

Use of oat fiber with different particle size in baking: rheological and textural effect

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Abstract

The objective of this work was to evaluate the effect of replacing wheat flour (HT) with oat fiber flour (HFA) with different particle size on the rheological, textural and baking properties. The particle size obtained after grinding oat fiber was 250 and 177 μm (microns). The replacement percentages used were 10, 20 or 30%. Flour mixtures were determined color, water retention capacity (CRA) and viscosity profile. The dough was measured for strength and extensibility by the Kieffer test, while the bread was measured for specific volume, water activity and texture profile. The results showed increases in force in the dough when the two fractions of HFA (250 or 177 μm) were used in the substitution of HT with respect to that obtained from HT (0.25 N). In extensibility, the most important increases were observed when 177 μm HFA was used. The specific bread volume was favored when 10 or 20% of HFA (177 μm) was used, observing very similar values between them (4.54 and 4.56 $\text{cm}^3 \text{g}^{-1}$, respectively), without showing significant differences to that obtained from HT (4.57 $\text{cm}^3 \text{g}^{-1}$). The texture profile showed the obtaining of softer breads when HFA (177 μm) was used, in its three different replacement percentages (4.86, 4.71 and 7.05 N), even improved as measured in HT (7.84 N).

Keywords: baking, oat fiber flour, wheat flour.

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Introduction

The development of food products that use compound flours has increased considerably, especially in the production of bakery and pastry products. The production of food based on compound flours can maintain similar characteristics to products made only from wheat flour; however, there are many more positive effects that can be achieved, among them are effects on functional, sensory, rheological, physicochemical properties and even on health benefits due to their nutritional contribution.

Among these vegetable flours used in the replacement of wheat flour in order to improve the nutritional, organoleptic characteristics and even lower production costs are mainly sorghum grain, millet, corn gluten, corn germ flours defatted corn, sprouted cornmeal, oats, rye, triticale, rice, amaranth, tapioca flour, barley and even beer distillates, among others (Chavan *et al.*, 1993). However, the replacement of wheat flour with others, can present important changes to be taken into account.

It has been observed that the substitution of wheat flour decreases the viscoelastic properties of the dough by the dilution of gluten. It is for the above, that substitutions of 10 to 20% have been shown to produce bread of acceptable quality and good organoleptic characteristics without an important impact on the color, crumb structure, texture and shelf life (Seibel, 2006).

Other researchers such as Verdu *et al.* (2015), investigated the effect of replacing wheat flour with chia at levels of 5, 10 or 15%, observing favorable effects on the gas retention capacity of the dough. Other studies have shown positive effects on bread firmness when 10% oatmeal and cornmeal have been used in wheat flour replacement, in addition to favoring the volume of the dough during fermentation. There are many cereals, vegetables or even by-products of the food industry that can be used to replace wheat flour; however, the use of these will depend greatly on the final properties that we wish to generate in the final product.

Oatmeal was used in this investigation, considering that it is the most nutritionally complete cereals, with high protein content (17%) and an important percentage of essential amino acids such as lysine (4.2 g 100 g⁻¹ protein), as well as high content of soluble and insoluble dietary fiber (Serna-Saldivar, 1996). Based on the above, the objective established in this investigation was to evaluate the effect of replacing wheat flour with oat fiber meal with different particle size on the rheological, textural and baking properties.

Materials and methods

Raw material

Wheat flour (HT) and oat fiber flour (HFA) were used. Oat fiber was ground in a Pulvex Mill (Granulator Model, Mexico City). The flour obtained was passed through the 60 (250 µm) and 80 (177 µm) mesh (Dura Tap Sieve Shaker Model DT168, Advantech MFG, New Berlin, WI, USA) meshes to obtain two particle size fractions, the which were mixed with the HT in the proportions of: 10/90, 20/80 and 30/70 (weight/weight).

Flour characterization

Moisture and protein analysis

Moisture and protein contents were determined by the following methods: 44-15.02, 46-13.01 (AACC, 2000).

Color determination

The Colorimeter was used (Konica Minolta Model Chroma Meter CR-400, Minolta Sensing, Inc., Osaka, Japan). The parameters evaluated were: L^* (luminosity), a^* (variation from red to green) and b^* (variation from yellow to blue).

