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# Effect of Vegetable Powders on the Bread Quality Made from Frozen Dough

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**Abstract:** Brazil is a major producer and consumer of bread and in 2015, the market turnover was 1.9 billion dollars, with 0.86 million tons of bread. In this way, it is an excellent food matrix for the incorporation of functional ingredients. Thus, the aim of this study is the inclusion of vegetable powder in bread formulations obtained from frozen dough and to evaluate the product quality. Tomato, broccoli and açaí powder were added in 5 to 10% in bread formulations for frozen dough production. The evaluation of the frozen storage effect on the bread quality was performed for 60 days through the crumb structure, texture and sensory analysis of the products. Statistical analysis was performed by ANOVA average test, regression and correlation analysis. The results showed that the incorporation of vegetable powders increased significantly, the protein and mineral contents and reduced carbohydrate levels. The frozen storage reduced bread quality parameters and increases bread hardness, however, the vegetable powders addition in breads promoted a lower reduction. A negative correlation was observed between the frozen storage time, crumb structure and the sensory parameters while a positive correlation to the hardness of the bread has been established. Therefore, the addition of tomato, broccoli and açaí powder can be a solution for improving the quality of frozen dough, without the use of chemical additives and in addition, it improves the nutritional value of the breads.

**Keywords:** Bread Quality, Crumb Structure, Freezing, Sensory Quality, Supplemented Breads

## 1. Introduction

Frozen bread dough is widely used in the baking industry, mainly due to its convenience. Dough freezing can reduce processing time and labor intensity, increase products shelf life and productivity, and facilitate distribution to distant locations [1].

Freezing and frozen storage of doughs for bread production, as well the freezing usage in many bread production stages damages the product's quality, as exposed by [2] and [3]. [4] assert that freezing deteriorates the bread making quality of frozen bread dough. A major shortcoming of frozen dough is the substantial deterioration of baking quality with increasing frozen storage period [5].

Protein network formed by gliadin and glutenin proteins in the wheat flour is affected during the dough freezing [6], the expansion pressure generated by the formation of crystals of ice during the freezing process may harm the gluten's structure and reduces bread quality. [7] also states that the freezing process weakens the dough structure, diminishing $CO_2$ retention capacity produced in fermentation process.

Therefore, due to these factors, products originated from frozen doughs generally have lesser quality when compared to fresh doughs, the breads have less volume and need more fermentation time [8], due to the multicomponent of dough and the complex structure of gluten network, lack of fundamental understanding of gluten deterioration has delayed technological improvement of frozen dough [9]. [10] claims that harmful alterations that occur during freezing and frozen storage might be handled in several degrees through food additives of chemical origin or special flours. [11] suggest that modifications in bread making products may avoid or minimize damages produced during freezing and frozen dough storage.

Freezing temperature exerts inconsistent effects on the yeast viability and dough structure. Yeast activity loss is more significant at lower freezing temperature whilst dough structure is better preserved at lower temperatures [12]. This requires dough to freeze at the optimum temperature, considering the combined contribution of yeast activity and dough structure to dough quality.

Incorporation of sucrose and salt could also depress the ice melting temperature and increase unfrozen water content of dough [13]. Therefore, the powdered vegetables inclusion can provide the functional properties and technological features that assist in maintaining the quality of frozen dough for bread production.

The aim of this study is the inclusion of vegetable powder in bread formulations obtained from frozen dough and to evaluate the product quality.

# 2. Materials and Methods

### *2.1. Bread Formulations*

Commercial Wheat flour enriched with iron and folic acid, (composed of 72.5% carbohydrates, 12.5% protein, 14.0% water, 0.6% fat, and 0.4% ash), refined sugar; Dry yeast (*Saccaromyces Cerevisae*), Hydrogenated Vegetable Fat (HVF), refined salt; and the vegetables powders tomato, broccoli and açaí were used in the bread formulations. The particle size of the vegetable powders was set at 20 mesh (0.84 mm) by sieving.

