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Evaluación de mezclas de harina de trigo integral con substituto de grasas

Evaluation of whole-wheat flour blends with fat replacer

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Resumen

Una dieta rica en fibras alimenticias con bajo contenido de grasas, ayuda a prevenir enfermedades crónicas. La utilización de harina de trigo integral y de substituto de grasa, agrega valor nutricional. Substitutos de grasa actúan reduciendo el nivel calórico. El salvado afecta las propiedades reológicas y la calidad del pan. Considerando el desafío de agregar valor nutricional, manteniendo la estructura y la estabilidad de la miga, nuestro objetivo fue evaluar las características físico-químicas y reológicas de mezclas de harina de trigo integral con substituto de grasa para futura aplicación en panes. Los valores de gluten de las mezclas de harinas indicaron que eran tecnológicamente aceptables para panificación. El efecto de la presencia del substituto de grasa fue observado solamente en la alveografía y en el color de las muestras con mayor nivel de sustituto, pues a mayor nivel de substituto, menores fueron los resultados de la tenacidad máxima de trabajo

Palabras clave: Almidón; Cereales; Propiedades fisico-químicas; Reología, Substituto de grasa.

Abstract

A diet rich in low-fat dietary fiber helps to prevent chronic diseases. The use of whole wheat flour and fat substitute, adds nutritional value. Fat substitutes act by reducing the caloric level. The bran affects the rheological properties and the quality of the bread. Considering the challenge of adding nutritional value, maintaining the structure and stability of the crumb, our objective was to evaluate the physicochemical and rheological characteristics of whole wheat flour blends with fat substitute for future application in breads. The gluten values of the flour blends indicated that they were technologically acceptable for baking. The effect of the presence of the fat substitute was observed only in the alveography and in the color of the samples with higher level of substitute, because at a higher substitute level, the lower the results of the maximum tenacity of work.

Key words: Physicochemical properties; Rheology, Fat Substitute.

Introduction

Low fat and rich in dietary fiber diet have been shown to decrease the risk of non-communicable diseases (7). Bread is a common staple food around the world that can be used to deliver ingredients for specific health purposes (19).

Starch is a major component of bread, and plays an important role in the texture and quality of the dough. Undesirable properties of native starches can be minimized using modified starches as quality improvers (16) and fat replacers (14).

While whole-wheat flour helps maintain health, the fiber affects bread quality, depending on composition and particle size (18, 26). The presence of bran considerably affects the rheological properties of dough and, subsequently, bread´s quality (26). The adverse effect of fibers on bread volume is highly correlated with gluten yield, since fiber interacts physically and chemically with gluten influencing gluten aggregation negatively (18).

Therefore, adding nutritional value to bread while maintaining the quality of crumb structure and stability of the gas cells (18) is a major challenge. To study the effect of adding a fat replacer to whole-wheat flour for baking: analysis of gluten content, dextrose equivalent, farinography, alveography, viscosity, color and microscopy were performed.

Material

This study used whole-wheat flour and white flour, obtained from the same batch of wheat (2012 harvest), provided by Cooperativa Agrária Agroindustrial (Guarapuava, Brazil). Samples were stored at -18 °C until the time of analysis. Enzymatically modified corn starch (Selectamyx C150, Dutch Starches International, Netherlands) was used as the fat replacer.

Methods

Preparation of blends of flour and fat replacer

Blends with different proportions of whole-wheat flour (WF) and white flour (refined flour, RF) were prepared and encoded according to the percentage of WF and RF used: 95.35WF (95.35WF+4.65RF); 85WF (85WF+15RF); 60WF (60WF+40RF); 35WF (35WF+65RF); 24.64WF (24.64WF+75.36RF), following the experimental design. Blends were homogenized with the fat replacer, according to the levels indicated in the experimental design.

Experimental design

A rotatable central composite design was used, with the percentage of whole-wheat flour (%WF) and the percentage of fat replacer (%FR) as independent variables (Table 1) (24). Of the 14 types of blends with 6 replicates at the central point, 12 types of blends with four center point replicates were evaluated in this experiment, adopting an orthogonal block design (6), which eliminates the effect of heterogeneity present in the units for comparison of experimental treatments.