Viscosity analysis

The viscosity profile of the flours was obtained according to method 76-21.02 (AACC, 2000). The Rapid Visco Analyzer Super 4 viscometer, Newport Scientific Australia (RVA) was used. The standard test profile 1 was selected using the ThermoLine software of the RVA.

Texture profile analysis in gels

The gels obtained after measuring the viscosity profile of the flours were measured. These were stored for 24 h at 8 °C. The TA-XT2 Texturometer (Texture Analyzer Stable Micro Systems, Surrey, UK) and the TA-3 device were used. The gel was compressed 50% of its height. The parameters obtained were firmness, elasticity, cohesiveness, rubberiness and chewiness (Verdú *et al.*, 2015).

Water retention capacity (CRA)

The CRA was performed according to method 56-11.02 (AACC, 2000). The calculations were developed according to Haynes *et al.* (2009).

Dough analysis

Strength (F) and extensibility (E)

The dough used was obtained from the Mixograph (National Mfg. Co. Lincoln, NE, USA), according to method 54-40.02 (AACC, 2000). The determination of F and E was performed following the technique described by Kieffer *et al.* (1998) at a test speed of 3.3 mm s⁻¹, with a texture analyzer (TA-XT2, SMS/Kieffer dough extensibility Rig Stable Micro Systems, Godalming, Surrey, England).

Bread analysis

Baking process

The baking process was carried out by method 10-10.03 (AACC, 2000). The ingredients (flour, yeast, sugar-salt solution, vegetable shortening and water) were mixed in the Mixograph bowl until the optimum kneading time. The obtained dough was introduced into a fermentation chamber at 30 °C and 90% RH for 40 min, then it was subjected to cooking at 215 °C for 17 min.

Physical properties of bread

Bread weight

The bread was weighed on a scale (Sartorius Basic Model BA 210, Göttingen, Deutschland) after baking.

Volume measurement

The volume of the bread was calculated by the method of displacement with the rapeseed seed.

Texture profile analysis in bread

The bread was cut into slices 1.5 cm thick. The TA-XT2 Texturometer (Texture Analyzer Stable Micro Systems, Surrey, UK) and the TA-40 device were used. The test speed was 1.7 mm s⁻¹ to compress the slice 50% of its height. The parameters obtained were firmness, elasticity, cohesiveness, rubberiness, chewiness and resilience (Verdú *et al.*, 2015).

Water activity (a_w)

From the crumb of the cold bread a disk of 4 cm in diameter and a thickness of 5 mm was taken. The AquaLab equipment (Dew Point Water Activity Meter 4TE, Pullman, WA, USA) was used to perform the analysis (Vásquez, 2016).

Statistical analysis

The design of experiments was completely randomized by one factor, the degree of replacement of HFA in HT. The results were analyzed by applying a multiple comparison procedure to determine which means are significantly different from others with a level of significance of 95%. To discriminate between the means, Fisher's minimum significant difference (LSD) procedure was used. Statistical analysis was carried out with the Statgraphics Centurion XVI Program.

Results and discussion

Flour analysis

Moisture, protein and color analysis of the flours

The results of moisture, protein, water retention capacity (CRA) and flour color are shown in Table 1. An increase in protein value was observed as the (%) substitution with fiber meal was increased. of oatmeal (HFA). This was more evident when the particle size of said flour was 177 μm (microns), reaching protein values of 13.51% with a difference of 1.56% greater than that determined in wheat flour (HT). In flours, this component is very important because of the capacity it shows in water retention, which can affect the functionality of the flours.

Table 1. Moisture, protein and color content of wheat flour (HT) and oat fiber meal flour (HFA) in different percentages with different particle sizes.

