

Changes on Dough Rheological Characteristics and Bread Quality as a Result of the Addition of Germinated and Non-Germinated Soybean Flour

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Abstract The increasing interest in functional and healthy food products has promoted the use of germinated soybean flour in the manufacture of foods for human consumption. Considering the beneficial effects of soy and its germination, farinograph and extensograph were used to study the effect of adding defatted flour of germinated (32 °C, 72 h) or non-germinated soybean—at different dry protein ratios (0, 0.5, 1.0, 1.5%)—to wheat flour on: water absorption (WA), maximum consistency time (MCT), dough stability (S), maximum resistance to extension (R_{\max}), and dough extensibility (L). Baking tests (straight-dough procedure) were also performed to evaluate the effect of this addition on bread characteristics: loaf volume, texture (firmness, compression force, resilience), color (L^* , a^* , b^*), crumb-grain structure (cell density, mean cell area, shape factor), and consumer acceptance (sensory analysis). Addition of both kinds of soybean flours increased the values of farinographic parameters (WA, MCT, S), although they did not have significant effects ($p > 0.05$) on extensographic properties (R_{\max} , L). Loaf volume and crumb color were improved as soy flour addition was increased, whereas crust color was not affected ($p > 0.05$). Texture analysis showed that the addition of soy flour produced breads similar or better than the control, whereas the addition of GSF produced a coarser crumb grain. No detectable differences

were found among samples during the sensorial analysis. Germinated soybean flour was better to improve dough breadmaking properties.

Keywords Germinated soybean · Rheological properties · Bread · Digital image analysis

Introduction

Soybeans are an economically important crop, which serve as a source of good-quality protein for animals and humans. The seeds contain up to 48% protein and also contain bioactive proteins including alpha-amylase and lipoxygenase which are considered very useful for the breadmaking process (Friedman and Brandon 2001). Moreover, the essential amino acid content in soybean exceeds the amino acid requirements of children and adults, which confirms the protein quality of this legume (Steinke 1991).

Germinated legumes are increasingly being used in many countries because they are a good source of vegetable proteins. It is known that during germination, a sequence of metabolic changes are triggered, improving the nutritional quality of germinated legumes as a result of an increase in the bioavailability of proteins, vitamins, carbohydrates, polyvalent minerals, and free limiting amino acids (Oloyo 2004) and a decrease in the anti-nutritional factors such as trypsin and chymotrypsin inhibitors (Sathe et al. 1983). In soybeans, the germination process also increases, among others, alpha amylase, lipase, and alpha galactosidase enzyme activities, whereas lipoxygenase activity is reduced (Adams et al. 1981; Bau et al. 2000). Furthermore, the

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lecithin content increases gradually and slightly during germination (Bau et al. 2000) and so does the ascorbic acid content (Bau et al. 1997).

Bread quality depends on the wheat flour quality and the breadmaking process conditions. Millers and bakers use various kinds of functional additives such as enzymes, bleaching agents, oxidants, emulsifiers, and dough strengtheners, among others (Stauffer 1990), to help stabilize and bring uniformity to the flour, the dough, or the bread. Some of these compounds (alpha amylase, lipase, lipoxygenase, lecithin, and ascorbic acid) are naturally found in sprouted soybeans, so the possibility of using germinated soybean flours as a natural baking additive may be an alternative to substitute chemical additives in breadmaking, which could bring an additional value to the already known nutritional improving effect of this seed.

The aim of this work was to evaluate the effect of the addition of germinated and non-germinated soybean flour on dough rheological characteristics and bread quality.

Materials and Methods

Material

Soybean seeds (*Glycine max* v. Hutchenson) from 2005 harvest (Sonora, México) were used. Commercial low protein wheat flour (10.2% protein ($N \times 5.7$), 0.56% ash, 55.0% farinographic water absorption) with no additives was utilized. This kind of flour is recommended for non-mechanical dough development processes of breadmaking. All other ingredients: table salt, sugar, skim milk powder, dry instant yeast, and vegetable fat were commercial grade.

Whole Soybean Flour Preparation

Soybean seeds were rinsed with tap water (30 s) and dried overnight in an oven (Afos mini klin, Hull, England) at 24 °C to a final moisture content of $8 \pm 0.5\%$. Dry seeds were milled in a Glen Creston micro hammer-cutter mill (Stanmore, Middlesex, UK), and flour was sieved through a 25 mesh ($\leq 710 \mu\text{m}$). Sieved flour was defatted with hexane (1:5 w/v) by stirring the suspension during 1 h at room temperature (22–25 °C). This extraction procedure was repeated four more times. Hexane was decanted, and defatted flour was dried at room temperature. Defatted whole soy flour presented a protein content of $43.6\% \pm 0.3$ ($N \times 6.25$ db).