Analysis of results

Analysis of variance (ANOVA) and Tukey's test ($p \leq 0.05$) were used to determine the significance of the data. Samples of the central treatment (9 to 12) are represented by the averaging them (9-12*) (Table 1).

Physical and chemical analysis

Gluten

Gluten analysis of blends of wheat flour was performed according to method 38-12 (1) with modifications. The first wash used a fine-mesh polyester sieve (opening 88 μm), while the second wash was performed using only the receiving pan of the sieve set, thus enabling output of the high-granulometry bran particles present in the flour and leaving only gluten. Analysis of gluten index, wet gluten and dry gluten was performed with a 2100 Glutomatic system (Perten, USA). Samples were analyzed in duplicate.

Dextrose equivalent

The degree of hydrolysis of the FR was evaluated by determination of its dextrose equivalent (DE). Determination of reducing sugars was performed by the 3,5-dinitrosalicylic acid (DNS) method (15).

Color

The color of the blends was evaluated in triplicate using a CIE L*a*b* system, with a CR 410 colorimeter (illuminant D65, 10° angle) (Konica Minolta, Japan) coupled to a DP-400 processor.

Scanning electron microscopy

FR samples were fixed on aluminum stubs with double-sided carbon tape and coated with two 200Å-thick layers of gold, using a SCD 005 sputter coater (Baltec, EUA). The samples were visualized and microphotographed in a JSM-6390LV scanning electron microscope (JEOL, Japan), at an accelerating voltage of 10 kV.

Rheological analysis

Farinography

The farinograph properties of the blends and FR were evaluated in two determinations by method 54-21 (1) in a Typ 820600 farinograph (Brabender, Germany), using 50 g of the sample (corrected to 14% moisture content), at a mixing speed of 63 rev/min^{-1} and consistency of 500 Farinograph Units.

Alveography

The viscoelastic properties of the blends and FR were analyzed, in duplicate, in a Chopin Alveograph (Chopin Technologies, France), in accordance with method 54-30A (1).

Viscosity

Viscosity of the blends and FR was determined in duplicate, with a Rapid Visco Analyzer (RVA) 3D (New-Port Scientific- Perten, Sweden) using Thermocline for Windows 3.1 software, according to method 76-21 (1) was used.

Results and discussion

Physical-chemical evaluation

Gluten content

Table 1 shows the results of wet gluten, dry gluten, and gluten index determination.

Table 1: Gluten content of the homogenized blends of wheat flour and fat replacer.

Blend	independent variables				
	WF (%)	FR (%)	WG (%)	DG (%)	GI
1	35.00	0.60	25.20^{ab} ± 0.27	8.46^{a} ± 0.04	93.00^{a} ± 0.00
2	35.00	2.60	27.02^{a} ± 0.06	8.84^{a} ± 0.03	90.00^{a} ± 2.83
3	85.00	0.60	24.39^{ab} ± 0.35	8.57^{a} ± 0.08	94.50^{a} ± 0.71
4	85.00	2.60	22.73^{ab} ± 0.67	7.89^{a} ± 0.24	93.50^{a} ± 0.71
5	24.64	1.60	26.98^{a} ± 2.32	8.52^{a} ± 0.61	88.00^{a} ± 4.24
6	95.35	1.60	21.65^{b} ± 0.77	7.73^{a} ± 0.32	92.50^{a} ± 0.71
7	60.00	0.18	22.39^{ab} ± 3.68	8.14^{a} ± 0.86	95.00^{a} ± 5.67
8	60.00	3.00	25.34^{ab} ± 0.16	8.78^{a} ± 0.00	93.50^{a} ± 0.71
9	60.00	1.60	23.88^{ab} ± 0.38	8.69^{a} ± 0.15	94.50^{a} ± 0.71
10	60.00	1.60	25.02^{ab} ± 1.17	8.70^{a} ± 0.11	94.00^{a} ± 1.41
11	60.00	1.60	23.45^{ab} ± 0.66	8.07^{a} ± 0.15	95.00^{a} ± 4.24
12	60.00	1.60	23.37^{ab} ± 0.16	8.97^{a} ± 0.07	93.50^{a} ± 3.53
9-12*	60.00	1.60	23.93^{ab} ± 0.00	8.60^{a} ± 0.03	94.00^{a} ± 2.83