Flour	Size particle (μm)	Humidity (%)	Protein (%)	CRA (%)	Color		
					L*	a*	b*
HT	177	10.15	11.95	66.63 \pm 0.77 ^c	94.61 \pm 0.22	0.14 \pm 0.01	7.58 \pm 0.11
HT-HFA 10%	250	10.56	12.34	69.43 \pm 0.9 ^d	93.75 \pm 0.02	0.12 \pm 0.03	7.64 \pm 0.13
HT-HFA 20%	250	10.22	12.73	77.52 \pm 0.57 ^e	92.94 \pm 0.05	0.27 \pm 0.02	7.81 \pm 0.02
HT-HFA 30%	250	10.09	13.12	89.89 \pm 1.04 ^f	92.39 \pm 0.09	0.31 \pm 0.02	8.06 \pm 0.15
HT-HFA 10%	177	10.51	12.47	63.43 \pm 0.61 ^a	94.15 \pm 0.12	0.13 \pm 0.01	7.59 \pm 0.11
HT-HFA 20%	177	10.04	12.99	62.44 \pm 0.61 ^a	93.74 \pm 0.23	0.15 \pm 0.01	7.85 \pm 0.03
HT-HFA 30%	177	10.26	13.51	64.88 \pm 0.42 ^b	93.53 \pm 0.35	0.19 \pm 0.04	7.91 \pm 0.15

HT= wheat flour; HFA= oat fiber flour; μm = microns; CRA= water retention capacity; L= luminosity; a= red to green; b= yellow to blue; (%)= level of replacement of HT with HFA. The percentage of protein is expressed on a dry basis.

However, in the bakery process not only a (%) high protein of the flours is important, so is the quality of these. This results in the formation of a gluten (gliadin and glutenin) with better viscoelastic properties with the possibility of forming a bread with a better specific volume, higher and rounded loaf. In general, it is assumed that a high presence of proteins and a special quality of bread shows that the viscoelastic properties of proteins are sufficient to explain the good volume of bread (Kieffer, 1998).

In the case of color, a decrease in L was observed with increasing % substitution for the two HFA particle sizes. Otherwise, it happened with the value of a and b.

This same behavior was observed by Hidalgo *et al.* (2014) in HT when the evaluation was carried out in flours with a size of 200 μm . Flour color parameters may be influenced by carotenoid content and genotypic characteristics, in addition to environmental conditions, grinding and storage conditions, among others.

With respect to CRA, significant increases were observed when the HFA used in the substitution of HT was 250 μm in particle size, even higher values were obtained than in HT (66.63%). The opposite happened when 177 μm HFA was used, observing values closer to that obtained in HT. Berton *et al.* (2002) attributed this behavior to the degree of grinding and the method used for grinding. In addition, they observed that the variation in the content of damaged starch, as well as the source of obtaining the flour are one of the most important factors in the variation of the CRA in the flours.

Viscosity analysis

The viscosity profile of the flours is observed in Table 2. The results obtained showed significant differences in the gelatinization temperature, observing differences of 16.68 $^{\circ}\text{C}$ to 20.23 $^{\circ}\text{C}$ for the flour mixtures with respect to HT. The swelling of the starch granule begins at the moment when the granule begins to hydrate being this an essential precursor for gelatinization, also when the starch is subjected to heat treatments in an aqueous environment undergoes a series of changes, absorbs water and swells breaking the crystalline structure forming a continuous gel.

Table 2. Viscosity profile of wheat flour (HT), and flours substituted with oat fiber meal (HFA) in different percentages with different particle size.

Flour	Size particle (μm)	Jelly Temperature ($^{\circ}\text{C}$)	Viscosity (cP)				
			Initial	Final	Minimum	Breaking	Restitution
HT	177	69.38 \pm 0.02 ^a	2255 \pm 32.1 ^b	2787 \pm 31.8 ^d	1607 \pm 78.2 ^b	648 \pm 53.9 ^b	1180 \pm 46.4 ^b
HT-HFA 10%	250	89.61 \pm 0.87 ^d	1138 \pm 85.5 ^a	1649 \pm 74.6 ^a	822 \pm 62.1 ^a	316 \pm 24.8 ^a	826 \pm 23.1 ^a
HT-HFA 20%	250	86.06 \pm 0.44 ^b	2846 \pm 75.2 ^c	3522 \pm 14.4 ^e	1787 \pm 37.9 ^{cd}	1059 \pm 38.8 ^e	1734 \pm 48.6 ^e
HT-HFA 30%	250	86.61 \pm 0.46 ^b	2847 \pm 70.4 ^e	3764 \pm 87.3 ^f	1823 \pm 39.9 ^c	1024 \pm 33.5 ^{de}	1941 \pm 54.5 ^f
HT-HFA 10%	177	86.36 \pm 0.07 ^b	2587 \pm 6.65 ^c	3184 \pm 4.7 ^c	1721 \pm 35.5 ^c	866 \pm 28.9 ^c	1463 \pm 40.1 ^c
HT-HFA 20%	177	87.48 \pm 0.44 ^c	2737 \pm 52.7 ^d	3378 \pm 65.2 ^d	1753 \pm 69.6 ^{cd}	984 \pm 61.2 ^d	1625 \pm 58.1 ^d
HT-HFA 30%	177	88.05 \pm 0.05 ^c	2830 \pm 21.1 ^{de}	3596 \pm 25.7 ^e	1813 \pm 55.8 ^{cd}	1016 \pm 44.1 ^{de}	1782 \pm 80.1 ^e