Germinated Soybean Flour Preparation

Germination procedure was done as reported by Gómez and López (2002) with some modifications. Seeds were rinsed

with tap water, sanitized by soaking them in a 0.5% sodium hypochlorite solution (during 15 min), and rinsing again with sterilized water. Soybeans were spread on a tray that had been covered with a sterile cotton layer, and then they were moistened (400 ml of sterilized water per 120 g of soybean seeds). The tray (seedbed) was covered to avoid moisture loss in the seeds. They were incubated to germinate for 72 h at 32 °C in a controlled temperature chamber (Hotpack Incubator, 305310, USA). The germinated seeds were dried in a fluid bed dryer (Johnson Matthey FBD/L72, England) during 3 h (flow air 1.2 m³/min, 24 °C) and later in an oven (Afos mini klin) at 24 °C overnight to a final moisture content of $8 \pm 0.5\%$. Milling and oil extraction of the germinated flour were done as described for whole soybean flour. Germinated defatted flour had a protein content of $44.8\% \pm 0.4$ ($N \times 6.25$ db).

Wheat–Soy Flour Samples Preparation

Whole and germinated soybean flours were added to wheat flour at three levels of addition. Added amounts of these flours were calculated based on soybean flour protein contents to represent an incorporation of 0.5, 1.0, and 1.5% of protein from each type of soybean flour. These protein concentrations were based on the results reported by Güemes-Vera et al. (2004). A control sample prepared with wheat flour was also used.

Bread Formulation

Bread formulation ingredients included: 100 g (14% mb) flour samples, 6 g sugar, 3 g shortening, 4 g skim milk powder, 1.6 g instant dry yeast, and 2.5 g of salt. Water addition for each bread sample was based on farinographic percentage of absorption of flours for a dough farinographic consistency of 500 Brabender Units (BU) as recorded on the farinogram. (Calderón-Domínguez et al. 2003).

Farinographic Measurements

A farinogram for each soybean–wheat flour and a farinogram for each bread formulation were performed in a 300-g Brabender Farinograph (Brabender OHG, Duisburg, Germany) following the procedure recommended by the manufacturer. Bread formulations were analyzed to determine the mixing times required to get the optimum dough development for the breadmaking process. Selected responses were: water absorption (WA), maximum consistency time (MCT), and dough stability (S). MCT is defined as the time when farinographic curve starts to fall, changing its slope when the dough softening begins (Calderón-Domínguez et al. 2003).

Extensographic Measurements

Extensographic parameters were measured with a Brabender Extensograph (Brabender OHG) according to the manufacturer's procedure. Only soybean–wheat flour samples were analyzed in this equipment. Extensographic measurements included: maximum resistance to extension (R_{\max}) and extensibility (L). R_{\max} is reported in BU, whereas L is reported in millimeters. Extensographic measurements were taken after dough resting times of 45, 90, or 135 min.

Breadmaking Procedure

The optimized straight-dough breadmaking method (Method 10-10B; AACC 2000), at the water level of farinographic absorption, was used to evaluate the effect of different levels of addition of soybean flour on the loaf quality (volume, texture, color, crumb–grain structure, and consumer acceptance). All dry ingredients were mixed for 1 min, adding water (30 °C) after such time. Dough was mixed in a minor pin mixer (Henry Simon Limited, Cheshire UK) for the time obtained from the farinographic evaluation of bread samples (MCT). After mixing, dough was weighed (40 g), rounded by hand, and placed into an adapted fermentation chamber (Precision Scientific, USA) at constant temperature (32 °C) and humidity (85%). A 40-g dough sample was selected after comparing it to a 171.4-g loaf bread sample (100 g flour) in which similar results were obtained. The fermentation process was divided into three fermentation steps and one proving step. The first step was 80 min long, and after that, the dough was rounded by hand and kept resting 40 min more. Dough was rounded by hand again and put back into the fermentation chamber for 25 min. Dough was later punched, rounded, molded, placed into a baking pan (aluminum pudding mold), and left resting for 55 min. Bread was baked at 210 °C for 20 min in a rotary oven (Henry Simon).