Mean values in the same column followed by different letters are significantly different ($p<0.05$). Results expressed as mean of two determinations ± standard deviation. *Average of samples 9 to 12. WF: whole-wheat flour; FR: fat replacer; WG: wet gluten; DG: dry gluten; GI: gluten index.

Wet gluten values between 21.65 and 27.02% were obtained, with a significant difference only between samples 2 (35WF+2.6FR) and 6 (95.35WF+1.6FR) and between samples 5 (24.64WF+1.6FR) and 6 (95.35WF+1.6FR), with lowest and highest whole-wheat flour levels, respectively. As whole-wheat flour level decreases (fiber content), the white flour level and the gluten value increases. Similar results were reported by Oro (20) or white and WF blends and Gonzalez et al. (8) in wheat flour.

Dry gluten values ranged from 7.73 to 8.84%, with no significant difference among samples. Dry gluten values correspond to slightly more than one-third of the wet gluten value (30). Oro (20) obtained similar values for white and WF blends; and by Gonzalez et al. (8) reported dry gluten values from 6.5 to 12.7%.

Gluten index values from the tested blends were 88.00-95.00, with no significant differences. According to Vázquez (30), these results characterize the blends as strong flours, which is technologically recommendable for bread baking.

Dextrose equivalent

DE corresponds to the degree of starch hydrolysis. The FR used in this study had a DE of 6.60 mg glucose/ml and a hydrolysis percentage of 46.89% at 90 °C for 15 minutes in DNS solution. Hydrolyzed starch with DE from 8 to 5 is indicated for use as a FR (11). Enzymatic hydrolysis of starch yields maltodextrin with low DE (≤ 6.0), which according to Setser and Racette (25) is similar to native starch resulting in low humectancy, making it appropriate for use as FR because of moisture retention viscosity.

The hydrolysis efficiency found in this study was similar to that reported by Uthumporn et al. (29) (52.6% for 24 h of hydrolysis).

Color

The color properties of the blends are shown in Table 2.

Table 2: Color analysis of the homogenized blends of wheat flour and fat replacer.

Blend	WF (%)	FR (%)	L*	a*	b*
1	35.00	0.60	89.72^{a} ± 0.11	0.53^{d} ± 0.04	8.03^{ef} ± 0.06
2	35.00	2.60	89.71^{a} ± 0.29	0.55^{d} ± 0.06	7.86^{f} ± 0.09
3	85.00	0.60	77.61^{d} ± 1.09	4.07^{a} ± 0.43	10.75^{b} ± 0.20
4	85.00	2.60	80.00^{c} ± 0.86	3.23^{b} ± 0.33	10.16^{c} ± 0.29
5	24.64	1.60	90.86^{a} ± 0.36	0.23^{d} ± 0.04	8.18^{def} ± 0.12
6	95.35	1.60	76.01^{d} ± 1.48	4.30^{a} ± 0.54	11.63^{a} ± 0.37
7	60.00	0.18	85.21^{b} ± 0.36	1.78^{c} ± 0.10	8.61^{d} ± 0.06
8	60.00	3.00	85.83^{b} ± 0.57	1.55^{c} ± 0.17	8.41^{de} ± 0.11
9	60.00	1.60	85.73^{b} ± 0.31	1.64^{c} ± 0.12	8.40^{def} ± 0.08
10	60.00	1.60	85.51^{b} ± 0.66	1.71^{c} ± 0.23	8.47^{def} ± 0.12
11	60.00	1.60	85.42^{b} ± 0.77	1.68^{c} ± 0.25	8.35^{def} ± 0.19
12	60.00	1.60	85.45^{b} ± 0.34	1.68^{c} ± 0.14	8.27^{def} ± 0.08
9-12*	60.00	1.60	85.51^{b} ± 0.31	1.68^{c} ± 0.09	8.37^{def} ± 0.04

Mean values in the same column followed by different letters are significantly different ($p<0.05$). Results expressed as mean of three determinations ± standard deviation. * Average of samples 9 to 12. WF: whole-wheat flour; FR: fat replacer; L*: luminosity; a* and b*: chroma coordinates.

