EFFECTS OF BY-PRODUCTS OF PEACH PALM AND GRAPE ON NUTRITIONAL, PHYSICO-CHEMICAL AND SENSORY PROPERTIES OF EXTRUDED BREAKFAST CEREALS

EFEITO DOS SUBPRODUTOS DE PALMITO PUPUNHA E UVA NAS PROPRIEDADES NUTRICIONAIS, FÍSICO-QUÍMICAS E SENSORIAIS DE CEREAIS MATINAIS EXTRUSADOS

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ABSTRACT: Extruded breakfast cereals they have low nutritional and high energetic values. The aim of this study was to develop extruded breakfast cereals by replacing part of corn meal by different proportions of by-products of grape (5-10%) and peach palm (7.5-15%). Samples were sweetened with xylitol while moisture was controlled with grape juice. Six formulations, which were produced in a 2^2 experimental design, were analyzed regarding their composition, besides their technological, mechanical, antioxidant and sensory properties. Addition of different amounts of flours, produced with the wastes of grape (GF) and peach palm (PF), increased the dietary fibers and antioxidant contents of cereals formulations. However, at the highest levels addition, there was a decrease in expansion and an increase in hardness and water solubility properties. Thus, the incorporation of grape and peach palm by-products at smaller proportions showed higher viability, since they exhibited satisfactory sensory acceptance, technological properties and bowl life.

KEYWORDS: **A**ntioxidants. *Bactis gasipaes.* Crispness. Dietary fibers. Energetic value. Sensory acceptance. *Vitis labrusca.*

INTRODUCTION

Changes in the population's eating habits have increased the demand for healthy foods that also reflect practices of consumption with adequate sensory acceptance. Formulations of various products have been adapted to meet this niche in the market. Commercial ready-to-eat breakfast cereals are practical foods based on starch and sugars; thus, they are considered to have low nutritional value (OLIVEIRA et al., 2017). Agroindustrial by-products may be used as alternatives in the development of nutritionally enriched and less caloric formulations, since they are rich in dietary fibers and bioactive compounds, such as antioxidants, with low impact on production costs (ELLEUCH et al., 2011). By-products of the wine industry, such as husks and seeds, account for 20% of the total volume of processed raw material (KARNOPP et al., 2017). Likewise, since only the core of peach palm stems has adequate texture to produce heart-of-palm, it generates 85% of waste (BOLANHO et al., 2014).

Replacing starch, the main component of extruded breakfast cereals, with high-fibers ingredients is a challenge to food industries, because the behavior of starch during the extrusion process determines their desired texture. As a consequence, nutritional composition and sensory acceptance depend on proportions of ingredients and extrusion conditions. Another factor that has to be considered in the development of extruded foods is crispness loss, since they are consumed after having been immersed in milk (TAKEUCHI et al., 2005). Therefore, it is important to investigate technological properties of breakfast cereals, when different proportions of components are used in their formulation, to guarantee adequate sensory acceptance (RIAZ, 2000).

The aim of this study was to evaluate the effect of partial replacement of corn meal with flours of peach palm and grape by-products on nutritional, technological, mechanical and sensory properties of breakfast cereals, by using a statistical approach.

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MATERIAL AND METHODS

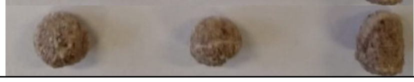
Corn meal (Caldo Bom®, Campo Largo, Brazil), xylitol (Clube Greens®, São Paulo, Brazil) and grape juice (Aurora®, Bento Gonçalves, Brazil) were bought in a local market.

The by-product of canned peach palm (*Bactis gasipaes)*, whose name in Brazilian Portuguese is *palmito pupunha*, was donated by the Marbbel Industry (Antonina, Brazil). Its stem, located below the edible portion, was separated, washed, cut and dried in an oven with forced air circulation (Marconi, Piracicaba, Brasil) at 60º C, up to 10±2 g.100g^{-1} of moisture. Waste - peels - of Bordeaux grape juice (*Vitis labrusca*) was donated by Econatura (Garibaldi, Brazil) as a dehydrated product. These by-products were milled (A-11 Basic, IKA, Campinas, Brazil) and sieved so as to have their granulometry standardized (0.65 mm).

Reagents used in the analysis of characterization had proven purity and the enzymes were donated by Prozyn® (São Paulo, Brazil).