A completely randomized design was applied, varying the percentages of the powdered vegetables in the bread formulations. The independent variables used in this study were: tomato, broccoli and açaí powder.

The bread dough control formulation comprised 300.0 g of wheat flour, 120.0 g water, 30.0 g hydrogenate vegetable fat, 15.0 g refined sugar, 11.0 g dry yeast, 2.0 g salt. Tomato, broccoli and açaí powders were added according to the following formulations: T1: 15.0 g tomato powder; T2: 30.0 g tomato powder; B1: 15.0 g broccoli powder; B2: 30.0 g broccoli powder; A1: 15.0 g açaí powder and A2: 30.0 açaí powder. These amounts of vegetable powder were adjusted based on previous studies on fresh bread realized by [14].

All these ingredients were mixed in a semi-industrial mixer, following a preliminary mixing of dry ingredients for 1 min at low speed. Mixing was done for 3 minutes at medium speed and for 6 minutes at high speed. A quantity of water was added in the mixer at the beginning of the medium speed period. Water was used at a temperature below 10°C to slow down the fermentation process before freezing of the dough. The temperature of the dough at the end of mixing was T = 16.0°C ±1.0°C. After the mixture the dough was left to rest for 5 min and then divided in pieces of 100.0 g and hand-molded in an ellipses form.

Doughs pieces were inserted in polyethylene bags and were frozen and storage in a domestic freezer at –15.0°C±2.0°C for 60 days. The crumb structure, textural and sensory acceptability determinations were carried out for all formulations, at the following frozen storage days: 0, 15, 30, 45, and 60th, considering 0 day as the non-frozen dough sample. The dough thawing were performed in fermentation chamber at 28.0°C±2.0°C and 80.0% relative humidity for two hours and two hours was allowed for the fermentation process. The doughs were baked without stream at 220.0°C for minutes and cooled at room temperature (28.0°C±2°C).

### *2.2. Quality Analysis*

#### *2.2.1. Chemical Composition*

Proximate composition was determined using AOAC Methods [15]. Moisture content was determined using the oven drying method, 925.10; crude protein by Kjeldahl digestion and distillation (N x 5.7 for bread; N x 5.66 for vegetable powders) was measured according to the Method 920.87. Crude fat was determined by hexane extraction using Method 945.16 and ash was determined by dry-ashing at 550°C according to the Method 923.03. Total available carbohydrates were calculated by difference, i.e. 100 − (% moisture + % protein + % fat + % ash).

#### *2.2.2. Crumb Structure Image Analysis*

Bread crumb structure was determined by digital image. Images were obtained from digitalization at a 550 dpi resolution on a HP ScanJet 2400 scanner, on the crumb's central area with a resolution of 900x900 pixels. Images were analysed by the ImageJ® 1.47v software (National Institute of Health, USA). Images were saved on jpeg format and cut to a field view of 900x900 mm, captured colored images were converted to 8-bit in shades of gray and thresholded by the Otsu algorithm. From that, it was possible to obtain the number of alveolus and pore circularity values [16].

#### *2.2.3. Texture Profile Analysis*

Texture Profile Analysis (TPA) was used to measure textural properties of breads. A cylindrical probe with 38.1 mm diameter was used in the test according to AACC method 74-9 [17]. A 4.5 kg load cell was used at the speed of 2 $mm.s^{-1}$. The bread samples were cut in cubes of 20 x 20 x 20 mm. Indicators determined by this test include Hardness property. The test was done in five replications using a Brookfield texturometer CT3 (Brookfield Engineering Laboratories, Middleborough, MA, USA).

#### *2.2.4. Sensory Analysis*

Sensory analysis tests were performed in a laboratory with individual booths. The group of judges was composed of men and woman, aged between 18 and 65 years. The samples were provided randomly to judges in plastic plates and coded with three digits. Water was also provided to clean off taste buds after the evaluation of each sample.