Samples 1 (35WF+0.6FR), 2 (35WF+2.6FR) and 5 (24.64WF+1.6FR), with lower WF content and different FR contents, had significantly higher luminosity values (L* tending to white) than the other samples, even with different FR levels, probably because of the white wheat flour content (Table 2). In samples 7, 8 and 9-12*, even with different levels of FR (0.18, 3.00 and 1.60%, respectively), there was no significant difference in L*, as all samples contained the same percentage (60%) of WF.

However, when WF content increases to 85%, the FR content showed an impact on L*. This was seen in samples 3 (85WF+0.6FR) and 4 (85WF+2.6FR), wherein sample 4 had a higher FR content and higher L* than sample 3 ($p \leq 0.05$). Regarding the a* chromaticity parameter, the samples behaved similarly as for L* (Table 2). The lowest a* chromaticity levels were observed in samples 1 (35WF+0.6FR), 2 (35WF+2.6FR) and 5

(24.64WF+1.6FR), which contained lower WF levels and different FR levels.

As a rule, as WF content increases, so does a* chromaticity. Among samples 7, 8 and 9-12*, which contained 60% WF and different levels of FR, there was no significant difference for the a* chromaticity parameter. However, when WF content was increased to 85%, as in samples 3 and 4 (with 0.6 and 2.6% FR respectively), a* chromaticity was significantly higher in the sample with lower FR content.

Regarding the b* chromaticity parameter, higher values were observed in samples with higher WF content: 11.63 for sample 6 (95.35WF+1.6FR), 10.75 for sample 3 (85WF+0.6FR) and 10.16 for sample 4 (85WF+2.6FR). All samples with a WF content $\leq$ 60 were statistically equal in terms of b* chromaticity, regardless of FR content.

As the WF content increases, the samples become darker, redder and yellower regardless of the FR levels. This is consistent with the findings of Hidalgo et al. (9). These authors suggest the effect of particle size on color attributes of WF. According to Hidalgo and Brandolini (10) flour color is determined by the combination of luminosity (L*) and yellow color (b*) where luminosity is affected by bran content and yellow chromaticity is dependent on carotenoid content.

Scanning electron microscopy

Figure 1 presents images of the fat replacer.

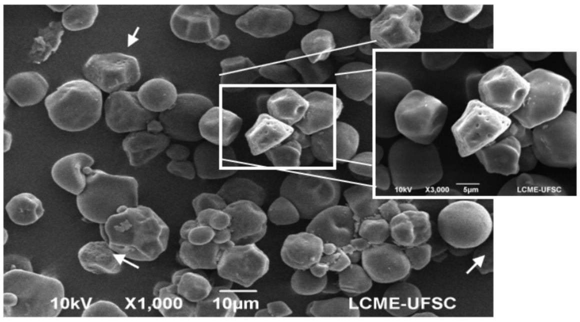

Figure 1: Scanning electron micrograph of the tested fat replacer. Arrow (→) shows evidence of enzyme activity.

There were irregularities in size and shape of the granular structure of the modified starch, as well as the presence of pores and crevices distributed randomly over the surface of the granules, indicating that hydrolysis of the starch granules did not occur evenly as confirmed by Uthumporn et al. (29). Thus, the observed image shows that the starch used as a FR in the present study probably underwent enzymatic attack. Similar images were published by Chen and Zhang (4) and Ma et al. (14).

Rheological evaluation

Farinography and alveography

The results are shown in Table 3.