Formulations of breakfast cereals were produced with the use of a 2^2 factorial planning, as shown in Table 1, which also includes the extruded products. Corn meal was added to complete 100% of each formulation while moisture contents were adjusted with grape juice up to 18 g.100g^{-1}. Mixtures were submitted to extrusion (Exteec Extruder, Ribeirão Preto, Brazil) by single-screw mechanical friction at 120 ºC, with two rotation knives (60 Hz) and a circular matrix, with feed rate of 0.2 kg.min^{-1}. After extrusion, cereal formulations were dried at 60 °C in an air convection oven until moisture reached 4±1 g.100g^{-1}, controlled by an infrared scale (Sartorius, Gottingen, Germany). Subsequently, 6.5 mL saturated aqueous xylitol solution (68 g.L^{-1}) was sprayed per 90.25 cm² of product. This volume was fractionated into three applications which were carried out every 10 min. At time intervals, formulations were dried at 80 ºC in an oven with air circulation and kept under these conditions for 1 h at the end of the application (OLIVEIRA et al., 2018). These procedures were defined after preliminary testing. Samples were stored in airtight packaging at 4 ºC for subsequent analysis.

Table 1. 2^2 factorial designs in breakfast cereal formulations: coded and decoded values (%) and appearance of cereals after the extrusion process

Formulations	GF (%)	PF (%)	Appearance
1	-1 (0)	+1 (15)	
2	+1 (10)	-1 (0)	
3	-1 (0)	-1 (0)	
4	+1 (10)	+1 (15)	
5	0 (5)	0 (7.5)	
6	0 (5)	0 (7.5)	

GF = grape by-product flour, PF = peach palm by-product flour

Flours of by-products and breakfast cereals formulations were analyzed in agreement with the AOAC's recommendations (HORWIZ; LATIMER 2005) concerning moisture (method 925.09), ashes (method 923.03), proteins (method 920.87), lipids (method 920.85) and soluble, insoluble and total dietary fiber (method 991.43). Total carbohydrates were determined by difference. Energetic values of breakfast cereal formulations were determined by the Atwater conversion factors: 4 kcal.g^{-1} for carbohydrates and proteins, 9 kcal.g^{-1} for lipids and 2 kcal.g^{-1} for dietary fibers. These analyses were performed in triplicate.

To determine the antioxidant potential of cereals formulations, 1 g of each sample was mixed with ethanolic solution 80:20 (v/v) for 4 h at 120 rpm in a shaker (Marconi, Piracicaba, Brazil). Extracts were separated by filtration and analyzed in triplicate. Determination of antioxidant activity against the DPPH• free radical (1,1-Diphenyl-2-picrylhydrazyl, Sigma-Aldrich) was based on Brand-William et al. (1995). Results were expressed as mmol of Trolox equivalent ((±)-6-

Hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid) per 100 g sample (mmol TE $100g^{-1}$). The total phenolic compounds test was performed as proposed by Singleton et al. (1999), being the results expressed as mg of gallic acid equivalent per 100 g sample (mg GAE $100g^{-1}$).

Instrumental color - parameters a*, b* and L* - was evaluated by a Hunterlab® colorimeter (Miniscan EZ, Reston, EUA), with 10 repetitions for each formulation.

Bulk density ($g.cm^3$) was determined by the displacement of millet seed mass and results were expressed as the ratio of mass to volume (OLIVEIRA, 2018). The expansion index (EI) was carried out as proposed by Alvarez-Martinez et al. (1988); diameters (mm) of the matrix and the extruded product were measured by a digital caliper (INSIZE 1137-150). Ratio of diameters was multiplied by 100 and results were expressed as percentage. Both analyses were conducted in 15 repetitions.

Water solubility (WSI) index was determined by mixing 2.5 g sample and 30 mL water; it was submitted to orbital agitation (Marconi, Piracicaba, Brazil) at 100 rpm for 30 min at 25 °C. After centrifugation at 2.10^3 *x* g for 10 min (Celm Combate, Barueri, Brazil), the supernatant was dried and weighted. Results were expressed as g of soluble solids in water per 100 g sample ($g.100g^{-1}$). To determine the water absorption index (WAI), the weight of each centrifugation residue was measured. Results were expressed as g of water or milk absorbed per g of sample ($g.g^{-1}$) (SEIBEL, BELÉIA 2009, LEORO et al., 2010). These analyses were done in triplicate.

Mechanical properties (hardness and crispness) were performed in the formulations before and after immersion in cold milk (from 10 to 15 ºC) for 30 s, 60 s, 120 s and 180 s. Five samples were randomly collected for each formulation. A texturometer (TA XT Plus Texture Analyzer, Stable Micro Systems, Godalming, UK) and an HDP-BS probe were used under the fixed conditions: distance from the probe to the base was 45 mm; test speed was 2 $mm.s^{-1}$; and post-test speed was 10 $mm.s^{-1}$. The equipment was adjusted to measure compression force and results of hardness (N) and crispness (number of peaks) were based on the collected data (OLIVEIRA et al., 2017, SACCHETTI et al., 2003).

Sensory analysis was performed in white light booths by a panel of untrained testers (n=59) in compliance with ethics requirements Ethics Committee - COPEP: CAAE: 66525917.8.0000.0104. The group was composed of individuals of both sexes, between 17 and 52 years old. Samples were coded by 3-digit random numerals and introduced, one by one, in white cups containing 2 g sample and, separately, a cup with milk was also served. Testers tasted the milk-immersed samples and graded them according to the structured hedonic scale, which ranges from 1 (extremely disliked) to 9 (extremely liked) for the following attributes: appearance, color, odor, texture, taste and overall acceptance (ISO, 2014). The acceptability index was calculated by the ratio between the global acceptance average and the highest grade, multiplied by 100 (DAMASCENO et al., 2016).