Sensory acceptability was conducted to evaluate the attributes color, flavor and texture. It was applied to 86 untrained judges, composted of 64 woman and 22 men. It was used a 9 point hedonic scale whose ends refer to extremely dislike (1) and extremely liked (9). The samples were presented to the judges and they were asked to grade them according to the proposed scale.

#### *2.2.5. Statistical Analysis*

The measured properties of different bread formulations and frozen storage time were analyzed by STATISTICA software (version 9.0, Statsoft, Tulusa, UK), significant results were further analyzed using Tukey test ($p \leq 0.05$), ANOVA, correlation and regression analysis was performed.

## 3. Results & Discussion

Proximate analysis was conducted to examine the chemical composition and nutritional value of the breads and vegetable powders and the results are summarized in Table 1.

Inclusion of vegetable powders can improve the nutritional value of breads and promotes significantly differences in the samples. An increase in protein, fat, ash and reduced carbohydrate levels was observed when vegetables powders is added in 5 to 10%, due the levels of this components in the proximate composition.

Tomato powder presented 10.12% of protein; 7.18% of ash and 13.55% fat, the breads processed with this ingredient obtained an increase of protein levels of 21.11% (T1) and 24,65% (T2), for ash levels this increase it was 98,85% and 124.57%, compared with the control, therefore, this ingredient can act as a fortifying agent. The same behavior can be observed by adding broccoli and acai powder. B2 bread is 32% richer in protein and 105.14% in ash levels and A2 bread is 39.10% richer in protein and 153.71% richer in ash than the control formulation.

***Table 1.*** *Chemical composition of breads added of functional ingredients and vegetable powders.*

| Samples | Moisture (%) | Protein (%) | Fat (%) | Ash (%) | Carbohydrate (%) |
|---|---|---|---|---|---|
| Control | $32.38^{d}$±0.04 | $7.34^{e}$±0.05 | $2.05^{e}$±0.03 | $1.75^{e}$±0.04 | $58.23^{a}$±0.09 |
| T1 | $32.12^{e}$±0.08 | $8.89^{d}$±0.02 | $3.69^{d}$±0.02 | $3.48^{d}$±0.07 | $51.82^{c}$±0.04 |
| T2 | $33.15^{c}$±0.12 | $9.15^{c}$±0.03 | $4.08^{c}$±0.03 | $3.93^{b}$±0.05 | $49.69^{d}$±0.10 |
| B1 | $31.49^{b}$±0.07 | $8.51^{d}$±0.09 | $4.48^{c}$±0.06 | $3.04^{d}$±0.02 | $56.48^{b}$±0.05 |
| B2 | $32.21^{de}$±0.02 | $9.69^{b}$±0.03 | $6.82^{b}$±0.04 | $3.59^{c}$±0.03 | $47.59^{f}$±0.07 |
| A1 | $33.05^{c}$±0.09 | $9.03^{c}$±0.07 | $6.05^{bc}$±0.09 | $3.61^{bc}$±0.02 | $48.26^{e}$±0.08 |
| A2 | $32.84^{a}$±0.05 | $10.21^{a}$±0.04 | $9.93^{a}$±0.07 | $4.44^{a}$±0.03 | $42,58^{g}$±0.04 |
| Tomato Powder | $7.46^{b}$±0.05 | $10.12^{b}$±0.04 | $13.55^{b}$±0.08 | $7.18^{b}$±0.03 | $61.69^{c}$±0.05 |
| Brócolli Powder | $8.19^{a}$±0.08 | $8.29^{c}$±0.03 | $9.88^{c}$±0.03 | $6.87^{c}$±0.04 | $66.77^{b}$±0.04 |
| Açaí Powder | $4.66^{c}$±0.03 | $11.91^{a}$±0.08 | $28.15^{a}$±0.13 | $10.90^{a}$±0.08 | $44.38^{d}$±0.11 |

[1]Lowercase letters in the same column do not differ significantly by Tukey test ($p \leq 0.05$); ± = Standard deviation.

Figure 1 shows the relationship between alveoli number and frozen storage.