Table 3: Farinography and alveography of the homogenized blends of whole-wheat flour and fat replacer.

Blend	Farinography			
	WA (%)	MT (min)	ST (min)	MTI (FU)
1	56.80^{h} ± 0.14	9.30^{h} ± 0.14	10.00^{f} ± 0.07	17.50^{b} ± 2.12
2	55.60^{i} ± 0.21	10.00^{g} ± 0.23	9.40^{f} ± 0.28	18.00^{b} ± 1.41
3	62.30^{b} ± 0.42	20.40^{a} ± 0.41	18.00^{b} ± 0.42	16.00^{bc} ± 2.28
4	61.30^{c} ± 0.28	16.20^{b} ± 0.21	17.60^{bc} ± 0.03	7.00^{d} ± 0.71
5	56.00^{i} ± 0.07	9.20^{h} ± 0.07	8.60^{f} ± 0.00	28.00^{a} ± 0.00
6	64.20^{a} ± 0.40	16.70^{b} ± 0.23	21.80^{a} ± 0.06	6.00^{d} ± 0.43
7	58.90^{d} ± 0.26	12.50^{d} ± 0.17	14.60^{de} ± 0.21	11.00^{cd} ± 1.41
8	56.60^{h} ± 0.21	12.35^{d} ± 0.11	12.60^{e} ± 0.23	15.00^{bc} ± 2.83
9	57.70^{fg} ± 0.14	11.70^{ef} ± 0.26	13.90^{de} ± 0.13	9.00^{d} ± 0.25
10	58.10^{ef} ± 0.17	15.00^{c} ± 0.42	17.60^{bc} ± 0.62	11.00^{cd} ± 0.14
11	58.50^{de} ± 0.24	10.50^{g} ± 0.57	14.00^{de} ± 0.49	7.00^{d} ± 0.17
12	57.40^{g} ± 0.04	11.20^{f} ± 0.21	16.90^{bc} ± 0.24	7.00^{d} ± 0.46
9-12*	57,90^{fg} ± 0.21	12.10^{de} ± 0.13	15.60^{cd} ± 0.05	9.00^{d} ± 0.61

Blend	Alveography			
	P (mm H_2O)	L (mm)	P/L	W (x 10^{-4} J)
1	104.0^{bcd} ± 1.4	27.0^{a} ± 0.0	3.85^{d} ± 0.06	124.0^{a} ± 1.4
2	113.0^{cd} ± 2.81	26.0^{a} ± 1.4	4.35^{d} ± 0.35	131.0^{a} ± 2.8
3	120.0^{ab} ± 1.4	11.5^{de} ± 0.7	10.45^{a} ± 0.52	61.0^{c} ± 4.2
4	102.0^{d} ± 1.4	9.5^{e} ± 0.7	10.76^{a} ± 0.65	40.0^{d} ± 0.0
5	103.5^{cd} ± 0.7	28.5^{a} ± 0.7	3.63^{d} ± 0.06	131.5^{a} ± 3.5
6	126.5^{a} ± 7.8	13.0^{cd} ± 1.4	9.75^{ab} ± 0.46	69.5^{c} ± 10.6
7	104.0^{cd} ± 2.8	22.0^{b} ± 1.4	4.73^{d} ± 0.18	104.0^{b} ± 7.1
8	113.5^{abcd} ± 2.1	15.5^{c} ± 0.7	7.33^{c} ± 0.47	76.5^{c} ± 0.7
9	114.0^{abcd} ± 1.4	15.0^{c} ± 0.0	7.60^{c} ± 0.10	76.0^{c} ± 0.0
10	118.0^{ab} ± 1.4	13.5^{cd} ± 0.7	8.75^{bc} ± 0.56	69.5^{c} ± 3.5
11	116.0^{abc} ± 4.2	14.5^{cd} ± 0.7	8.00^{c} ± 0.10	73.5^{c} ± 7.8
12	114.0^{abcd} ± 5.6	14.50^{cd} ± 0.7	7.88^{c} ± 0.78	70.0^{c} ± 2.8
9-12*	115.5^{abc} ± 2.1	14.0^{cd} ± 0.0	8.05^{c} ± 0.29	72.0^{c} ± 1.4

Mean values in the same column followed by different letters are significantly different ($p<0.05$). Results expressed as mean of two determinations ± standard deviation. * Average of samples 9 to 12. WA: water absorption; MT: mixing time; ST: stability; MTI: mixing tolerance index; FU: Farinograph Unit; P: tenacity; L: extensibility; P/L: tenacity/extensibility ratio; W: deformation energy.