Collected data were expressed as mean followed by standard deviation. The normality test was performed on data with 6 or more replicates ($n \geq 6$); data normality in replicates was assumed when $n<6$, where n is the number of replicates. The Shapiro-Wilk ($p \geq 0.05$) ($n<30$) and the Levene's ($p \geq 0.05$) tests were applied to test normality and homogeneity of variances (homoscedasticity), respectively. Significant mean differences were determined by the one-way analysis of variance (one-way ANOVA). Data sets with normal distribution ($p \geq 0.05$) and homoscedastic ($p \geq 0.05$) were compared by the Fisher mean comparison test ($p \leq 0.05$). The Welch and the Kruskal-Wallis tests (both $p \leq 0.05$) were applied to data normally distributed with unequal variance (heteroscedastic) and samples without normal distribution, respectively (GRANATO et al., 2014). Evaluation of quantitative effects of independent variables (grape flour and peach palm flour) on responses was performed by multiple linear regressions, based on the response surface methodology (RSM). Two-dimensional contour plots were generated for each response variable from significant regression coefficients. The Statistica software v. 13.3 (StatSoft, USA), licenciated by the Pos Graduate Program in Food Science and Technology of State University of Ponta Grossa, was used for all statistical analyses.

RESULTS AND DISCUSSION

Flours of grape (GF) and peach palm (PF) by-products exhibited dietary fibers as their main component (>50 g.100 g^{-1}), besides considerable contents of proteins (~10 g.100 g^{-1}) and ashes (4 -7 g.100 g^{-1}) (Table 2). Thus, it can be inferred that these by-products have potential to promote nutritional enrichment of food products (KARNOPP et al. 2017, BOLANHO et al. 2015).

Table 2. Proximal compositions of flours of grape and peach palm by-products used in breakfast cereal formulations

Flours	Moisture[a]	Ashes[a]	Proteins[a]	Lipids[a]	TDF[ab]
GF[c]	2.39±0.57	3.85±0.08	9.83±1.36	8.54±0.30	54.81±0.77
PF[d]	1.18±0.13	7.08±0.10	10.32±0.10	1.97±0.08	51.01±1.13

[a](g.100 g^{-1}); [b]TDF = total dietary fiber; [c]GF = Grape by-product flour; [d]PF = peach palm by-product flour

Regarding results of the analysis of extruded breakfast cereals, they were found to vary considerably, a fact that may be due to the complexity of the extrusion process and limited conditions of control of the equipment.

Table 3 shows proximal compositions of formulations. Moisture contents ranged from 4.00 to 5.63 g.100 g^{-1}; these values provide stability against possible changes caused by microorganisms and chemical reactions during shelf life. Resulting values are in accordance with current legislation (BRASIL, 2019) that establishes maximum value of 15 g.100g^{-1} of moisture in this kind of product. The higher the contents of PF and GF added to the formulations, the higher the ash content; it shows that the by-products led to increase in minerals in the formulated cereals. The values of lipids content ranged from 0.34 to 1.16 g. 100 g^{-1} and GF was mainly responsible for increase in the fat content of the products. On the other hand, the highest protein content was found when the highest level of PF was added (formulations 1- GF = 0%, PF = 15% and 4 - GF = 10%, PF = 15%). GF addition also contributed to increase the content of this nutrient by comparison with formulation 3, without the addition of any flour.

Addition of the by-products under study increased the total dietary fiber content (TDF) of breakfast cereals, i. e., from 368 to 746%, by comparison with formulation 3 (without any addition of by-products). According to the Food and Drug Administration (FDA, 2019), a product can be considered a "fiber source" when it has at least 3 g fiber in 30 g food. Therefore, formulation 4 (GF = 10, PF = 15) can be classified as a fiber source, with 3.67 g fiber per portion. According to the American Diabetes Association (2019), for good health maintenance, recommended daily fiber intake ranges from 25 to 30 g. However, most people do not reach this goal. Therefore, the development of food formulations containing high fiber content is important. Addition of GF and PF led to increase in both soluble (SDF) and insoluble (IDF) dietary fibers contents. GF showed a tendency to contribute more significantly to increase in SDF. The highest IDF content was found in formulation 4, which contained the highest levels of GF (10%) and PF (15%). Adequate balance in the consumption of soluble and insoluble fibers is important due to the different properties of each fraction. The soluble fiber fraction, composed of pectin, gum and some hemicelluloses, is related to decrease in cholesterol and postprandial glucose. Insoluble fiber is associated with intestinal transit regulation, since it includes cellulose, lignin and most hemicelluloses (DANG, VASANTHAN, 2019).

