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High nutritional value muffins produced with wholemeal rye (*Secale cereale* L.) and wholemeal bean (*Phaseolus vulgaris* L.) flour mix

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Abstract

The combination of flours from cereal and legume results in less caloric products, with high contents of fiber, proteins, ash and antioxidants. Thus, this study aimed at developing muffins made with different proportions of wholemeal rye flour (WRF) and wholemeal common black bean flour (WBF). Physicochemical and physical analyses were performed to characterize starches, flours and the muffins. Sensory analysis was also carried out. WRF had the highest values for L* value, moisture and ash contents, whereas WBF had more proteins and lipids, and heterogeneous particle size distribution. The formulation with the highest acceptability grade with total replacement of whole wheat flour, was that containing 70% WRF and 30% WBF (F2). This sample was characterized as high-quality muffin, chocolate flavor, chocolate odor, light and soft crumb. Its texture was defined as low hardness, chewiness and high cohesiveness. It was concluded that the F2 formulation had a high dietary fiber content (20%), low lipid content (8%), containing 32% resistant starch, 9% protein and 51.43 mg GAE 100^1 g^{-1} of total phenolic content, being considered an excellent nutritional food option.

Keywords: ABTS; CATA; DPPH; flour blends; sensory evaluation.

Practical Application: In this study, the use of a combination of flours from cereal and legume was made with production of muffins. Different proportions of whole rye flour (WRF) and whole common black bean flour (WBF) were tested. The formulation with the highest acceptability grade with total replacement of whole wheat flour, was that containing 70% WRF and 30% WBF (F2). This formulation had a high dietary fiber content (20%), low lipid content (8%), containing 32% resistant starch, 9% protein and 51.43 mg GAE 1001 g^{-1} of total phenolic content, being considered an excellent nutritional food option.

1 Introduction

Studies on rye (*Secale cereale* L.) have increased in last decades due to its nutritional profile. Products made from rye flour have high levels of dietary fiber (DF) (Pasquali et al., 2019), vitamins, minerals and essential amino acids (Andersson et al., 2014).

Several bakery products are made with whole and refined flour blends. In Brazil, blends are used in the proportion of 60:40 (whole to refined flour), regarding the demand and preference of the consumer. A rye-rich diet reduces insulin level, the risk of diabetes, constipation problems and helps to reduce the risk of cardiovascular diseases and cancer (Andersson et al., 2014). The combination of wholemeal rye flour with wholemeal pulses (dry legumes) flour is a worldwide trend (Ramírez-Jiménez et al., 2018). The common beans (Fabaceae family) are cheap sources of protein, especially in poorer areas and for vegans and vegetarians. Beans are one of the main crops produced worldwide, mainly in developing countries (Los et al., 2020). Besides high protein and low-fat contents, beans have vitamins, minerals, complex carbohydrates, lysine (Los et al., 2018; Ramírez-Jiménez et al., 2014). Cereals are deficient in lysine but this can be overcome when associated with pulses. Therefore, cereal / pulse flour mix enables nutritional enrichment.

DF divides into three classes: total fiber, soluble fiber and insoluble fiber. Solubility is related to branching and side chains, and crude fiber is formed only by insoluble fiber (Brennan, 2005). Wholemeal rye flour has a high content of DF, arabinoxylans and β-glucans (Andersson et al., 2014). These compounds are undesirable, related to flatulence after fermentation; recently, however, studies have shown that their fermentation exert prebiotic action, facilitating the absorption of calcium benefiting bone metabolism (Roberfroid et al., 2010).

There is a growing interest in developing ingredients to replace wheat flour in baking. In the last decade there has been a sharp increase in demand for fast and easy to prepare foods that benefit the consumer's health, forcing food industry to seek unconventional flours. Rye falls within this category, because its cultivation does not require much agrichemicals, as it has good performance in field (Bukhovets et al., 2021).

One way to ensure access to quick and easy to prepare products with improved nutritional value is to develop new formulations with higher fiber and protein contents. Muffins are baked mini-cakes, sweet and highly caloric, widely accepted and consumed (Matos et al., 2014). Traditionally muffins are made

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with wheat flour, sugar, vegetable oil or fat, egg, milk and baking powder; new formulations have been studied, taking advantage of food by-products as ingredients (Matos et al., 2014).