In the farinograph parameters, samples with the same WF content and different levels of FR, showed that water absorption decreased significantly and there was no significant difference in stability (Table 3).

Farinograph water absorption values ranged from 55.60 to 64.20% in the WF blends and 59.0% for the white flour. Notice that the whole and white flours used here were obtained from the same batch of grain. These values confirm that the blends are adequate for baking (30).

Increased WF content also increased water absorption and sample retention in the 600 µm sieve, indicating larger particle size due to fragments from the bran. This same statement was made by Seyer and Gélinas (26), Sudha et al. (28), Oro (20) and Noort et al. (18). In the other hand, FR can decrease water absorption (17).

The FR seems to acts as a lipid, plasticizing the dough and coating the protein structure of the gluten and starch granules, preventing them from absorbing water during the mixing process (5).

According to Ortiz and Lafond (21), wheat bran has high water absorption due hemicellulose, cellulose and lignin content with a large number of hydroxyl groups capable of interacting with water through hydrogen bonding. Increased bran particle size results in higher amounts of water needed to hydrate the bread dough (21). However, studies by Noort et al. (18) found that water absorption decreased as the average size of the wheat bran particles in the dough increased.

Dough mixing time ranged from 9.20 to 20.40 min (Table 3). Increasing WF content, increased mixing time. This is consistent with other studies, with increased contents of different fibers, such as β-glucan (27); wheat bran, rice, oats and barley (28). The effect of FR content on mixing time, has not been reported.

The studied flour blends and fat replacement exhibited stability values between 8.60 and 21.80 minutes (Table 3). According to Cauvain (3), white flours technologically indicated for bread making must have stability values of 10.0 to 16.0 min.

The higher the WF content, the higher the stability of the resulting dough, which is consistent with the results of Skendi et al. (27). Some studies (20, 26, 28) have reported the opposite, i.e., increased stability with increasing white wheat flour content. A study with superfine green tea powder particles was demonstrated the impact of size particles on the formation of the gluten network (13).

Mixing tolerance indices ranged from 6.00 to 28.00 FU (Table 3). As the WF content increased, the MTI decreased. This behavior is consistent with a previous study in which content of different fibers, such as wheat bran, rice, oats and barley, reduced the MTI (28).

Alveography showed, tenacity values (P) from 102.0 to 126.5 mm H_2O (Table 3). These results showed a trend toward increased tenacity values with increasing WF content. There was no significant difference in tenacity with the same WF content and different FR levels except between samples 3 (85WF+0.6FR) and 4 (85WF+2.6FR). These results suggest that a greater amount of FR leads to reduced resistance; which consistent with (31) where the addition of inulin and carob to dough, increased tenacity, thereby enabling it to support more fermentation. Similar results for tenacity (P) were found with WF of uniform particle size (20) and hydrocolloids (23).

Dough extensibility (L), ranged from 9.5 to 28.5 mm. The extensibility increased with lower WF content, in accordance to (20).

Tenacity/extensibility (P/L) ratio ranged from 3.63 to 10.76 (Table 3). Among the samples, there was no significant difference in extensibility between samples with the same WF content and different amounts of FR. However, increased WF content, resulted in greater tenacity and lower extensibility, causing increase of tenacity/extensibility ratio, probably due to presence of fibers that cause dilution of the gluten network and increase its resistance to extension. Similar results were found by Oro (20).