Energetic values of formulations ranged from 355 to 406 kcal 100 g^{-1} (data not shown). Each 30 g portion exhibited values from 106 (formulation 4) to 122 kcal (formulation 3). Thus, consumption of the portion with the lowest energy leads to a caloric decrease in 12.6%, by comparison with the formulation without any addition of by-products.

Partial replacement of corn meal with GF and PF reflected positively in the total phenolic content (TPC) and the antioxidant capacity (DPPH) of cereals formulations (Table 3); values ranged from 43.15 to 139.58 mg GAE.100g^{-1} and from 3.89 to 15.25 mmol TE.100g^{-1}, respectively. The highest values of TPC and antioxidant activity (AA) were obtained when the highest contents of GF and PF were used (formulation 4), followed by formulation 2, which contained only GF. When these formulations were compared to formulation 3 (without any by-product addition), there was an increase in TPC and AA over 300%. Danesi et al., (2018) and Kuck; Noreña (2016) reported high TPC values in by-products of peach palm (130 mg GAE.100g^{-1}) and grape juice (2626 mg GAE.100g^{-1}), respectively, and showed the importance of using this waste in food formulations.

The effect of independent variables, GF and PF, on TPC and AA of formulations can be observed in Figure 1, which shows a positive effect ($p \leq 0.20$). The highest values of these parameters coincide with the highest level of corn meal replacement with PF and GF, indicating that, even after the extrusion process, antioxidant compounds of by-products were maintained in the final products. In the production of breakfast cereals enriched with apple waste, Leyva-Corral et al., (2016) observed increase in antioxidant activity; the extrusion process did not affect these compounds, a fact that corroborates findings of this study. Quiles et al. (2018) also reported that inclusion of by-products in extruded products contributes to improve their nutritional value by increasing contents of dietary fiber and antioxidant compounds. The antioxidants play a fundamental role in oxidation reactions by neutralizing reactive oxygen species and chelating pro-oxidant transition metals.