HT= wheat flour; HFA= oat fiber flour; μm = microns; cP= Centipoise; (%)= level of replacement of HT with HFA. Means with the same letter within the column are not significantly different $p < 0.05$.

Studies conducted by Hüttner *et al.* (2010) worked with three different oatmeal to evaluate their baking capacity, which were analyzed in their viscosity profile obtaining gelatinization temperature values (82.37 to 83.57 $^{\circ}\text{C}$) very similar to those obtained in this study. This gelatinization behavior was attributed to the amount of starch and the damaged starch in the flours, as well as the particle size. With regard to the initial and final viscosity, fundamental parameters in the rheological behavior of the flours, the tendency to increase was observed as the level of HT substitution increased.

This was best appreciated when 250 μm HFA was used in the replacement of 30% HT. The initial viscosity is related to a combination of the swelling of the starch granules and the rate of breakage of the granules. Flours with high swelling capacity of their starch granules tend to have a high

initial viscosity. With regard to the final viscosity, increases in this parameter are associated with the formation of a gel during cooling due to a re-association between starch molecules, mainly by amylose generating increases in the final viscosity (Lei *et al.*, 2008).

Parameters such as minimum viscosity, rupture and restitution showed a tendency to increase as the % substitution increased, this happened for the two HFA particle sizes (250 and 177 μm) used in this study. These parameters mentioned above are the result of a complex interaction between flours and water, affected by temperature and time and are frequently altered by the same flour by changing the time or temperature of the different stages.

Texture profile analysis in gels

Table 3 shows the texture results performed on the gels obtained during the viscosity analysis. The gel formed at the end of the RVA cooling cycle is essentially a three-dimensional network of intertwined amylose molecules that incorporate swollen, broken and dispersed starch granules. Baxter *et al.* (2004), observed an important relationship with the final viscosity of the gel and the reduction of firmness and adhesiveness. However, in our study, although if significant differences were observed in the initial and final viscosity of the gels obtained from the different flours, a behavioral pattern was not observed.

Table 3. Texture profile of the gels obtained from the viscosity profile of wheat flour (HT) and oat fiber meal flour (HFA) in the different percentages with different particle size.

Gel	Particle size (μm)	Firmness (N)	Elasticity	Cohesiveness	Rubberiness	Chewiness
HT	177	20.33 \pm 6.08 ^d	1.11 \pm 0.15 ^b	0.52 \pm 0.01 ^{ab}	10.72 \pm 3.32 ^c	11.68 \pm 2.05 ^c
HT-HFA 10%	250	3.4 \pm 0.26 ^a	0.97 \pm 0.01 ^a	0.45 \pm 0.07 ^a	1.21 \pm 0.24 ^a	1.51 \pm 0.35 ^a
HT-HFA 20%	250	14.72 \pm 4.58 ^c	0.96 \pm 0.01 ^a	0.51 \pm 0.02 ^{ab}	7.42 \pm 2 ^b	7.17 \pm 1.9 ^b
HT-HFA 30%	250	10.15 \pm 1.21 ^{bc}	0.97 \pm 0.01 ^a	0.53 \pm 0.03 ^b	5.38 \pm 0.34 ^b	5.24 \pm 0.31 ^b
HT-HFA 10%	177	4.89 \pm 0.14 ^{ab}	1 \pm 0.01 ^{ab}	0.52 \pm 0.02 ^{ab}	2.54 \pm 0.03 ^a	2.55 \pm 0.06 ^a
HT-HFA 20%	177	3.22 \pm 0.61 ^a	0.97 \pm 0.01 ^{ab}	0.48 \pm 0.01 ^{ab}	1.58 \pm 0.33 ^a	1.54 \pm 0.33 ^a
HT-HFA 30%	177	14.18 \pm 0.23 ^c	0.94 \pm 0.01 ^a	0.53 \pm 0.03 ^b	7.55 \pm 0.33 ^b	7.08 \pm 0.25 ^b

HT= wheat flour; HFA= oat fiber flour; μm = microns; N= Newton; (%)= level of replacement of HT with HFA. Means with the same letter within the column are not significantly different $p < 0.05$.