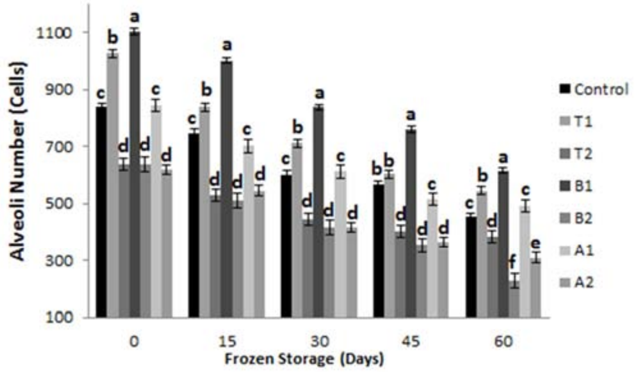



***Figure 1.*** *Alveoli number behavior in function of dough frozen storage.*

Alveoli number is an important quality parameter for the crumb structure. As can observed in Figure 1, the crumb structure of breads was significantly influenced ($p \leq 0.05$) by the addition of functional ingredients and the frozen storage time.

The inclusion of 5% broccoli improves the number of alveoli (1102) for bread produced from non-frozen dough, the addition of 10% this ingredient reduce this parameter to 636 alveoli, which reduces the quality of the bread crumb, compared to the control formulation, getting 838 alveoli. The tomato and açaí powder added at 5% promoted a crumb structure with more alveoli than the control formulation, 1025 and 845 respectively.

The number and circularity of the alveoli were influenced by the frozen storage in all the formulations. The control formulation showed a decrease of 46.06% over the 60 days of frozen storage, with significant differences between all periods studied. The addition of 5% tomato powder, promoted great differences in the number of alveoli reduction (46.92%) compared to the control, however, the addition of 10% this ingredient produced reduction of 39.96%. This result may be related to the fragility of the gluten network due to the addition of a greater amount of tomato powder, which is not a gluten-forming raw material, which led to lower formation of alveoli initially (638 cells).

Reduction caused by frozen storage during 60 days in the B1 formulation it was 44.19% and the bread added of 10% of broccoli powder obtained reduction of 64.15% showing that there was damage to crumb structure, by gluten weakening. Formulations added açaí powder showed a reduced number of alveoli during frozen storage of 41.89% and 49.83%, A1 and A2, respectively.

After 60 days of frozen storage the samples A1, T1 and B1 had higher numbers of alveoli to the control formulation, showing that incorporation of 5% of vegetable powder in bread formulations can improve the crumb structure of breads made from frozen dough.

The ANOVA showed significant interactions in storage time and type of bread for all variables and it was found high inverse correlation (r = - 0.83) for the number of alveoli and frozen storage.

Incorporation of vegetable powders, that according Table 1, they have considerable amounts of fiber and minerals may impair the gluten network formation, allowing the escape of carbon dioxide produced and reduces the amount of alveoli.

Degradation of quality in breads during the frozen storage has been described in terms of zero, first or higher order kinetics. Numerous research studies have applied zero-order (Eq. 1) or first-order (Eq. 2) models to describe the degradations of food product quality by [18]:

$$C = C_0 - kt \quad (1)$$

$$C = C_0 \exp(-kt) \quad (2)$$

Regression analysis to number of alveoli is presented in the Table 2.

***Table 2.*** *Regression analysis to alveoli number of bread crumb structure in function of frozen storage (t).*

| Sample | Equation | R² | Order Kinetics |
|---|---|---|---|
| Control | C = 831.4 – 6.360t | 0.9771 | 0 |
| T1 | C = 983.6 – 7.980t | 0.9631 | 0 |
| T2 | C = 607.3 – 4.260t | 0.9195 | 0 |
| B1 | C = 1106 – 8.106t | 0.9913 | 0 |
| B2 | C = 623.4 – 6.493t | 0.9888 | 0 |
| A1 | C = 811.4 – 5.940t | 0.9499 | 0 |
| A2 | C = 610.4 – 5.313t | 0.9499 | 0 |

B1 formulation presented most alveoli reduction rate as a function of time, followed by T1 formulation. All formulations showed a reduction in the number of alveoli as a reaction of zero order and with a high coefficient of determination ($R^2$), having a good fit of the experimental data for the proposed model.