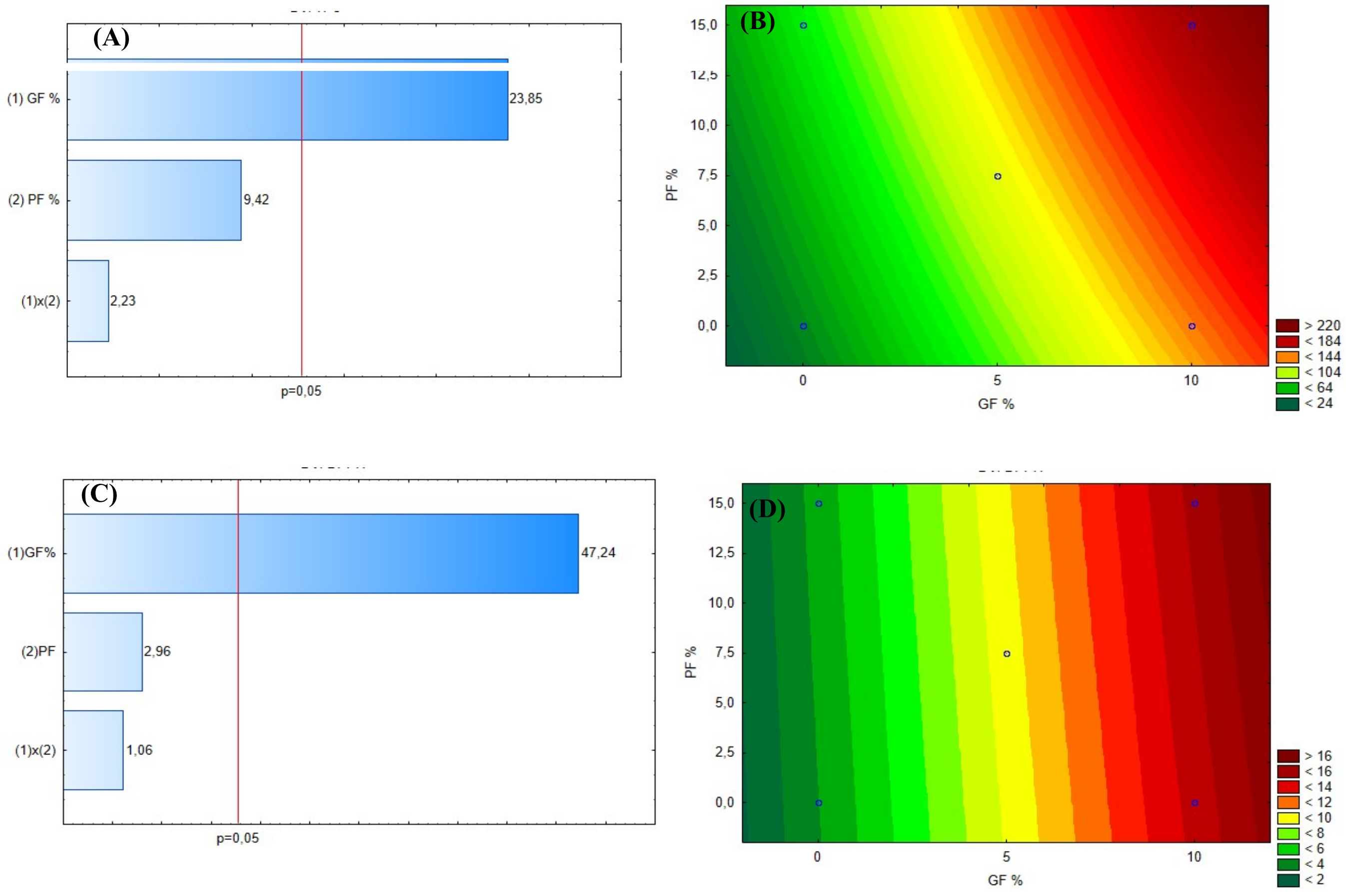


Figure 1. Effect of grape by-product flour (GF) and peach palm by-product flour (PF) in the content of total phenolic compounds and in the antioxidant activity: A) Pareto diagram for total phenolic compounds. B) Contour surface for the dependent variable total phenolic compounds. C) Pareto diagram for antioxidant activity e D) Contour surface for the dependent variable total phenolic compounds (DPPH)

Table 3. Proximal compositions and antioxidant potential of breakfast cereal formulations produced with different amounts of corn meal and flours of grape and peach palm by-products

Formulations*	Proximal composition (g.100g^{-1})								DPPH (mmol TE.100g^{-1})	TPC (mg GAE.100g^{-1})
	Moisture	Ashes	Proteins	Lipids	TDF	SDF	IDF	CHO		
1	4.32^{c}±0.01	1.45^{b}±0.01	6.44^{a}±0.27	0.65^{c}±0.09	6.97^{b}±0.59	0.49^{b}±0.04	6.48^{b}±0.55	80.17^{c}±0.94	4.32^{d}±0.17	75.23^{e} ±2.03
2	4.06^{d}±0.18	1.13^{e}±0.04	6.11^{b}±0.02	0.82^{b}±0.06	6.04^{b}±0.24	2.93^{a}±0.71	5.29^{c}±0.37	82.01^{b}±0.25	14.34^{b}±0.45	139.58^{b}±0.62
3	4.23^{c}±0.08	0.58^{f}±0.03	5.00^{c}±0.01	0.34^{e}±0.00	1.64^{c}±0.48	0.09^{c}±0.00	1.55^{d}±0.48	88.20^{a}±0.50	3.89^{e}±0.07	43.15^{f}±4.34
4	5.63^{a}±0.07	2.01^{a}±0.03	6.60^{a}±0.02	1.16^{a}±0.03	12.23^{a}±0.62	1.12^{b}±0.22	11.11^{a}±0.40	72.37^{e}±0.67	15.25^{a}±0.11	191.59^{a}±6.34
5	4.51^{b}±0.02	1.36^{c}±0.01	6.14^{b}±0.00	0.51^{d}±0.02	7.09^{b}±0.07	0.91^{b}±0.20	6.19^{b}±0.27	80.38^{c}±0.03	9.80^{c}±0.10	119.21^{d}±1.77
6	4.00^{d}±0.02	1.23^{d}±0.03	6.22^{b}±0.11	0.65^{c}±0.02	7.29^{b}±1.21	0.75^{b}±0.13	6.54^{b}±0.50	73.27^{d}±1.27	9.48^{c}±0.23	125.52^{c}±2.30
p-value **	0.037	0.091	0.048	0.192	0.260	0.038	0.948	0.226	0.14	0.07
p-value ***	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

TDF = total dietary fiber; SDF = soluble dietary fiber; IDF = insoluble dietary fiber; CHO = total carbohydrates; DPPH = antioxidant activity by DPPH test; TPC = Total phenolic compounds; *According Table 1. **p-value (homoscedasticity); ***p-value (ANOVA/Welch). Different letters in the same column indicate a statistically significant difference at the 5% level by Fisher Test.

The color of extruded products is the result of non-enzymatic reactions and of pigment degradation caused by processing conditions. Values of this parameter are shown in Table 4 and the color of formulations can also be observed in Table 1. Breakfast cereals containing GF (formulations 2, 4, 5 and 6) were darker (lower luminosity - L*) and tended more to blue (lower chromaticity b*) than the other formulations, a fact that is related to anthocyanin pigments found in this residue. On the other hand, the formulation without any addition of by-products had the highest values of L* and b*, due to the high percentage of corn flour, a carotenoid-containing raw material, which makes the product become yellow (7).