The firmness measurement showed significant differences between the gels obtained from the different flour mixtures and that of HT, examining in the latter the highest value for this firmness parameter. Regarding elasticity, significant differences were observed between HT and the values of the gels obtained when using 250 μm HFA in the substitution of HT. Contrary to this, the determination of cohesiveness showed no significant differences. On the other hand, the gum and chewable results did show significant differences between the gels obtained from the different substitutions; however, these differences were more evident when compared with the values obtained from HT.

The previous behavior observed for this texture profile may have been influenced by the concentration of starch, protein, time and temperature, agitation, as well as particle size that are determinants in the viscosity profile of the flours, which results in influencing in the resulting gel that was used to measure the texture profile.

Dough analysis

Strength (F) and extensibility (E)

The results of F and E are shown in Figure 1. The F increased in all the doughs obtained from the flour mixtures that were made with HFA and HT in the different (%) substitution, being more evident when HFA was used (250 μm) at 30%, registering values of 0.61 N, more than double that obtained from HT (0.25 N). Similar values were also observed in this parameter of F when HFA (177 μm) was used, obtaining values with ranges from 0.32 to 0.39 N. The most similar ones (0.33 and 0.32 N) were obtained in the substitutions of 20 and 30%, respectively.

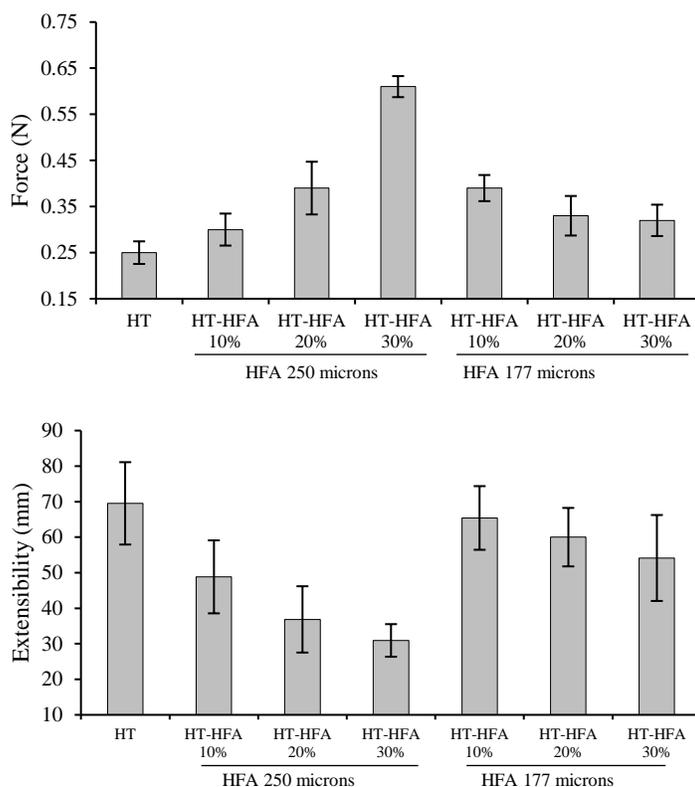


Figure 1. Strength and extensibility of the dough obtained from wheat flour (HT) and the flours substituted with oat fiber flour (HFA) in the different percentages with different particle size.

The strength of the dough can be a determining factor in the quality of bread. The lack of strength or excess of it is capable of causing problems of regularity in the quality of bakery products. Important factors that can influence this parameter are the quantity and quality of the gluten present in the flours, as well as the kneading conditions. Studies conducted by Islas *et al.* (2005), found

that the extensibility and strength of the dough depends to varying degrees on the protein composition, the total amount of glutenin in the flours and the proportion of polymeric and monomeric proteins.

