometric, colorimetric, and soluble solids) using Principal Component Analysis.

The Principal Components (PCs) were generated from data from nine instrumental evaluations and four sensory evaluations, totaling 13 dependent variables.

The first two principal components explained a large proportion of the total variation, that is, 78.8%, where PC1 and PC2 were responsible for 46.2 and 32.6%, respectively, which allowed the plot of the scores and the burdens of the components to be related to the levels of the studied treatment factor (2: FCSH; 3: FCA25; 4: FCA90; 5: FSA25; and 6: FSA90) (Figure 2). It was found that the formation of different groups was different between treatments, according to the dependent variables evaluated.

By analyzing the eigenvectors (Table 5) corresponding to component 1, which represent the relative importance of each variable, we obtained -0.38 for Hue that differentiated sample 2 (FCSH), 0.40 for soluble solids, and 0.38 for a^* and chroma (purity or color intensity) featuring samples 3 (FCA25) and 4 (FCA90) as analogous samples. In PC2, eigenvectors of 0.45 for sensory viscosity and 0.48 for sensory color were responsible for grouping samples 5 (FSA25) and 6 (FSA90), and -0.44 for sensory rupture differentiated sample 4 (FCA90) from the rest (Figure 2).

Figure 2. Plotting scores and loads of PC1-PC2 in relation to dependent variables using the following samples: 2 = Cooked beans without hydration; 3 = Cooked beans with prior hydration at 25 °C; 4 = Cooked beans with previous hydration at 90 °C; 5 = Cooked beans without prior hydration at 25 °C; and 6 = Cooked beans without prior hydration at 90 °C. FAEM/UFPEl-DCTA, 2015.

Table 5.

Eigenvectors corresponding to two principal components (PC1 and PC2) for dependent variables related to the tested samples. FAEM/UFPEl-DCTA, 2015.

Variables	PC1	PC2
L	-0.07	-0.058
a^*	0.38	0.046
b^*	-0.23	0.216
Hue	-0.38	0.123
Chroma	0.37	0.143
Hardness	-0.36	-0.208
Cohesiveness	0.32	-0.091
Chewiness	-0.31	-0.279
Soluble Solids in the broth	0.40	-0.042
Hardness - Sensory	-0.003	0.394
Rupture - Sensory	0.05	-0.44
Viscosity - Sensory	-0.113	0.45
Color - Sensory	-0.05	0.48
Eigenvalue	6.00	4.23
Variation (%)	46.2	32.6
Accumulated variation (%)	46.2	78.8

Sample 2 (FCSH) formed a group and the variables responsible for differentiation were b^* , Hue, hardness, and chewiness. Positive correlations were observed between b^* and Hue ($r = 0.83$), hardness and Hue ($r = 0.66$), chewiness and Hue ($r = 0.58$), chewiness and hardness ($r = 0.89$). Negative correlations were observed between b^* and cohesiveness ($r = -0.65$), b^* and soluble solids broth ($r = -0.51$), Hue and cohesiveness ($r = -0.83$), Hue and soluble solids broth ($r = -0.90$), Hue and a^* ($r = -0.76$), Hue and chroma ($r = -0.73$), hardness and cohesiveness ($r = -0.66$), hardness and soluble solids in the broth ($r = -0.86$), hardness and a^* ($r = -0.89$), hardness and chroma ($r = -0.95$), chewiness and cohesiveness ($r = -0.36$), chewiness and viscosity ($r = -0.67$), chewiness and a^* ($r = -0.82$), and chewiness and chroma ($r = -0.93$).

These data confirm what was previously observed: non-hydrated grains are harder and do not release compounds sufficient for thickening the broth. Furthermore, hardness and chewiness were strongly related.

The other group was formed with sample 3 (FCA25) and 4 (FCA90), where positive correlations were observed between variable cohesiveness, soluble solids in the broth, a^* , and chroma. Results demonstrated that the temperature of hydration water was not critical for distinguishing between these variables. Correlations were observed between soluble cohesiveness and solids in the broth ($r = 0.84$), cohesiveness and a^* ($r = 0.58$), cohesiveness and chroma ($r = 0.55$), soluble solids in the broth and a^* ($r = 0.92$), soluble solids in the

broth and chroma ($r = 0.88$), and a^* and chroma ($r = 0.97$). For the variables, cohesiveness, soluble solids in the broth, a^* , and chroma negative correlations were obtained with b^* , Hue, hardness, and chewiness, as described above.

Sample 4 (FCA90) showed different behavior compared with other samples mainly related to sensory rupture variable. This variable was negatively correlated with sensory hardness ($r = -0.97$), sensory color ($r = -0.96$), and sensory viscosity ($r = -0.76$).

The other group formed was represented by samples 5 (FSA25) and 6 (FSA90) that showed the same behavior as the sensory hardness variables, sensory color, and sensory viscosity. Positive correlations were observed between sensory hardness and sensory color ($r = 0.88$), sensory hardness and sensory viscosity ($r = 0.59$), and sensory color and sensory viscosity ($r = 0.90$). However, negative correlations were found with respect to sensory rupture, as described above. The L^* was not important in differentiating the groups formed.

DISCUSSION

Assessing the proximal composition of similar treatments, Toledo et al.³³ found that hydration does not promote changes in the percentage of proteins present. However, Ramirez-Cárdenas³⁰, found lower protein values when the water of hydration was discarded before cooking in three different varieties of beans studied. A change in protein value was not observed for the processing used to evaluate the Guapo Brillhante bean. This is probably because the analyses were performed with beans and broth, which is a common practice in bean consumption. This result is very important because, in the case of beans, no change in the protein thermo stability could be revealed by constitutional analysis, indicating versatile pre-preparation techniques.