Technological parameters (Table 4) showed that the water absorption index (WAI) ranged from 3.81 to 5.56 $g.g^{-1}$. These values are compatible with those found by Carvalho et al. (2009), i. e., from 5.01 to 6.48 $g.g^{-1}$, in fried extruded products obtained from the mixture of cassava and peach palm flours. Addition of the by-products under study - GF and PF - at high proportions reduced the amount of starch of the formulations introduced in the extruder and decreased WAI values, since this parameter is associated with the amount of water absorbed by the starch (MERCIER et al., 1998). This result is interesting because the amount of water absorbed by the breakfast cereal is associated with the time it remains crisp and gain in moisture depends on the absorption capacity of each cereal and the critical time related to texture change, from a crunchy to a softened product (TAKEUCHI et al., 2005).

Regarding results of the water solubility index (WSI), the highest values were found in formulations 2 (10% GF, 0% PF) and 3 (100% corn meal); they show that these flours had high content of soluble compounds and low molecular weight ones. ISA is related to the number of soluble molecules and the degree of compound degradation during the extrusion process (QUILES et al. 2018).

In relation to the milk solubility (MSI) and milk absorption (MAI) indexes, their values were found to be higher than those obtained in water (WAS and WAI). Similar effect was verified by Leoro et al., (2010) in breakfast cereals with passion fruit waste. The lowest value of MAI was obtained in the formulation with the highest content of by-products (formulation 4 -10%GF and 15%PF). These results were favorable to bowl life of breakfast cereals that are commonly consumed with milk.

Extruded products are aerated and have pores formed by the expansion of their component matrices (RIAZ, 2000). The combined use of GF and PF was found to significantly reduce the expansion index (EI) and increase bulk density (BD). It can be explained by the rupture of extruded bubble walls, due to the presence of fibers, which interfere in gas retention and in the expansion. Intermediate results of EI and BD were found in formulations 1 and 2, which contained only one of the by-products (either PF or GF).

Regarding mechanical properties of breakfasts cereals (Table 5), formulations showed significant difference in the crispness parameter, whose minimum value was observed in formulation 4 (10% GF and 15% PF); this result may be due to its high fibers contents (12.23 ± 0.62 $g.100g^{-1}$). Differences among formulations were maintained along immersion time and reduction in crispness was observed, except in formulation 4, which showed increase in the number of peaks until 180 s. Mechanical properties are related to sensory quality, hardness and crispness and associated with morning cereal expansion characteristics (DING et al., 2005). Since it is a product consumed with milk, soaking time is important to determine product quality.

Evaluation of maximum compressive strength (hardness) of breakfast cereals before milk soaking showed that formulations 1 (15% PF), 2 (10% GF) and 3 (100% corn meal) exhibited lower hardness values than the other samples. This result is positive, because these samples had their dietary fibers contents increased, a fact that enhances application of grape and peach palm by-products to breakfast cereals. In general, hardness was reduced over immersion time in samples under analysis; the highest change in values - from before to after milk immersion – was observed when the highest amounts of flour were used (formulation 4 - 10% GF and 15% PF); this formulation also exhibited the highest value of hardness as a dry product.

Table 4. Color and technological parameters of breakfast cereal formulations produced with different amounts of corn meal and flours of grape and peach palm by-products.

Formulations+	L*	a*	b*	WAI ($g.g^{-1}$)	WSI ($g.100g^{-1}$)	MAI ($g.g^{-1}$)	MSI ($g.100g^{-1}$)	BD ($g.L^{-1}$)
1	60.49 ^{b}±1.05	4.35 ^{b}±0.24	26.16 ^{b}±1.40	5.16 ^{b}±0.05	21.85 ^{c}±0.09	6.51 ^{b}±0.12	57.39 ^{bc}±5.07	343 ^{d}±18
2	32.56 ^{d}±0.56	4.68 ^{a}±0.17	2.18 ^{e}±0.25	3.81 ^{d}±0.11	32.16 ^{a}±2.37	6.24 ^{b}±0.61	67.15 ^{a}±9.17	342 ^{d}±34
3	62.73 ^{a}±1.25	2.35 ^{e}±0.18	27.29 ^{a}±1.02	5.74 ^{a}±0.54	32.40 ^{a}±0.49	6.47 ^{b}±0.54	47.92 ^{d}±5.74	184 ^{e}±9
4	32.14 ^{d}±0.78	3.23 ^{d}±0.17	2.23 ^{e}±0.41	3.67 ^{d}±0.00	26.26 ^{b}±1.10	4.75 ^{c}±0.05	58.93 ^{ab}±0.77	593 ^{a}±23
5	37.57 ^{c}±0.67	3.38 ^{cd}±0.17	5.29 ^{c}±0.40	4.35 ^{c}±0.05	21.69 ^{c}±0.37	13.45 ^{a}±0.05	48.00 ^{d}±2.03	448 ^{b}±20
6	37.59 ^{c}±0.99	3.48 ^{c}±0.17	4.52 ^{d}±0.25	5.56 ^{a}±0.02	20.38 ^{c}±0.17	13.36 ^{a}±0.06	49.03 ^{cd}±0.88	428 ^{c}±25
p-value**	0.109	0.500	≤0.001	0.043	0.093	0.100	0.191	0.300
p-value***	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	0.002	≤0.001

WAI = water absorption index; WSI = water solubility index; MAI = milk absorption index; MSI – milk solubility índex; EI = expansion index; BD = bulk density;
+According Table 1. **p-value (homoscedasticity);***p-value (ANOVA/Welch). Different letters in the same column indicate a statistically significant difference at the 5% level by Fisher Test.