In the case of E, a very particular behavior was recorded when HFA (250 μm) was used, the E tended to decrease as the (%) substitution increased, an inverse behavior to that of F. The lowest values (30.94 mm) were observed when the substitution was 30%. This same behavior was also observed when HFA (177 μm) was used. The tendency was to decrease as was the replacement with HFA (250 μm); however, not in the same magnitude. The 30% substitution (54.14 mm) with HFA (177 μm) showed values of more than 23 mm difference with respect to the same percentage of substitution with HFA (250 μm).

The industrial characteristics of the dough such as strength and extensibility, and the quality of the final product derived from wheat are partially determined by the amount of protein. Important effects on extensibility are determined by high molecular weight and low molecular weight glutenins, in addition to gliadins, protein fractions found in cereals. However, the high molecular weight of glutenins is not only the reason for the appearance of extensibility. It is the fact that gluten proteins are exceptionally cohesive, mainly due to their ability to form hydrogen bonds between the side chains of the amino acid glutamine, which accounted for 35% of all residues (Kieffer, 1998).

In general terms, it was observed that the highest values in extensibility (69.52, 65.41 and 60.01 mm) together with force values of 0.25, 0.39 and 0.33 N respectively, were the doughs that produced the highest specific volumes of bread.

Bread analysis

Physical properties of bread

Among the physical properties analyzed in bread were weight (g), volume (cm^3), specific volume ($\text{cm}^3 \text{g}^{-1}$) and water activity. These results are observed in Figure 2. Regarding the weight of the bread that has an important relationship with the loss of dough during cooking, this is the loss of water after the bread is made. Studies conducted by Verdú *et al.* (2015) with chia flour at different replacement percentages (5, 10 and 15%) of wheat flour obtained a reduction in the weight loss of bread by increasing the degree of substitution.

In our study this behavior was not observed, contrary to this a minimum increase (1.48 g) of the bread weight was obtained when using HFA (250 μm) at a replacement level of 30%, with respect to that obtained from HT (47.69 g). In contrast, when using HFA (177 μm) at the same substitution level of 30%, a tendency to decrease (47.61 g) was analyzed, although very close to that obtained in HT. On the other hand, when the bread volume was analyzed, a decrease in this was obtained by increasing the (%) substitution with HFA, this was more evident when the 30% substitution was made with 250 μm HFA (116.65 cm^3) with regarding the elaborated only of HT (217.68 cm^3).