In the present study, an alternative muffin was developed; wheat flour was completely replaced by rye wholemeal/bean wholemeal flours; the other ingredients remained unchanged (whole milk, vegetable oil, baking powder, cocoa powder, *demerara* sugar, egg, baking powder and chocolate drops - 70% cocoa). The novelty of our study is to produce a nutritious and tasteful food with alternative cheap ingredients instead of wheat flour.

2 Material and methods

For the preparation of the formulations, the flours were combined with the following ingredients: whole milk, soy oil, chemical yeast, cocoa powder, *demerara* sugar, egg and drops of chocolate.

2.1 Wholemeal flours

The wholemeal rye flour (WRF) (BRS *Serrano* cultivar, crop 2017), was kindly provided by São Luiz mill (Guarapuava-PR, Brazil). The wholemeal bean flour (WBF) (black beans IPR *Uirapuru* cultivar, crop 2018, supplied by Feijão Pontarollo - Ponta Grossa- PR, Brazil) was obtained by drying the beans in a forced-air oven (Tecnal, TE 394/1 Piracicaba-SP, Brazil) at 40 °C/24 h (14% final moisture). Then, the beans were grinded in a cyclone rotor mill with 0.595 mm sieve (Fortinox Star FT 51, Piracicaba-SP, Brazil) and stored in plastic bags.

2.2 Muffin processing

In parallel with the standard formulation (ST) with 32.20% of whole wheat flour (WWF), the proportions (in weight) of each ingredient in the formulations was: F1 = 70% WBF/30% WRF; F2 = 70% WRF/30% WBF; F3 = 50% WBF/50% WRF (Table 1).

A total of 65 tests was made varying WBF and WRF (%) (F1, F2 and F3 formulations). All the ingredients were weighed, then mixed and beaten in an orbital planetary mixer (BAT600, Cadence, Brazil) until homogeneous batter. The batter was divided into individual shapes of 50 g, and baked at 230 °C/8 min.

2.3 Granulometry

The granulometry of the flours was verified following the method nº 66-20 (American Association of Cereal Chemists, 2000). One hundred grams of flour was used in a granulometric sieve system (1.41 mm; 0.841 mm; 0.420 mm; 0.250 mm; 0.177 mm; 0.106 mm and the bottom) (Bertel Ind. Metal. Ltda., Brazil). The material retained in each sieve was weighed for percentage calculations.

Table 1. Formulations of the developed Muffins.

Ingredients (%)	F1	F2	F3	ST
WBF	22.67	9.53	16.14	0.00
WRF	9.53	22.67	16.14	0.00
WWF	0.00	0.00	0.00	32.20
Total	100	100	100	100

WRF = Wholemeal rye flour; WBF = Wholemeal bean flour; WWF = whole wheat flour. Other ingredients (%) - Whole milk: 21.3; Soybean oil: 5.22; Baking powder: 2.49; Alkaline cocoa powder: 4.54; *Demerara* sugar: 22.67; Egg: 11.33; Chocolate drops: 0.25.

2.4 Proximal composition

The total protein contents by the Micro-Kjeldahl were calculated using 6.25 as nitrogen conversion factor for bean flour and muffin, and 5.83 for rye flour. The moisture, ash, lipid contents of the F1, F2, F3 and ST were determined according to AOAC (Association of Official Analytical Chemists, 2010). The determination of DF of the muffins was done following Ruiz-Ruiz et al. (2013) with the enzymatic-gravimetric method/ Megazyme kit (Wicklow, Ireland).

2.5 Color analysis

The color analysis was made by the CIEL*a*b* system using a previously calibrated MiniScan EZ 4500L (HunterLab, USA) colorimeter. The parameters were: luminosity (L* = 0 means black and L* = 100 means white); a* and b* are chromatic coordinates (+a* = red and -a* = green; +b* = yellow and -b* = blue). Chromaticity (chroma) and hue angle (H°) were estimated by the Equations 1 and 2, respectively (Falade & Omiwale, 2015).

$$\text{Chroma} = \sqrt{a^{*2} + b^{*2}} \quad (1)$$

$$\text{H}° = \tan^{-1}\frac{b*}{a*} \quad (2)$$

2.6 Specific Volume (SV)

The millet seed displacement method was used. The SV is the ratio between the volume and the weight, measured one hour after baking the cake (Huang et al., 2008).