Table 5. Mechanical properties of breakfast cereal formulations produced with different amounts of corn meal and flours of grape and peach palm by-products: dry products and milk-immersed ones at 30s, 60s, 120s and 180s.

Formulations+	Crispness (peacks numbers)							Maximum compressive strength - Hardness (N)						
	Dry	MI30s	MI60s	MI120s	MI180s	p-value *	p-value **	Dry	MI30s	MI60s	MI120s	MI180s	p-value*	p-value **
1	$32^{cB}\pm1$	$45^{aA}\pm3$	$29^{cC}\pm1$	$24^{abD}\pm3$	$25^{bD}\pm1$	0.065	<0.001	$3.2^{eAB}\pm0.7$	$2.0^{eC}\pm0.2$	$3.9^{dA}\pm0.7$	$3.2^{dA}\pm0.4$	$2.5^{dB}\pm0.6$	0.095	<0.001
2	$35^{bcA}\pm3$	$31^{dB}\pm3$	$35^{aA}\pm2$	$26^{aC}\pm3$	$30^{aBC}\pm2$	0.418	0.003	$7.1^{dB}\pm0.8$	$4.6^{cD}\pm0.4$	$5.9^{cC}\pm0.9$	$4.3^{dD}\pm0.6$	$10.8^{aA}\pm0.6$	0.152	<0.001
3	$43^{aA}\pm3$	$35^{bB}\pm1$	$31^{bC}\pm1$	$23^{bD}\pm1$	$20^{cE}\pm1$	0.070	<0.001	$7.0^{dA}\pm0.7$	$4.1^{cdB}\pm0.2$	$2.7^{dC}\pm0.4$	$7.0^{cA}\pm0.7$	$5.0^{cB}\pm1.2$	0.003	<0.001
4	$19^{eD}\pm1$	$31^{cdA}\pm1$	$26^{dB}\pm1$	$25^{abBC}\pm2$	$24^{bC}\pm1$	0.038	<0.001	$37.9^{aA}\pm3.7$	$6.2^{dB}\pm1.0$	$10.2^{bC}\pm1.8$	$15.2^{aB}\pm3.3$	$12.0^{aB}C\pm1.5$	0.001	<0.001
5	$28^{dB}\pm1$	$32^{cdA}\pm1$	$25^{dC}\pm1$	$26^{abC}\pm3$	$25^{bC}\pm2$	0.281	<0.001	$21.2^{bA}\pm2.3$	$11.8^{aC}\pm0.7$	$16.9^{aB}\pm2.6$	$9.4^{bCD}\pm1.1$	$8.4^{bD}\pm2.1$	0.006	<0.001
6	$36^{bA}\pm3$	$34^{bcB}\pm1$	$30^{bcC}\pm2$	$27^{aD}\pm1$	$26^{bD}\pm2$	0.003	<0.001	$19.8^{bA}\pm1.2$	$13.6^{dC}\pm0.7$	$7.7^{cB}\pm0.5$	$10.2^{bA}\pm0.7$	$7.1^{bB}\pm0.6$	0.328	<0.001
p- value*	0.031	0.001	0.610	0.617	0.261	-	-	<0.001	0.038	<0.001	<0.001	0.012	-	-
p-value**	<0.001	<0.001	<0.001	0.041	<0.001	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	-	-

Dry = dry product; MI30s = immersed in milk for 30s; MI60s = immersed in milk for 60s; MI120s: immersed in milk for 120s; MI180s: immersed in milk for 180s;
+According Table 1. *p-value (homoscedasticity);**p-value (ANOVA/Welch). Different lowercase letters in the same column or uppercase letters in the same line indicate a statistically significant difference at the 5% level by Fisher Test.

Table 6 shows results of the sensory analysis of milk-immersed breakfast cereals and acceptance rates. Among formulations under evaluation, the one that received the highest percentages of replacement of corn meal with waste flours (sample 4 - 10% GF and 15% PF) had the lowest means of all parameters. It was the only one which differed ($p<0.05$) from the control formulation (without any addition of by-products) concerning appearance, color and aroma.

Table 6. Sensory results of milk-immersed breakfast cereal formulations, produced with different amounts of corn meal and flours of grape and peach palm by-products.