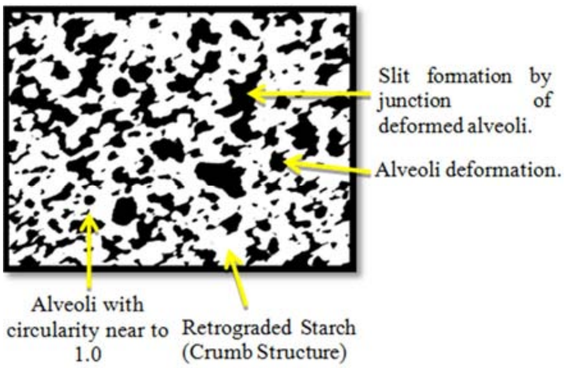


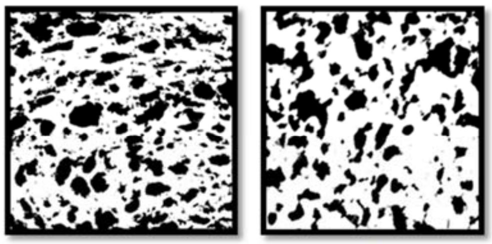

***Figure 2.*** *Crumb Structure of digital analysis of A2 bread after 60 days of frozen storage.*

[19] report that Starch-Protein interaction affects starch gelatinization and retrogradation, for this reason, the addition of 5% vegetable powders may cause the reduction of starch gelatinization, preserving the number of alveoli formed in the dough mixing. However, the addition of 10% of the ingredients may cause damage to the gluten network and reducing the number of alveoli and their circularity, as shown in Figure 2.

Several authors report limit amount of inclusion of fiber and minerals in bread, they promote an adverse effect on the gluten formation, reduces the quality of the bread due to the dilution effect of gluten or gluten-mineral and gluten-fiber interactions, thus, causing damage in the gluten network [20], [21] and [22].

This relationship may be explained through formation of the gas cells during bread fermentation process, it's the result of oxygen consumption by yeast incorporated into the dough during mixing and $CO_2$ production and diffusion in the dough through phase equilibrium between the liquid and gaseous phase. Then an elevation of system pressure occurs and elevating the bread volume and providing pressure to the gas cell, future alveoli that will be filled with carbon dioxide and expanded during the baking generating its formation [23] and [24].

The bread crumb porosity was significantly affected by the type of bread. The addition of 5% of vegetable powders promotes increased porosity of the bread crumb. As frozen storage time increased, the degree of crumb porosity decreased, as shown in Figure 3.



(a) (b)

***Figure 3.*** *Crumb Structure of digital analysis of control bread made from unfrozen dough (a) and frozen dough after 60 days.*

The advance of frozen storage time is found there deformation and reduction in the number of alveoli. The junction of these forming cracks is also observed. As can observed frozen storage drastically reduces and promotes deformation of alveoli, increase the density and damaging the crumb structure. According [25], dough is a complex system, of which its structure is based on the backbone of gluten newtwork and interacts with other components. This phenomenon could be also a result of the fiber weakening or crippling dough structure and reducing $CO_2$ retention [22].

The measured alveoli circularity of bread crumb made from frozen and unfrozen dough is reported in Figure 4.

Inclusion of vegetable powders and frozen dough storage influenced significantly ($p \leq 0.05$) the alveoli circularity. The ANOVA show interactions in storage time x alveoli circulatiry for all variables and presents high inverse correlation (r = - 0.94).

All formulations added of 5% vegetable powders obtained alveoli more circular than the control formulation after frozen storage time. B1 formulation have the greatest value of alveoli circularity during 30 days, posteriorly, later, there were no significant differences between T1 (0,728), B1 (0.774) and A1 (0.770).