2.7 Texture Profile Analysis (TPA)

TPA was performed from the second day of storage to determine the distribution of moisture inside the crumb. The TA.XT2 (Stable Micro Systems, Godalming, UK) texturometer was used in the following parameters: probe compression platens P/100 φ 100 mm; double compression 2.0 mm/s; distance 40%; rupture test 1.0%; force 100 0 g and time 5 s (Judacewski et al., 2016). The parameters analyzed were: hardness, adhesiveness, elasticity, cohesiveness and masticability.

2.8 Sensory analysis

Sensory evaluation was made after approval by the Research Ethics Committee of the State University of Ponta Grossa (UEPG) (protocol # 3.234.380). Untrained assessors (n = 100) took part, consisting of students, staff and the community of the UEPG. They were asked to respond an acceptability test regarding aroma, flavor, color and texture attributes according to hedonic scale (1, extremely dislike; and 9, extremely like). Regarding purchase intent, the samples were assessed using a five-point scale: 1, certainly would not buy; and 5, certainly would buy. The "just about right" (JAR) scale was applied, for sweetness, texture and smell, which asked to the assessor to select between the ideal option, much or little at each attribute. The CATA data were presented with 25 attributes as: characteristic color, difficulty to swallow, crumbled mass, wet, cohesive, adhesive, spongy, fibrous, chocolate flavor, soft, chocolate smell, fibrous, sandy, bright, open surface, extremely tasty, high quality, chalky texture, light dough, fragile mass, difficulty to chew, low chewability, sweet odor and wouldn't pay extra for the product. In the same form, questions made also involved the frequency of consumption of the product and whether the consumer would pay more if he knew the benefits that the product would bring. For data analysis, univariate statistics based on the chi-square test or multivariate analyses are preferred (Meyners & Castura, 2014; Ares et al., 2014).

2.9 Antioxidants

Ethanolic extracts used to determine total phenolic content (TPC), and antioxidant potential (Antoniewska et al., 2018) of dried, grinded and degreased muffins were prepared by suspending 1 g of the muffin sample in 10 mL ethanol/water 4:1 (v/v). The samples were left for 1 h 30 min on a shaking plate. The extracts were paper filtered. The total antioxidant capacity of muffin formulation with the highest score in the sensory evaluation was determined according to the methods: 1,1-diphenyl-2-picrylhidrazil (DPPH) (Sánchez-Moreno et al., 1998); ABTS (Van den Berg et al., 1999) and FRAP (Benzie & Strain, 1996). TPC was analyzed using the Folin-Ciocalteu Reagent at $\lambda = 720$ nm with gallic acid as standard (Singleton & Rossi, 1965). The results were expressed as gallic acid equivalent (mg GAE/100 g extract). A volume of 0.1 mL of extract was diluted in 8.4 mL of deionized water plus 0.5 mL of Folin-Ciocalteu reagent, and after 3 min the solution was saturated with 1 mL of Na_2CO_3 solution. After 1 h resting, the absorbance was read.

2.10 Statistical analysis

The results expressed by mean values and standard deviation were subjected to analysis of variance (ANOVA) to verify if there was any difference between the means. The means were compared by Tukey's test ($p \leq 0.05$) performed with ASSISTAT 7.7 software. Sensory data were analyzed by the XLStat 2015 software (Addinsoft, 2015).

3 Results and discussion

3.1 Granulometry

The size of particles can directly interfere with the digestibility of the final product (Figure 1).

The WRF has most of its particles retained by 0.84 and 0.42 mm sieves (Figure 1). It can be considered a flour with homogeneous particles with total average diameter of 0.89 mm. Warechowska et al. (2019) reported 0.074 mm particle size for flour in bread making. In that case, smaller particles enabled better bread quality. For the WBF there was a heterogeneous distribution of particles. Percentages of retention were above 10% and 20% in the 0.841 mm sieve and 0.106 mm, respectively. The 0.420 mm sieve had the highest retention (Figure 1). The average total particle size for WBF was 0.50 mm.