Loaf Specific Volume

Loaf weight was measured immediately after baking, whereas loaf volume was evaluated 120 min later using the rapeseed displacement method. Specific volume is the ratio between loaf volume and loaf weight expressed in cubic centimeter per gram of loaf.

Crumb Quality

Crumb quality was evaluated through a digital image analysis (DIA) method. DIA was carried out using a system composed of a personal computer (Intel Pentium M 1, 60 GHz, 504 MB ram, 80-GB hard disk Toshiba-Satellite Japan), a flat-bed scanner (Benq Corporation, 5000 Colour Scanner, the USA),

and three different software packages: MiraScan, (Benq), ImageJ (National Institutes Health, Bethesda, MD, USA), and SigmaScan Pro Image Analysis 5.0 software (Jandel Scientific, USA).

Loaf samples were analyzed 24 h after baking. They were kept inside polyethylene hermetic bags to avoid moisture loss until analysis was carried out. Samples were cut transversally into two 2.5-cm-thick slices using an electric knife (Moulinex Classic 012, France). Bread crumb images were obtained by scanning the samples with the flat-bed scanner. Brightness and contrast parameters of the scanner program were kept in the default value of the program (zero) for all samples. Images were saved as bitmap files, with a 300 DPI resolution and in real-color format (RGB, 256 million colors). Images were cropped (Image J) to a field of view of 420×420 pixels. The cropped color images were duplicated and one of each was converted into an 8-bit grayscale image. The grayscale images were thresholded with the Otsu algorithm (Gonzales-Barrón and Butler 2006) using the imageJ software. Measurements were carried out using the Sigma Scan Pro 5.0 software to get the total cells number of the cropped image, the pore size (overall mean cell area), the number of pores per square centimeter (cell density), and the circularity of pores as a shape factor. A perfect circle has a shape factor of 1.0, whereas a line has a shape factor approaching zero (Aguilera 2001). All measured parameters were extracted to an electronic spreadsheet by the software. The final data were processed in Excel 2000 software (Microsoft Office Corporation, USA).

Color

Color was evaluated in the crust as well as in the crumb using a Colormate-HDS spectrophotometer (Milton Roy, USA) with a D65 illumination source at a 10° observer angle. Color was measured on five different points on each sample, taking them in the central and outward parts of the loaf, avoiding its edges. Luminosity (L^*) and chromaticity ($\pm a^* y \pm b^*$) were evaluated (Calderón-Domínguez et al. 2005).

Crumb Texture Analysis

Loaf bread samples were kept inside polyethylene hermetic bags until analyses were performed 18 h after baking. The loaf crust was cut off to obtain a 4-cm height sample, allowing only crumb texture measurements. A double compression test was carried out using a texture analyzer-TX2 (Stable Micro Systems, UK). Compression was achieved through a 1.5" (3.81 cm) diameter acrylic cylinder probe (TA-11) which covered almost the total surface of the product. Cross head's speed was set at 1.8 mm/s, and bread

was compressed to 50% of its original height. Double compression test renders two curves (force vs time) and different textural parameters such as compression force, firmness, total compression work, and resilience (manufacturer's specifications). The compression force at 50% (Kgf units) is the highest point of the first curve. Firmness is the necessary force (Kgf units) to start deforming the product, and it is represented by the height of the first curve at its first inflection point. Resilience represents the capacity of the product to return to its original height after the second compression: the nearest the value of resilience gets to 1, the less capability of the product to get its original height back.

Sensorial Analysis

Two different sensorial evaluations were carried out. A closeness to a reference standard test and a multi-sample likeability rating test (Pedrero and Pangborn 1989). Both tests were performed with a panel that consisted of 100 non-trained personnel of different ages (17–50 years old). Loaf samples were sliced with an electric slicing knife (Moulinex Classic 012, France), discarding crusts. Each sample was labeled with a three-digit random code. A hedonic scale was used for the second evaluation, which consisted of seven levels of acceptance as follows: like very much, like, like slightly, neither like nor dislike, dislike slightly, dislike, dislike very much. These parameters were assigned with a rating value for data treatment: 10 for the “like very much” level of acceptance, to 4 for the “dislike very much” level of acceptance. The results of the “like very much”, “like” and “like slightly” levels, as well as the “dislike slightly”, “dislike” and “dislike very much” ones were gathered together in two groups named the “like” and the “dislike” groups respectively; consequently, only three groups are shown in the sensory evaluation results.