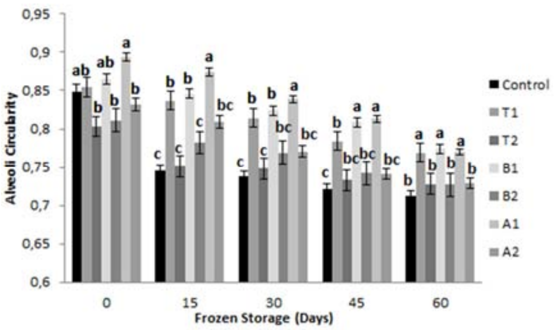



*Figure 4. Alveoli circularity behavior in function of dough frozen storage.*

Control formulation had the lowest value of circularity between 15th and 45th days, this result shows that the addition of vegetable powders preserves the structure and circularity during the storage period, improving the structural quality of the crumb. The interaction between starch and vegetable powder protein can promoted this phenomenon.

[26] stated that the interaction between protein and starch is mainly electrostatic in nature, between the anionic groups of the starch and the positively charged groups of the protein.

During the dough thawing process can there is a competition for water in the weight distributed in dough between the starch and the protein, causing water re-distribution between the two polymers, as alert [27], which delayed the progress of starch gelatinization [28] and provides the maintenance of the alveoli which have been produced during the dough mixing.

ANOVA showed significant influence of frozen storage and the bread hardness (Figure 5), the addition of 10% broccoli powder caused a significant difference when compared to bread added 5% broccoli powder, the only significant difference for addition of ingredients to the hardness.

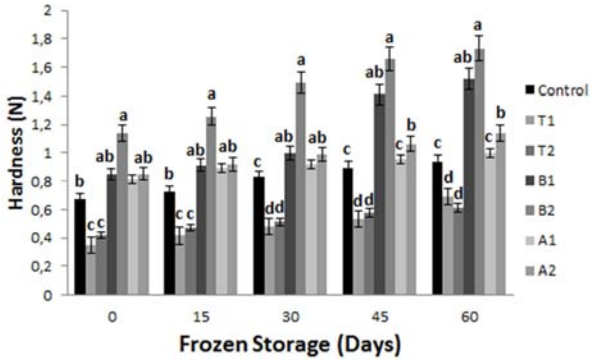



*Figure 5. Crumb bread hardness during frozen storage dough.*

B1 formulation had the highest hardness during 60 days of frozen storage, deferring statistically from the others samples. Formulations B1, A1 and A2 don't present significant difference until to 30th days of frozen storage. The inclusion of tomato powder in 5% or 10% does not affect the hardness of the breads; however, they have the lowest values during the study period.

Increase of bread hardness along the storage time was observed by [29] and [22] that found hardness value between 0.643-0.959 N, to increase as the addition of pea fiber and bean were added, a greater hardness value is associated to low-quality bread.

ANOVA showted that the addition of functional ingredients in 5% or 10% proportions promoted a significant decrease ($p \leq 0{,}05$) of the acceptance values for the sensory attributes of color, flavor and texture, the results are summarized in the Table 3.