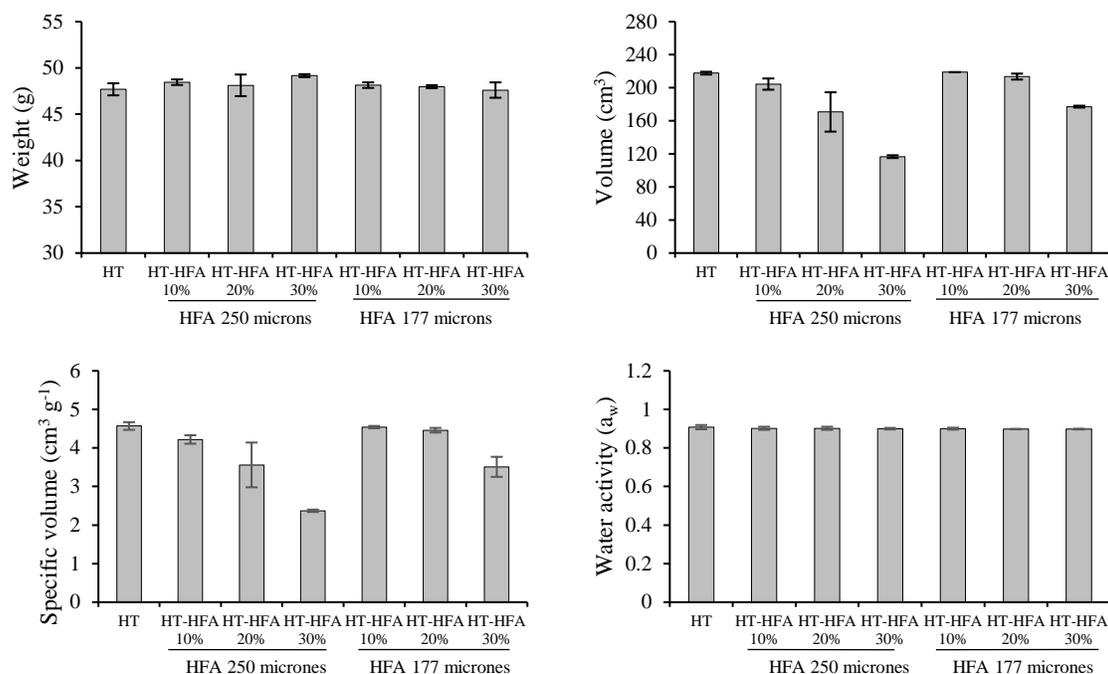


Figure 2. Weight (g), volume (cm³), specific volume (cm³ g⁻¹) and water activity (a_w) of bread obtained from wheat flour (HT) and flours replaced with oat fiber meal (HFA) in different percentages with different particle size.

It was also noted that when HFA (177 μm) was used at 10 or 20% (218.88 and 213.56 cm³, respectively) in the replacement of HT, the values obtained were very similar to those of HT. This is possible to explain how a dilution of HT gluten by increasing the % substitution with HFA. The optimal development of gluten is vital for the development of bread and crumb structure, this has an important relationship with the specific volume of bread.

Regarding the specific volume, important improvements were registered when 177 μm HFA was used, the smaller particle size favored the substitutions at 10 or 20% of HT, observing values very similar to that obtained from HT (4.57 cm³ g⁻¹). This parameter is influenced by the quality and quantity of the proteins capable of forming a gluten with good viscoelastic characteristics and doughs with force to encapsulate the air generated during the fermentation process.

Finally, regarding the water activity of the breads obtained from the different mixtures, we can say that no significant changes were observed, values of around 0.9 were reached, value considered as normal in baking.

This parameter is important to keep below 0.95 to avoid the rapid development of fungi and yeasts that could affect the shelf life of the product. Studies conducted by Verdú *et al.* (2015) when making bread with mixtures of wheat flour and chia obtained values higher than those found in our study with ranges from 0.96 to 0.98.

Texture profile analysis

The texture profile of the loaves obtained is presented in Figure 3. This analysis is a technique that tries to use common bases for the subjective and objective methods used to estimate the quality associated with palatability/chewiness. Breads with lower or softer firmness values were obtained when 177 μm HFA was used in the replacement of HT in the 3 different % substitution (4.86, 4.71 and 7.05 N, respectively), otherwise this happened when 250 μm HFA was used, the above was more evident when the substitution occurred at 30% (57.39 N).