Formu-Lations[+]	Apperance	Color	Aroma	Texture	Flavor	Overall aceptance	Acceptance index (%)
1	$7.1^{a}\pm1.4$	$6.9^{a}\pm1.5$	$6.4^{a}\pm1.6$	$7.3^{ab}\pm1.4$	$6.8^{ab}\pm1.7$	$6.7^{ab}\pm1.4$	75
2	$7.3^{a}\pm1.2$	$7.2^{a}\pm1.2$	$6.3^{ab}\pm1.4$	$7.1^{ab}\pm1.3$	$6.8^{ab}\pm1.5$	$6.9^{a}\pm1.3$	77
3	$6.3^{a}\pm1.9$	$6.7^{ab}\pm1.6$	$6.2^{ab}\pm1.7$	$7.4^{a}\pm1.9$	$7.3^{a}\pm1.7$	$6.9^{a}\pm1.9$	77
4	$5.3^{b}\pm1.7$	$5.9^{b}\pm1.7$	$5.4^{b}\pm1.7$	$4.9^{c}\pm2.0$	$4.8^{c}\pm2.1$	$4.9^{c}\pm1.7$	61
5	$6.5^{a}\pm1.4$	$6.8^{ab}\pm1.3$	$6.0^{ab}\pm1.4$	$6.6^{b}\pm1.9$	$6.2^{b}\pm1.7$	$6.5^{ab}\pm1.4$	72
6	$6.6^{a}\pm1.4$	$6.5^{ab}\pm1.5$	$6.2^{ab}\pm1.5$	$6.3^{b}\pm1.8$	$6.1^{b}\pm1.9$	$6.1^{b}\pm1.6$	67
p-value *	≤0.001	≤0.001	<0.018	≤0.001	≤0.001	≤0.001	-

[+]According Table 1. *p-value (Kruskal-Wallis test). Different letters in the same column indicate a statistically significant difference at the 5% level by Kruskal-Wallis Test.

Replacement of corn meal with either 15% PF (formulation 1) or 10% GF (formulation 2) showed similar values ($p> 0.05$) in texture, flavor and overall acceptance by comparison with formulation 3 (without any addition of PF and GF). Thus, these formulations had the highest acceptability indices (AI) (≥75%); AI values higher than 70% indicates that the formulations are accepted in the sensory point of view (16). These results are associated with their lower hardness values and higher crispness ones (Table 5), as well as their lower fiber contents (Table 6), by comparison with those found in the other formulations (4, 5 and 6). According to Onwulata et al., (2001), fibers content influences texture by increasing hardness of breakfast cereals. As a result, acceptability indices decrease, due to society's cultural issues, since the habit of fiber ingestion is poor. It explains the lowest grades obtained by all attributes under evaluation in formulation 4 (10% GF and 15% PF), which had the highest fiber content (~ 11%). On the other hand, the combination of the lowest levels of GF (5%) and PF (7.5%) – formulations 5 and 6 – led to similar scores in appearance, color, aroma and overall acceptance by comparison with formulations 1, 2 and 3 ($p>0.05$). In these formulations, averages were higher than those reported by Oliveira et al., (2018) in extruded breakfast cereals enriched with flours of whole grain wheat and jabuticaba skin.

CONCLUSION

Replacement of corn meal with grape and peach palm by-products led to nutritional enrichment of breakfast cereals, especially in fiber and antioxidant compounds. Formulations containing the lowest levels of PF and GF had more favorable results from sensory and technological points of view. Therefore, the use of the by-products under study proved to be a promising alternative to add value to them in production of breakfast cereals, thus, contributing to strengthen production chains, stimulate sustainability and offer a healthy alternative to the consumer market.

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RESUMO: Os cereais matinais apresentam baixo valor nutricional e alto valor energético. O objetivo deste estudo foi desenvolver cereais matinais extrusados substituindo parte da farinha de milho por diferentes proporções de subprodutos de uva (5-10%) e palmito pupunha (7.5-15%). As formulações foram adoçadas com xilitol e a umidade controlada com suco de uva. Seis formulações foram produzidas utilizando o delineamento experimental 2^2, onde foram analisados com relação à composição proximal, propriedades tecnológicas, mecânicas, antioxidantes e sensoriais. A adição de diferentes quantidades de farinhas produzidas com os subprodutos de uva (FU) e palmito pupunha (FP) aumentou as fibras dietéticas e o conteúdo de antioxidantes nas formulações de cereais matinais desenvolvidas. No entanto, nos mais altos níveis de adição ocorreram um decréscimo na expansão e aumento na dureza e solubilidade em água. A incorporação de subprodutos de uva e palmito pupunha em menores proporções mostrou alta viabilidade, pois apresentaram satisfatória aceitação sensorial, propriedades tecnológicas e *bowl life*.

PALAVRAS-CHAVE: Aceitação sensorial. Antioxidantes. *Bactis gasipaes.* Crocância. Fibras dietéticas. Valor Energético. *Vitis labrusca.*

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