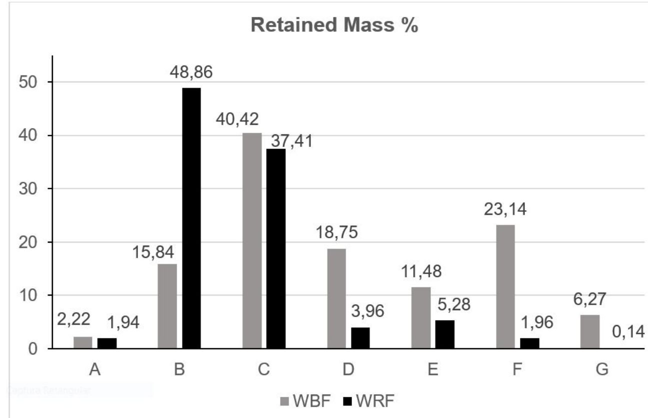

Figure 1. *Percentage of particle size profile of WBF and WRF.* WBF = Wholemeal bean flour; WRF = Wholemeal rye flour; Sieves A = 1.41 mm; B = 0.841 mm; C = 0.420 mm; D = 0.250 mm; E = 0.177 mm; F = 0.106; G = bottom.

3.2 Proximal composition

The proximal composition analysis was performed for the F2 formulation (70% WRF/30% WBF), which had the highest score in sensory analysis. The same parameters, except DF, were also determined for the WRF and WBF, and the results are shown in the Table 2.

Jeong & Chung (2018) observed lower, but close moisture values (31 and 33%) for muffins made with bean flour and waxy rice flour, respectively. This may be related to the chemical composition of bean and rye flour, since proteins and fibers contribute to a higher water holding capacity, which increases the moisture content of the muffin. Flours from whole grains have higher ash contents due to the highest concentration of minerals in the outermost part of the grain (bran). Among the samples, the WRF had the highest ash content. The ash content was close to previously reported data (1.9 to 2.0%) (Jeong & Chung, 2018), and higher than Trindade et al. (2018) from 1.16 to 1.27% when evaluating muffins added of bean flour. Low lipid values of the flours (2.3 ± 0.17 and 2.7 ± 0.01) were in line with the literature. Lestari et al. (2017) reported lipid content for common bean meal of 1.9% and Ramírez-Jiménez et al. (2014) of 1.7%; similar values were found in our study. The lipid levels of the flours (WRF and WBF) from our work were lower than that of the muffin formulation (F2), since most muffin lipid comes from the other ingredients.

Even so, when our results are compared with others, the value of lipids still remains low. Jeong & Chung (2018) reported 16.8 -17.7% and Trindade et al. (2018) 13.09 -13.91% of lipids in muffins.

To be considered a source of protein, according to the Brazilian legislation (Brasil, 2012), a product must have 6 g 100 g^{-1} of protein and the protein must contain predetermined levels of essential amino acids (Brasil, 2012). By the amount of protein found in muffin with wholemeal rye and bean flours it could be considered a source of protein, however, a specific analysis for quantification of amino acids must still be performed to confirm this statement. Regarding the fiber content of a product, to be considered high fiber, the product must have 6 g 100 g^{-1}; our muffin-type cake has 3.4 times more fiber, therefore rich in fiber.

3.3 Color analysis

Color analysis was made for the four different muffin formulations after baking, and also for whole bean and rye flours. The values are shown in Table 3. All muffin formulations did not show significant difference in brightness. The color of the baked muffins has tended to black, due to the alkaline cocoa powder. All samples showed greater tendency to red (a*) and yellow (b*).

The WRF was the lightest flour (> L*value) (Table 3). The WBF was made with all parts of the grain, including the tegument, responsible for the concentration of dark pigments such as anthocyanins, which can determine the color, tone and intensity of the seeds. Warechowska et al. (2019) evaluated the physicochemical properties, antioxidant potential and cooking quality of primitive rye flour and found for three different cultivars values presenting higher tendency for green color and lower tendency for red color (a*). Regarding the b* parameter all samples showed a greater tendency to yellow color. The chromaticity establishes the color intensity of a sample, revealing that values close to zero have neutral colors and close to 60, vivid colors; all samples presented values which can characterize them as neutral colors.

3.4 Texture Profile Analysis (TPA), physical analysis and specific volume (Table 4)

The specific volume indicates the crumb characteristics, the greater the specific volume, the better was the development of the batter while beating. In this process the crumb had optimum aeration, forming large wells and an open texture.

It can be observed that F3 had the lowest specific volume. This formulation was characterized in sensory analysis as one of the less soft, less humid and more fibrous, suggesting that it did not have good development of the batter. By contrast, the F2 formulation, obtained weight and specific volume equal to the ST. However, with greater height, this formulation had better development during cooking.

Hardness had no significant difference between the samples, but the lowest value was found for F2 (Table 4), suggesting that it is the least hard among the samples. Adhesiveness is the necessary work to overcome the attraction force between the product and the contact surface of the probe. The most adhesive sample was F4 whereas the least adhesive was F3.