Analysis of Results

All experiments (rheological and bread quality) were done in triplicates for each sample. Bread samples for sensorial analysis were produced only for this analysis. Analysis of variance and Tukey's test were used to analyze results (Bruning and Kintz 1977).

Results and Discussion

Wheat–Soybean Flour Dough Farinographic Properties

The results of the farinographic studies are shown in Table 1. WA, which represents the amount of water required to center the farinogram curve on the 500 BU line, increased

Table 1 Wheat–soybean flour farinographic properties

Samples ^a	WA ^b (%)	MCT ^b (min)	S ^b (min)
Control	55.0 ^a	19.0 ^a	20.3 ^a
WSF 0.5%	55.0 ^a	20.6 ^b	22.7 ^b
WSF 1.0%	55.7 ^b	20.8 ^b	22.7 ^b
WSF 1.5%	56.3 ^c	21.8 ^c	23.2 ^c
GSF 0.5%	55.7 ^b	19.0 ^a	21.7 ^d
GSF 1.0%	56.2 ^c	19.8 ^d	21.8 ^d
GSF 1.5%	56.7 ^d	20.3 ^b	22.6 ^b

Each result is the average of three repetitions. Values followed by the same letter in the same column are not significantly different.

^a *WSF* Whole soybean flour, *GSF* germinated soybean flour

^b *WA* Water absorption, *MCT* maximum consistency time, *S* stability

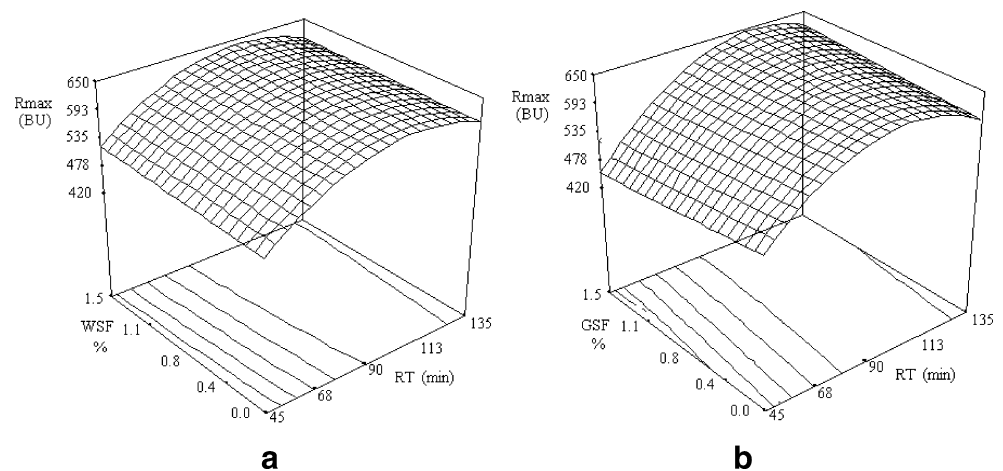
steadily with each increment of soybean flour in the blends, except when wheat flour was supplemented with 0.5% of whole defatted soybean flour (WSF). Flour added with GSF showed larger WA values as compared to flours added with WSF. The addition of soybean flours generated an average increment of 0.5 g of water per 0.5 g of protein added to the samples. The main difference between WSF and GSF was that WA remains invariable when WSF was added at the lowest concentration (0.5%). The slightly larger WA values obtained with GSF samples as compared to non-germinated and control samples may be the result of an increment in the enzymatic activity and/or the generation of hydrophilic components due to germination. Indrani et al. (1997) and Doxastakis et al. (2002) reported an increment in water absorption from 60.4 to 67.2 and from 56.7 to 57.9%, respectively, for wheat flour added with 5 to 15% of defatted soy flour.

Table 1 also presents the results of adding different concentration of WSF and GSF to wheat flour on dough MCT and dough stability (*S*). Wheat flour added with WSF resulted in larger values for both parameters as compared to the other samples. GSF addition also increased MCT and *S*, but in a smaller amount than WSF. Maximum consistency time is the time required to get the dough optimum consistency, whereas *S* shows how long the dough can be mixed without losing its optimal rheological properties. When a low-protein wheat flour has to be used in breadmaking, the use of additives to improve dough rheological characteristics (dough strength, mixing tolerance water absorption) are recommended. Both soybean flours improved these parameters.