Gluten strength (W) values ranged from 40.0 x 10^{-4} to 131.5 x 10^{-4} J (Table 3). There was a significant difference between samples 3 (85WF+0.6FR) and 4 (85WF+2.6FR) probably because increasing FR decreased the deformation energy required to inflate the bubble to the bursting point. In short, the higher the WF content, the lower the gluten strength value. Similar behavior was reported Wang et al. (31) and Oro (20).

Viscosity

The results of the viscosity properties of flour blends and FR are shown in Table 4 and illustrated in Figure 2.

Table 4: Pasting properties of the homogenized blends of wheat flour and fat replacer

Blend	Paste Temp (ºC)	Max Visc (cP)	Min Visc (cP)
1	$50.40^{a} \pm 0.28$	$1032.00^{b} \pm 21.21$	$641.00^{b} \pm 26.87$
2	$50.42^{a} \pm 0.46$	$1207.50^{a} \pm 50.20$	$805.00^{a} \pm 38.18$
3	$50.22^{a} \pm 0.11$	$361.50^{e} \pm 24.75$	$315.00^{ef} \pm 18.38$
4	$50.42^{a} \pm 0.46$	$386.00^{e} \pm 19.80$	$344.50^{def} \pm 17.68$
5	$50.45^{a} \pm 0.42$	$1334.00^{a} \pm 90.51$	$803.00^{a} \pm 84.85$
6	$50.52^{a} \pm 0.25$	$267.00^{e} \pm 0.00$	$224.50^{f} \pm 3.53$
7	$50.25^{a} \pm 0.00$	$669.00^{cd} \pm 9.90$	$469.00^{cd} \pm 48,08$
8	$50.60^{a} \pm 0.00$	$679.00^{cd} \pm 48.08$	$534.00^{bc} \pm 38.18$
9	$50.75^{a} \pm 0.78$	$607.00^{d} \pm 29.70$	$438.00^{cde} \pm 8.48$
10	$50.35^{a} \pm 0.35$	$578.00^{d} \pm 63.64$	$434.00^{cde} \pm 4.24$
11	$51.15^{a} \pm 1.41$	$794.00^{c} \pm 26.87$	$570.50^{bc} \pm 4.95$
12	$55.90^{a} \pm 6.43$	$666.50^{cd} \pm 62.93$	$487.50^{c} \pm 43.13$
9-12*	$52,04^{a} \pm 1,54$	$661,37^{cd} \pm 13,96$	$482,50^{cd} \pm 8,84$

Blend	BD (cP)	Final Visc (cP)	Retrog (cP)
1	$391.00^{b} \pm 5.66$	$1599.0^{ab} \pm 16.97$	$985.00^{ab} \pm 9.90$
2	$402.50^{b} \pm 12.02$	$1843.5^{a} \pm 88.40$	$1038.50^{a} \pm 50.20$
3	$46.50^{d} \pm 6.36$	$1135.5^{de} \pm 57.27$	$820.50^{abc} \pm 38.89$
4	$41.50^{d} \pm 2.12$	$1177.0^{cd} \pm 130.11$	$832.50^{abc} \pm 112.43$
5	$531.00^{a} \pm 5.66$	$1814.0^{a} \pm 121.62$	$1011.00^{ab} \pm 36.77$
6	$42.50^{d} \pm 3.53$	$846.5^{e} \pm 34.65$	$622.00^{c} \pm 31.11$
7	$200.00^{c} \pm 57.98$	$1292.0^{bcd} \pm 107.48$	$823.00^{abc} \pm 59.40$
8	$145.50^{cd} \pm 9.90$	$1464.5^{bcd} \pm 94.04$	$930.50^{ab} \pm 55.86$

9	169.00ᶜ ± 38.18	1250.50ᶜᵈ ± 21.92	812.50ᵇᶜ ± 13.43
10	144.00ᶜᵈ ± 59.40	1249.50ᶜᵈ ± 56.57	815.00ᵇᶜ ± 52.32
11	223.50ᶜ ± 21.92	1478.50ᵇᶜ ± 79.90	908.00ᵃᵇ ± 74.95
12	179.00ᶜ ± 19.80	1352.50ᵇᶜᵈ ± 118.09	865.00ᵃᵇ ± 74.95
9-12*	178,87ᶜ ± 5,12	1332,60ᵇᶜᵈ ± 29,87	850,12ᵃᵇ ± 21,04