The lack of uniformity in the particle size of the flour can considerably affect the texture and appearance of a formulation.

Table 2. Proximal composition of F2 muffin and of WRF and WBF (Mean ± SD).

Component (%, m/m)	F2	WRF	WBF
Moisture	27.36 ± 0.42	12.4 ± 1.41	10.2 ±0.02
Protein	8.40 ± 0.59	11.6 ± 0.48	19.2 ±0.56
Lipid	12.11 ± 0.16	2.3 ± 0.17	2.7 ± 0.01
Ash	2.60 ± 0.05	1.6 ± 0.03	0.6 ± 0.02
DF	20.36 ± 0.03	n.a.	n.a.

n.a.: not analyzed

Table 3. Color analysis of wholemeal bean and rye flours, and of muffin formulations.

	L*	a*	b*	°H	chroma
WRF	82.54 ± 0.09	1.66 ± 0.04	7.79 ± 0.04	77.96	7.96
WBF	77.09 ± 0.01	0.46 ± 0.01	7.32 ± 0.14	86.37	7.33
F1	23.20 ± 3.71[a]	9.67 ± 0.59[a]	12.82 ± 0.99[a]	52.85	16.06[c]
F2	24.52 ± 2.42[a]	11.62 ± 0.26[a]	16.43 ± 2.76[a]	54.65	20.13[a]
F3	24.09 ± 9.84[a]	10.93 ± 2.83[a]	15.81 ± 3.92[a]	55.22	19.22[ab]
ST	24.05 ± 2.42[a]	11.25 ± 1.39[a]	14.49 ± 3.35[a]	54.65	18.34[b]

Data presented as mean ± standard deviation. Averages followed by the same letter in the same column do not differ statistically by Tukey's Test ($p < 0.05$). F1 = 70% WBF and 30% WRF; F2 = 70% WRF and 30% WBF; F3 = 50% WBF and 50% WRF; ST = 100% WWF; WRF = Wholemeal rye flour; WBF = Wholemeal bean flour; ST = standard formulation.

Table 4. Physical analysis, specific volume (cm^3 g^{-1}), and texture profile data of muffin formulations.

	F1	F2	F3	ST
Weight (g)	48.04 ± 2.15[b]	50.75 ± 1.68[ab]	54.18 ± 2.41[a]	50.02 ± 1.45[ab]
Height(mm)	37.66 ± 1.12[c]	43.42 ± 0.12[a]	40.69 ± 0.96[b]	42.76 ± 1.12[ab]
Width (mm)	57.81 ± 1.22[a]	59.10 ± 1.09[a]	60.16 ± 1.42[a]	58.89 ± 1.39[a]
Hardness	1574.71 ± 31.94[a]	995.19 ± 75.14[a]	1516.00 ± 44.44[a]	1171.34 ± 31.94[a]
Elasticity	0.79 ± 0.02[a]	0.79 ± 0.06[a]	0.65±0.08[a]	0.78 ± 0.01[a]
Cohesiveness	0.51 ± 0.01[a]	0.63 ± 0.06[a]	0.52 ± 0.06[a]	0.56 ± 0.02[a]
Chewability	649.62 ± 13.08[a]	500.28 ± 112.15[a]	476.23 ± 114.25[a]	523.01 ± 14.47[a]
Adhesiveness	-3.33 ± 1.81[ab]	-1.20 ± 0.79[a]	-1.05 ± 1.31[a]	-7.73 ± 3.39[b]
Specific volume	1.28 ± 0.06[ab]	1.39 ± 0.038[a]	1.25 ± 0.00[b]	1.40 ± 0.05[a]

Results presented as mean ± standard deviation. Means followed by the same letter in the same column do not differ statistically by Tukey's Test ($p < 0.05$). F1 = 70% WBF and 30% WRF; F2 = 70% WRF and 30% WBF; F3 = 50% WBF and 50% WRF; ST = standard formulation.

When the formulation has a regular distribution, the food absorbs water evenly and the cooking of the batter is also uniform. The rate at which a deformed sample returns to its original size and shape in the five second period until the second deformation occurs is called elasticity. The samples showed no significant difference for this parameter (Table 4). Cohesiveness is defined by the ratio of the area of positive force during the second compaction, indicating the tendency of the particles to hold together (Chevanan et al., 2006). Chewiness is described as the energy required to chew a sample to the appropriate consistency until it is homogeneous to swallow (Bertolino et al., 2011). The statistical analysis showed no significant difference between the samples for those parameters ($p > 0.05$).