Wheat–Soybean Flour Dough Extensographic Properties

Figure 1 shows the effect of resting time as well as the effect of the addition of different concentrations of soybean flours to wheat flour on resistance to extension. It can be seen from Fig. 1a that as the concentration of WSF increased at low resting times (45 min), maximum resistance to extension

Fig. 1 Effect of soybean flours and resting time on maximum resistance to extension (R_{\max}). *BU* Brabender units. *WSF* Whole soybean flour (a). *GSF* Germinated soybean flour (b)



(R_{\max}) kept invariable. Doughs added with GSF presented slight differences as compared to WSF samples. Samples with the smallest amount of GSF did not affect the response; nevertheless, when the concentration of GSF was increased, a significant decrease in R_{\max} was observed, varying from 503 BU to 453 BU (Fig. 1b). Indrani et al. (1997) reported that the extensograph resistance to extension decreased gradually from 990 to 780 BU when replacing wheat flour with 5, 10, and 15% defatted soy flour. Dough extensographs obtained after 90 min of resting showed that the incorporation of any concentration of soybean flours produced a slight increase (1.6–3.2%) on R_{\max} as compared to the control sample. R_{\max} results evaluated at 135-min resting showed that the addition of the soybean flours did not affect the response. Only the already known effect of resting time on R_{\max} was observed for these samples.

Table 2 shows the results of the change on extensibility as resting time and soybean concentration were varied. This parameter increased with the addition of 1.0 or 1.5% of WSF to wheat flour at short resting times (45 min), whereas using GFS-wheat flour blends at any concentration did not have significant effect on this parameter. Table 2 also shows

Table 2 Wheat–soybean flours extensographic properties

Samples ^a /RT ^b	L^c (mm)		
	45 min	90 min	135 min
Control	140 ^a	141 ^a	142 ^a
WSF 0.5%	147 ^a	142 ^a	147 ^a
WSF 1.0%	159 ^b	146 ^a	147 ^a
WSF 1.5%	162 ^b	151 ^a	148 ^a
GSF 0.5%	147 ^a	143 ^a	140 ^a
GSF 1.0%	151 ^a	147 ^a	145 ^a
GSF 1.5%	155 ^a	150 ^a	148 ^a

Each result is the average of three repetitions. Values followed by the same letter in the same column are not significantly different.

^a *WSF* Whole soybean flour, *GSF* germinated soybean flour

^b *RT* Dough resting time, 45, 90 and 135 min

^c *L* Extensibility (mm)

that as resting time increases, the extensibility values of samples added with soy is not longer affected as compared to the control sample. Published reports about this parameter differed; Hegazy and Faheid (1990) cited that dough extensibility decreased as the amount of soybean flour increased, whereas Indrani et al. (1997) and Maforimbo et al. (2006) reported that this parameter increased when soybean flour is added. In this work, the extensibility only changed when adding WSF at its larger concentrations, whereas GSF did not affect it.

The effect of the addition of soybean flours on the farinographic and extensographic parameters may be related to a change on dough viscosity more than a chemical action on the gluten proteins, which are responsible for the dough viscoelasticity properties. Aykroyd and Doughty (1964) reported that soybean contains a considerable amount of carbohydrates, such as pectins, and hemicelluloses, including pentosans, as well as protein. These components may have an influence on the dough water absorption capacity and on the dough viscosity. Ribotta et al. (2005) explained that a very sticky dough was obtained when they used an active enzyme soybean flour in bread production; this effect resembles a flour with high levels of pentosans. On the other hand, Labat et al. (2002) reported that the presence of water-extractable pentosans in wheat flour delayed the development time of gluten (MCT), whereas Wang et al. (2004a, b) stated that pentosans interfere with gluten reagglomeration during mixing. The different effects on dough properties generated by the GSF as compared to WSF may be the result of enzyme activity. More studies about the possible interfering effects of soy carbohydrates on dough rheology are required.