*Table 3. Sensory attributes of bread during 60 days of frozen storage.*

| Color | 0 | 15 | 30 | 45 | 60 |
|---|---|---|---|---|---|
| Control | $7.89^{Aa}$±0.23 | $7.60^{a}$±0.25 | $7.29^{ab}$±0.31 | $7.12^{ab}$±0.20 | $6.55^{b}$±0.25 |
| T1 | $7.31^{ABa}$±0.26 | $7.16^{a}$±0.14 | $6.91^{b}$±0.24 | $6.85^{b}$±0.28 | $6.81^{b}$±0.22 |
| T2 | $6.85^{Ba}$±0.18 | $6.70^{ab}$±0.31 | $6.55^{b}$±0.18 | $6.43^{b}$±0.16 | $5.70^{c}$±0.24 |
| B1 | $7.37^{ABa}$±0.22 | $7.14^{ab}$±0,24 | $6.97^{ab}$±0.18 | $6.52^{b}$±0.19 | $6.50^{b}$±0.25 |
| B2 | $7.54^{ABa}$±0.29 | $6.50^{ab}$±0.27 | $6.25^{bc}$±0.21 | $6.12^{bc}$±0.23 | $5.31^{b}$±0.31 |
| A1 | $6.33^{Ca}$±0.26 | $6.29^{a}$±0.25 | $6.25^{a}$±0.22 | $5.70^{a}$±0.18 | $4.56^{b}$±0.29 |
| A2 | $6.08^{Ca}$±0.28 | $5.19^{ab}$±0.27 | $4.66^{bc}$±0.30 | $4.17^{bc}$±0.21 | $3.64^{c}$±0.28 |
| Flavor | 0 | 15 | 30 | 45 | 60 |
| Control | $7.43^{Aa}$±0.17 | $7.04^{a}$±0.21 | $7.02^{a}$±0.19 | $6.54^{b}$±0.25 | $6.37^{b}$±0.26 |
| T1 | $7.08^{ABa}$±0.22 | $6.89^{a}$±0.23 | $6.54^{b}$±0.29 | $6.31^{b}$±0.29 | $5.77^{c}$±0.16 |
| T2 | $7.14^{ABa}$±0.26 | $7.10^{a}$±0.23 | $6.35^{ab}$±0.17 | $6.12^{ab}$±0.35 | $5.77^{b}$±0.21 |
| B1 | $7.70^{Aa}$±0.16 | $7.14^{ab}$±0.28 | $7.08^{ab}$±0.24 | $6.85^{ab}$±0.27 | $6.58^{b}$±0.23 |
| B2 | $7.54^{Aa}$±0.21 | $7.10^{ab}$±0.29 | $6.62^{abc}$±0.23 | $6.14^{bc}$±0.24 | $5.66^{c}$±0.36 |
| A1 | $7.12^{ABa}$±0.22 | $6.97^{a}$±0.23 | $6.70^{ab}$±0.30 | $6.22^{b}$±0.29 | $5.87^{c}$±0.24 |
| A2 | $6.56^{Ba}$±0.26 | $6.55^{a}$±0.21 | $6.43^{a}$±0.28 | $6.14^{b}$±0.31 | $5.45^{c}$±0.19 |
| Texture | 0 | 15 | 30 | 45 | 60 |
| Control | $7.38^{Aa}$±0.19 | $7.33^{a}$±0.21 | $7.31^{a}$±0.12 | $6.58^{b}$±0.27 | $6.25^{c}$±0.18 |
| T1 | $7.20^{Aa}$±0.20 | $7.00^{a}$±0.27 | $6.91^{ab}$±0.15 | $6.68^{b}$±0.25 | $5.97^{c}$±0.10 |
| T2 | $7.27^{Aa}$±0.23 | $7.18^{a}$±0.18 | $6.83^{a}$±0.28 | $6.68^{a}$±0.25 | $6.47^{a}$±0.27 |
| B1 | $7.25^{Aa}$±0.22 | $6.81^{ab}$±0.33 | $6.64^{ab}$±0.26 | $6.12^{b}$±0.23 | $5.87^{b}$±0.30 |
| B2 | $7.08^{Aa}$±0.28 | $6.58^{b}$±0.30 | $6.12^{b}$±0.30 | $6.04^{b}$±0.20 | $5.75^{b}$±0.33 |
| A1 | $7.25^{Aa}$±0.24 | $6.64^{ab}$±0.26 | $6.45^{ab}$±0.19 | $6.22^{ab}$±0.31 | $5.75^{b}$±0.25 |
| A2 | $5.97^{Ba}$±0.28 | $5.95^{a}$±0.33 | $5.87^{a}$±0.28 | $5.68^{a}$±0.21 | $5.50^{a}$±0.31 |

Means±standard deviation. Different letter superscripts in the same row indicate significant difference ($p<0.05$).