3.5 Sensory evaluation

The participation in the sensory analysis comprised 78% women and 22% men, totaling 100 people aged 18 - 50 years, with the majority (75%) of evaluators aged between 18 - 25 years. All signed the Term of Free and Informed Consent, agreeing to participate in the analysis and allowing the use of the information provided. In the frequency of consumption analysis (Figure 2), most assessors marked it as sporadic.

In their answers about the consumption, when questioned whether they would overpay for the product, for all formulations the assessors replied that they would pay more ($ 0.25) if they knew it was a source of DF. The ST obtained the highest acceptability score (83.11% of acceptability), the F1 formulation with acceptability of 77.77% was followed by F2 with higher proportion of rye flour (81.22% of acceptability), which did differ significantly from F1. Therefore, the formulation chosen for characterization was F2. The least accepted formulation was F3 (75.33%), that contained 50% bean flour and 50% rye flour, which is directly related to the muffin texture, perceived as the most fibrous, humid and harder. It can be verified in the physical analysis that the formulation had a lower specific volume and higher weight, suggesting that it did not obtain good development during baking. In the texture analysis the F3 was less adhesive, and it can be related to the granulometry of the flours, that directly affect the texture, as they do not absorb water in a regular way and the cooking of the batter is not uniform.

Just-about-right (JAR)

The Just-about-right (JAR) scale data are shown in Table 5. These results show the frequency of attributes marked as above, ideal or below the desired by the consumer. This enables to evaluate by penalty analysis, how much the deviation from ideal can affect the acceptability score. The characteristics that obtained a frequency higher than 20% were considered significant. The F1 was penalized for lack of sweetness and to be too soft. The F2 formulation was penalized for being too soft, F3 for being too sweet, too soft, and for the smell below ideal. These results are confirmed by the TPA analysis. The ST was also penalized for being not sweet and for the smell, but it was evaluated to have an ideal texture. The data from the penalty analysis for sweetness, texture and smell are presented in Table 5. The consumers perceived a lack of sweetness for all samples, since 70% cocoa chocolate was used, leading to a product with less sweetness and more bitterness.

The WRF can improve the softness of the batter, since the F2 sample was the softest. This is directly related to batter hydration (fiber content), which has the role of water retention. Results showed that WBF reduces softness, as seen in F3 and F1.

CATA

The terms marked by the consumers that achieved a minimum frequency of 20% were submitted to Cochran's Q test that demonstrates with which attributes the samples correlate. The sample characterized as moist was the F1 formulation, as flours with smaller particles absorb water faster. The F1 has the highest percentage of bean flour, which has a higher proportion of particles with heterogeneous distribution. The characteristic

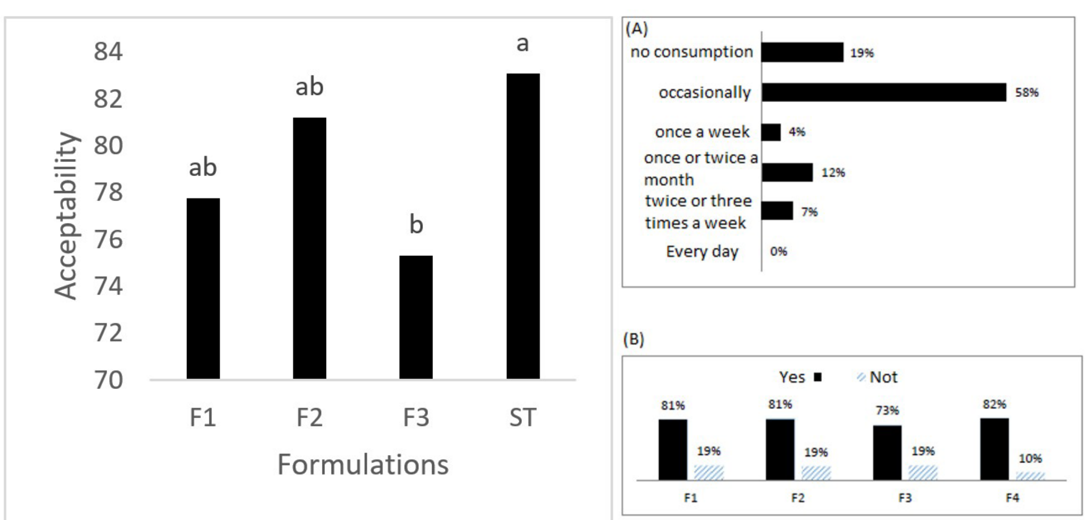

Figure 2. Assessors muffin's consumption frequency (A) and the results related to the questioning whether consumers would pay more for the sample for the sample (B).