The influence of temperature on the soluble protein values in water was detected by measuring a higher content of leached compounds. According to Liu et al.³⁴ the soluble proteins are responsible for the gelation of the broth, thereby promoting thickening of the same.

As for fiber content, this value remained stable across treatments, with good indication for quality. According to Bourdon³⁵, beans are a food rich in fiber that produce satiety, and high levels of cholecystokinin, which relates to reductions in levels of plasma glucose and insulin in diabetic patients. There was lower fiber content in the raw grain. González³⁶ noted that heat treatments can have variable effects on dietary fiber and that cooking causes disruption of the cellular components of beans (cellulose, hemicellulose, lignin, pectin and gums), and it can also provide interactions between proteins, and lipids, as well as qualitative and quantitative changes in the composition of total fiber of cooked foods compared to the raw foods.

When evaluating the hydrated beans, it was observed that the use of water allowed a higher concentration of the ash content. Toledo et al.³³ found difference in ash levels between the different types of cooking. It was also observed that hydrating the grain in a water already at high

temperature (90°C), the ash content is released out of the grain in this Fabaceae (Table 1). The hydration promotes leaching of minerals³³. The effect of hydration the grains for cooking was also observed by Barampama & Simard³⁷, with a common bean (*Phaseolus vulgaris*, cultivar Dore de Kirundo) after cooking without water hydration (20%), and without hydration (12%). These authors considered that the decreasing could be explained by the loss of minerals by diffusion in the water, and the increment in ash content possibly due to the accumulation of some minerals in the substrate, as happens during fermentation.

The bioavailability of minerals from leguminous sources is subject to the presence of substances that promote absorption, whose concentrations vary according to the type of legume. It is possible to attenuate these negative effects with appropriate cooking procedures in the preparation of these grains, since most of these compounds are water soluble, and thermolabile³⁸.

As for color, beans in all treatments maintained the appropriate color, with a small variation in the a^* parameter, demonstrating that pre-hydrated beans lose pigmentation via leaching compounds. We also found lower values in the case of non-hydrated beans in the analysis of soluble solids in broth. This fact may be related to the levels of anthocyanins present in grains, mainly in the bean. Content is related to the color of the bean³⁹. The hydration process promoted the leaching of anthocyanins into the broth. Schneeman⁴⁰ found out the anthocyanins is more concentrate in beans with cooking water.

Perina et al.⁴¹ found a value of 11.57% of total soluble solids in the bean broth. Our results are consistent with a study that found that hydration of the grains with the addition of boiling water increases the loss of soluble solids of the grains¹³.

After examining texture parameters, it was found that pre-hydrated beans were softer after cooking, which favors chewiness. Goycoolea et al.⁴² point out that beans with hydration prior to cooking are lighter than uncooked beans cooked at the same time.

According to Wani et al.⁴³ in studying different bean varieties, hardness values varied from 9.63 to 28.11 N. As for the cohesiveness, the values found in this study (0.14 to 0.16) were similar to this author, who found a value of 0.15 for the local red bean variety. Values differed for chewiness, since higher values were observed for the variety Guapo Brillhante (0.41 to 1.16 N/mm) compared to those cited by the author (0.35 N/mm). The presence of brightness, thickness, and uniformity of deposition of the wax layer on the surface of the tegument (grain external layer) of the Guapo Brillhante bean may justify the lower values of water absorption, as well as greater resistance to the chewiness²⁸.

The quality of a product is related to various characteristics that make up the food, thus, a sensory analysis can be used as a technique for evaluating the characteristics of food. The ODP test has been proposed as a quick method that provides quantitative information on the product

characteristics studied¹⁹. This method aims to remove the training steps and final selection of the judges. For that, references are brought together with samples evaluated to be used in the comparison.

Sensory analysis performed on different treatments of black beans showed that the evaluators noticed differences in hardness, viscosity of the broth, color and rupture of the tegument (grain external layer).

Texture is an evaluation widely used to determine the quality of grain consumption⁴⁴. Hardness is a characteristic that makes up the grain texture and is of great importance for the consumer's acceptance of bean crops. Although in the instrumental evaluation the hydrated beans were softer than the non-hydrated, this parameter was well evaluated sensorially.

The higher viscosity perceived by the evaluators, the presence of soluble solids in the water after cooking, and hydrated grains is confirmed by Sathe and Salunkhe⁴⁶. Viscosity depends on the protein type of the solids concentration, the viscosity being one of the functional properties of the proteins. There were positive correlations regarding the color, viscosity, and cohesiveness among these samples. In the samples cooked after the water was discarded beans were perceived as lighter in color with a lower viscosity in the broth.

It was found, therefore, that the sixteen evaluators identified slight differences in the sensory profile of the different treatments.

CONCLUSION

The study showed that there were no effects of hydration in the grains protein and fiber content. However, the protein soluble content increased when the temperature of the water was increased, and when the water was discarded the ash content decreased. In hydration treatment, the soluble-solid content of the broth increased, since the beans had to be milder with respect to hardness and chewiness.

In the OPD test, the disposal of the water was what differentiated sensory samples. Evaluators perceived lighter colors with a lower broth viscosity.

In summary, by comparing the sensory to the instrumental attributes, a difference was observed between treatments, with high correlations on all variables.

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