This phenomenon was observed for the T1 and T2 samples (7.31 and 6.85) in the color attribute, A1 and A2 in the flavor and texture attributes.

Frozen storage time significantly reduced the average hedonic attributes, however, T1 formulation in the color attribute decreased only 4.48%, presenting no significant influence of storage time on this parameter. Most rejection of color was presented by the samples added açaí powder (4.56 and 3.64) respectively. A2 formulation had the biggest reduction (40.13%) in color acceptance when compared to bread produced by non-frozen dough.

[30] reported modification of the colorimetric parameters of bread made from frozen dough, an increase of lightness (L*) and modification of the a* and b* parameters, this result suggests that the bread produced from frozen dough promotes degradation of pigments derived from vegetable powders, which may have contributed to reducing the color acceptability.

Control and B1 formulations were the only ones present hedonic values within the acceptance zone after 60 days of dough frozen storages getting 6.37 and 6.58, respectively. The Tukey test identifies significant differences between the storage times for all samples. The degradation of flavor and aroma components by freezing and frozen storage may have been the main reason for this result.

[31] also reported significant reduction in the bread flavor stored in frozen conditions for up to 21 days. According [32] a volatile compound's profile of bread depends on many factors such as the recipe, the type of fermentation, the baking stage and storage also affects the flavor.

The effect of bread type and frozen storage time variables on bread textural acceptability property was significant ($p \leq 0.05$).

Table 4 was prepared to study the correlation between crumb structure, textural and sensorial properties of the breads made from frozen dough.

***Table 4.*** *Correlation coefficients between variables of bread.*

| Variables | Number of Alveoli | Alveoli Circularity | Hardnesss | Color | Flavor | Frozen Storage | Samples |
|---|---|---|---|---|---|---|---|
| Number of Alveoli | - | - | - | - | - | -0.65* | -0.29 |
| Alveoli Circularity | 0.78* | - | - | - | - | -0.69* | 0.18 |
| Hardness | -0.43* | -0.24 | - | - | - | 0.77* | 0.51* |
| Color | 0.66* | 0.35* | -0.39* | - | - | -0.51* | -0.70* |
| Flavor | 0.77* | 0.62* | -0.24 | 0.72* | - | -0.84* | -0.20 |
| Texture | 0.64* | 0.39* | -0.59* | 0.80* | 0.76* | -0.69* | -0.57* |

*Indicate significant correlation ($p<0.05$).

Table 4 was prepared to study the correlation between crumb structure, textural and sensorial properties of the breads made from frozen doughs.

As indicated in Table 4, there was a significant ($p \leq 0.05$) negative correlation ($r = -0.65$ and $-0.69$) between frozen storage with number and circularity of alveoli and hardness ($r = -0.77$). This can be explained by the ice crystal formation during freezing dough can puncture the dough gluten-structure and compromise their ability to retain gases and reduce the crumb structure quality [33]. As a result, the bread becomes firmer (increased hardness) and the porosity of crumb decreases [34].

With the inclusion of vegetable powder there was a significant and negative correlations with the sensory properties color and texture, which was expected, as the pigments present in these ingredients have changed the color of bread and including the fact that non gluten-forming powders increases the hardness ($r = 0{,}51$) of the breads, in accordance with results obtained by Salinas et al., (2015), and breads with increased hardness reduce sensory acceptability for texture attribute ($r = -0.59$).

# 4. Conclusions

The inclusion of vegetable powders improves the nutritional quality of bread, by increasing protein and ash content and reduces the level of carbohydrates. Frozen storage reduces the physical and sensory quality of breads. The inclusion of 5% vegetable powders in bread formulations can promoted increase number and circularity of alveoli, improving crumb structure during frozen storage. A addition of 10% vegetable powder reduce the crumb structure quality and promotes higher hardness of breads and does not preserve the quality of the product when compared to control formulation during frozen storage. The results indicated that using tomato and broccoli powders can improve the sensory attributes and reduces the percentage of loss quality along the frozen storage.

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