Table 5. Penalties for the attributes sweetness, texture and smell of the muffins.

	Sweetness			
	Absence/Excess	Penalties	Hedonics	Adjusted Hedonics
F1	Absence	1.11	7.00	8.11
F2	Absence	1.15	7.31	8.46
F3	Absence	1.14	6.78	7.92
ST	Absence	1.02	7.48	8.50
	Texture			
	Absence/Excess	Penalties	Hedonics	Adjusted Hedonics
F1	Absence/Excess	0.75/0.25	7.00	7.72/7.25
F2	Excess	0.95	7.31	8.26
F3	Absence	1.08	6.78	7.86
ST	Ideal	0.00	7.48	7.48
	Smell			
	Absence/Excess	Penalties	Hedonics	Adjusted Hedonics
F1	Ideal	0.00	7.00	7.72/7.25
F2	Ideal	0.00	7.31	7.31
F3	Absence	0.59	6.78	7.37
ST	Absence	0.33	7.48	7.81

Results presented in the form of means that differed statistically by Tukey's Test ($p < 0.05$). F1 = 70% whole bean flour and 30% rye wholemeal flour; F2 = 70% rye wholemeal flour and 30% bean flour; F3 = 50% bean wholemeal and 50% rye wholemeal flour; ST = standard formulation.

of "fibrous" and "fibrous batter" was attributed to F3; F2, on the other hand, was reported as less fibrous. This characteristic may be related to the granulometry of the flours. The ST sample was described with "taste of want more" and less bright. The brightness may be related to the absorption of water. With an acceptability score similar to ST, F2 was characterized with chocolate flavor, high quality, light dough, chocolate odor and soft. This suggests that the rye flour was neutral in flavor, enhancing the chocolate flavor and odor compared to the other flours.

3.6 Antioxidants

Polyphenols are usually found in colored seed husks such as black beans. In cotyledons where no pigmentation is found, lowest concentrations are found. The total antioxidant capacity of the muffin formulation with the highest grade in sensory analysis (F2) are 51.43 ± 2.06 TPC (mg GAE/100 g sample), 2.46 ± 4.59 DPPH (μmol of trolox/g sample), 15.69 ± 1.05 ABTS (μmol of trolox/g sample), and 0.65 ± 3.45 FRAP (μmol of trolox/g sample). Trindade et al. (2018) evaluated TPC in different muffin formulations by replacing wheat flour with bean flour of different classes and got a lower value of 37.06 mg GAE 100 g^{-1} sample for the formulation developed with black bean flour. The ingredients used in the formulation were similar to this work, leading to the conclusion that the combination of whole rye and bean flours has a higher concentration of phenolic compounds of the product developed as a muffin-type. The objective of these analyses was to verify the antioxidant capacity after baking the muffin. Thus, it was possible to verify that even after being submitted to the drying process of the grains in the processing and cooking of the flour applied in the muffin, it still showed antioxidant activity. Zieliński et al. (2008) evaluated the antioxidant property of breads made with rye flour and obtained values higher than those found here for DPPH (3.15 and 4.22 μmol of trolox g^{-1} sample) and for ABTS (8.57 and 6.79 μmol of trolox g^{-1} sample).

4 Conclusions

The use of whole cereal and legume flours increased the fiber content of the muffin. Muffins made with 70% WRF and 30% WBF had greater sensory acceptance. Their texture was defined as low hardness, chewiness, gumminess, and high cohesiveness. Physicochemical analyses of the formulation resulted in high fiber content (20%), low lipid content (8%) and 9% of proteins being an excellent option of nutritious food. A homogeneous granulometry of flour related to a better water absorption, resulting a better development, smoother and more homogeneous crumb with better acceptability by consumers. Lastly, the muffin made with 70% WRF/30% WBF (F2) could be considered a source of fiber and had high protein content, being a nutritious alternative for a diverse audience, both children and adults.

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