Mean values in the same column followed by different letters are significantly different (p<0.05). Results expressed as mean of two determinations ± standard deviation. * Average of samples 9 to 12. Paste Temp: pasting temperature; Max Visc: maximum viscosity; Min Visc: minimum viscosity; BD: breakdown (maximum viscosity minus minimum viscosity at constant temperature); Final Visc: final viscosity; Retrog: retrogradation (final viscosity minus minimum viscosity at constant temperature); cP: centipoise.

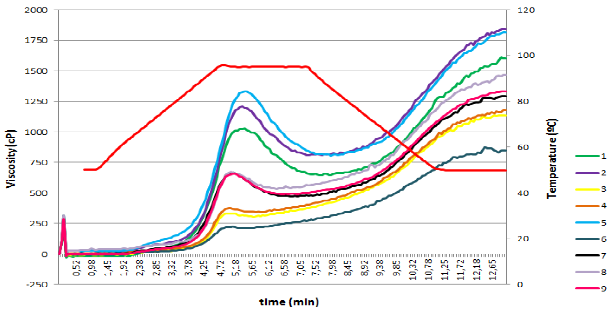

Figure 2: Pasting properties of the homogenized blends of flour and fat replacer. 1, 2, 3, 4, 5, 6, 7, 8 and 9 denote samples of flour blends; sample 9 represents the average from sample 9 to 12.

At first, observing the behavior of the paste properties of the samples, it is clear that paste viscosity values decreased as the WF content increased (Figure 2). However, as shown in Table 4, the pasting temperatures ranged from 50.22 to 52.04%, with no significant differences, suggesting that the samples possessed similar gelling properties as confirmed by Leon et al. (12).

In paste properties parameters, samples with the same WF content and different levels of FR, showed no significant difference in paste viscosity, maximum viscosity, minimum viscosity, breakdown, final viscosity and tendency to retrogradation values (Table 4). The maximum viscosity, minimum viscosity, breakdown and final viscosity tendency to retrogradation values presented a gradual increase as the WF content of the blends decreased ($p \leq 0.05$).

The experimental design followed as Table 1, showing the percentages of whole-wheat flour (%WF) and fat replacer (%FR) as independent variables for each of that treatments. The gluten, farinography, alveography and viscosity results and their significance according to ANOVA and Tukey's test ($p \leq 0.05$) are also included (Tables 1, 2, 3 and 4; Figure 2). In order to enhance the significance of the results of the analysis it is suggested to increase the levels of the fat replacer. That is, with a new experimental design it could be possible to verify the behavior of the fat replacer functioning as a fat mimic, as expected. In this sense, fat affects the gluten network (22), weakening protein interactions as more fat is used, resulting in lower water absorption and mixing time (22) as well as in decreased viscosity values (2).

Conclusion

Gluten content analysis indicates that the flour used in this experiment is strong, technologically amenable to use in bread baking, and has gluten index values within the stated range for commercial flour.

Both dextrose equivalent and starch microstructure analysis showed that the tested FR can be indicated for use in bread manufacturing.

The fiber in WF interfered mainly with the rheological attributes (farinography, alveography, and viscosity) of dough and the color of bread, in proportion to its content.

The effects of the FR were only observed in samples 3 (85WF+ 0.6FR) and 4 (85WF+2.6FR), with high wholegrain flour contents. In these cases, a higher FR content resulted in a reduction of tenacity and mechanical work and an increase in luminosity. This suggests that the FR made the dough more stable (enabling it to support a longer fermentation period) and whiter, thus supporting its use, at the tested concentrations, for manufacturing of WF breads, with the purpose of adding nutritional value and quality for the consumer.

In order to enable a more robust evaluation of the effect of fat replacer content on the rheological analyses, it is suggested to develop a new experimental design with higher levels of fat replacer.

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