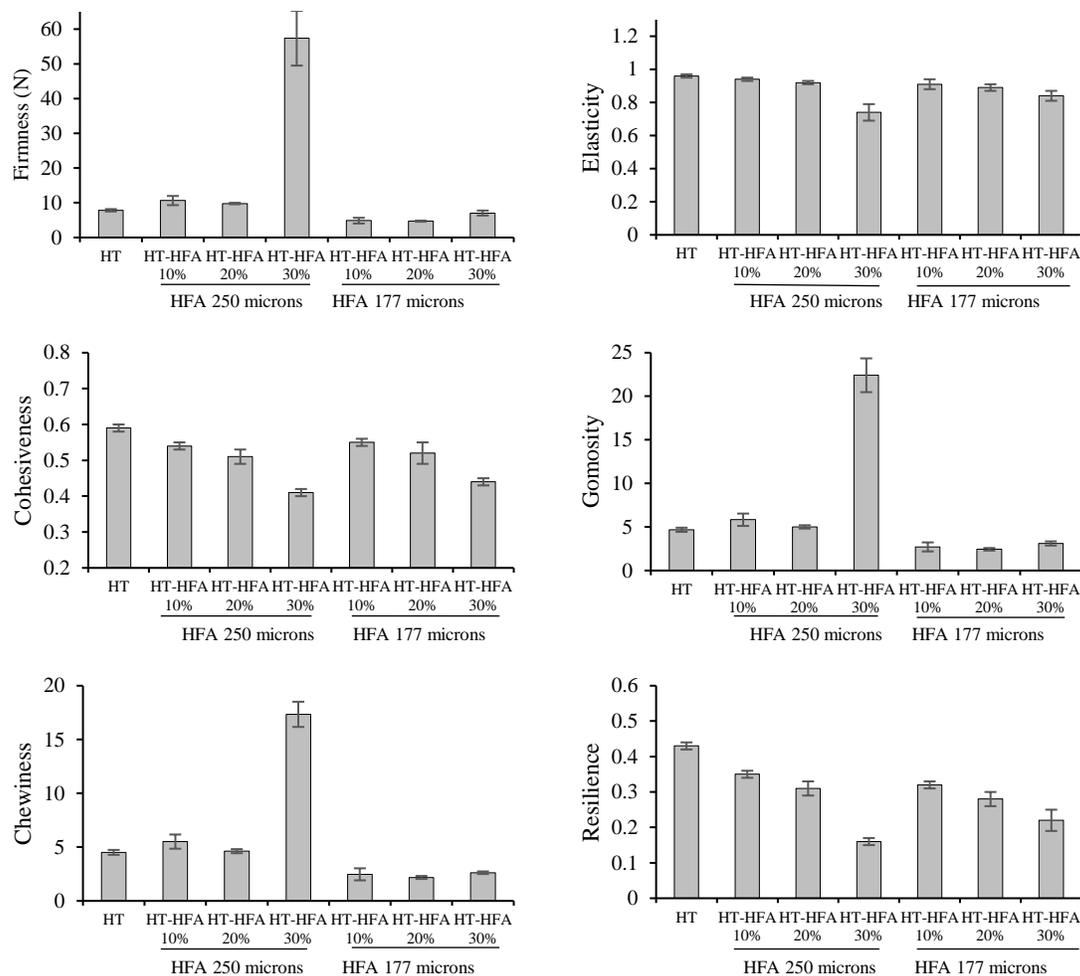


Figure 3. Texture profile of the bread obtained from wheat flour (HT) and the flours substituted with oat fiber flour (HFA) in the different percentages with different particle size.

Studies conducted by Gianonne *et al.* (2016) related to the aging of wheat bread, they observed that high firmness values were attributed to a low fermentative capacity along with the low gluten content and the excessive tenacity of gluten. With regard to elasticity and cohesiveness, these parameters showed a tendency to decrease as the % substitution for the two HFA particle sizes (250 and 177 μm) increased.

In addition, they found that the cohesiveness of bread is related to the degree of integration of the flour components in the dough matrix. As regards gum and chewiness, they did not show significant differences when HFA (177 μm) was used in the three % substitution; however, if there was a tendency to increase with increasing % substitution with HFA (250 μm), this could be better appreciated when it was used at 30%, observing values of 22.41 and 17.34, well above those found in HT (0.59 and 4.68, respectively) for these same parameters.

Regarding gum, studies by Bhol and Bosco (2014), observed important effects in this parameter with the influence on the water absorption capacity and variations in the chemical composition of breadcrumbs. With regard to chewiness, studies conducted by López and Goldner (2015), observed an important relationship with the level of dehydration of the crumb. At higher dehydration, crumbs showed lower chew values. Finally, the resilience parameter showed the same trend as cohesiveness.

There was a decrease by increasing the (%) substitution for the two particle sizes (250 and 177 μm) of HFA used in this study. This decrease was most noticeable when using HFA (250 μm) to replace HT in 30%. Studies carried out by Vásquez (2016), observed this same behavior when in making bread used oatmeal, corn or sorghum in the replacement of wheat flour.

The above may be related to the decrease in CRA of flour mixtures by increasing the (%) replacement of HT. Studies conducted by López and Goldner (2015) concluded that the parameters related to the bakery texture profile are determined by the quality, variety and chemical composition of the flours involved in the bakery process.

Conclusions

The use of HFA of a smaller particle size (177 μm) in the replacement of HT at 10 or 20%, favored a better balance of strength and extensibility in the doughs, as a consequence of this it was the obtaining of breads with very similar volume to the elaborated only of HT. Softer breads were also obtained when this same HFA particle size was used in the three % substitution, it even improved to that obtained only HT, regardless of whether the CRA observed in these flour mixtures has been less than quantified in wheat flour.

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