Farinographic Parameters of Bread Formulations and Specific Volume

Farinographic evaluation of these samples was carried out to determine the mixing time (MCT) required to apply

during breadmaking (Table 3). This result shows that MCT increased as the concentration of soybean flours was raised in the formulations. The use of WSF or GSF gave the same results. Stability increased when GSF was used at its highest concentrations, having larger values than the control samples. Both parameters (MCT, *S*) presented smaller values as compared to those obtained with the wheat–soybean flour mixtures (Table 1). This difference must be generated by the added bread formulation ingredients, allowing a fast hydration and dough development processes. This effect was not expected because the ingredients, mainly the hygroscopic ones such as sugar, salt, or powder milk should have increased the dough development time (Calderon-Dominguez et al. 2005). The shorter mixing time and the dough stability found in this work as result of soybean flours addition may be explained as the result of a rise in the enzyme activities promoted by the ingredients used in the breadmaking formulation. On the other hand, addition of GSF improved the bread volume as compared to control and to WSF formulations. Ribotta et al. (2005) reported that bread added with active enzyme defatted soybean flour showed better performance on specific loaf volume than bread prepared with soy protein isolates. These results could be explained as consequence of the low soybean flours concentrations that act more as a chemical or biological additive than as a nutritional fortifier ingredient.

Crumb and Crust Quality

Crumb quality was analyzed for color, structure, and texture, whereas crust was only analyzed for color characteristics. Table 4 shows that the crumb color tended to be yellow ($+b^*$). Addition of GSF decreased the yellow color of the crumb as the soybean flour concentration increased, resulting in a more achromatic crumb. The decrement of the “ $+b^*$ ” value measured at the crumb may be related to a change in the enzymatic activity as reported

Table 3 Full bread wheat–soybean dough farinographic parameters and specific volume

Samples ^{a,b}	MCT ^c (min)	<i>S</i> ^c (min)	Specific volume ^c (cm ³ /g)
Control	9.8 ^a	17.3 ^a	3.8 ^a
WSF 0.5%	10.2 ^a	17.5 ^a	4.3 ^b
WSF 1.0%	11.3 ^b	18.7 ^a	4.5 ^c
WSF 1.5%	11.7 ^b	19.2 ^b	4.6 ^d
GSF 0.5%	11.0 ^a	17.8 ^a	4.4 ^c
GSF 1.0%	11.7 ^b	18.9 ^b	4.7 ^d
GSF 1.5%	11.7 ^b	19.8 ^b	4.8 ^d

Each result is the average of three repetitions. Values followed by the same letter in the same column are not significantly different.

^a WSF Whole soybean flour, GSF germinated soybean flour

^b Water absorption was the same as in Table 1.

^c MCT Maximum consistency time, *S* stability

Table 4 Changes in bread crumb color as result of soybean flour addition

Samples ^a	<i>L</i> ^{*b}	<i>a</i> ^{*b}	<i>b</i> ^{*b}
Control	64.5 ^a	0.7 ^a	12.9 ^a
WSF 0.5%	62.2 ^a	0.5 ^b	11.6 ^b
WSF 1.0%	62.5 ^a	0.5 ^b	11.3 ^b
WSF 1.5%	61.0 ^a	0.5 ^b	10.7 ^c
GSF 0.5%	61.5 ^a	0.4 ^c	12.7 ^a
GSF 1.0%	62.7 ^a	0.4 ^c	11.8 ^b
GSF 1.5%	62.4 ^a	0.2 ^c	10.2 ^c

Each *r* result is the average of three repetitions. Values followed by the same letter in the same column are not significantly different.

^a WSF Whole soybean flour, GSF germinated soybean flour

^b *L** lightness; it extends from 0 (black) to 100 (white); $+a^*$, redness, $-a$ greenness; $+b^*$ yellowness, $-b$ blueness

for germinated soybean (Bau et al. 2000). Crust color parameters were not affected ($P>0.05$) by the addition of soybean flours, remaining unchanged as the concentration of these flours was increased in the formulation (data not shown). The addition of GSF had an improving effect on the color of the samples, making it whiter and without changing the crust color.

Crumb texture results are presented in Table 5. Firmness, compression force, and resilience were the evaluated crumb parameters. Compression force remained invariable for all samples, whereas firmness changed depending on which kind of soybean flour was used. WSF rendered the least firm crumb, whereas GSF produced the firmest crumb. Resilience, which measures the capacity of the crumb to recuperate its original state after the application of a compression force, was affected by soybean flour addition improving this response. Breads produced with GSF flours had a better recovery compared to the control sample and to WSF added breads.

Crumb structure evaluation is presented in Fig. 2. The shape factor (*S*), which gives information about the circularity of the cell, remained invariable ($p>0.05$) with

Table 5 Changes in bread crumb texture as result of soybean flour addition

Samples ^a	Firmness (Kgf)	CF ^b	Resilience
Control	0.93 ^a	2.1 ^a	0.18 ^a
WSF 0.5%	0.88 ^b	2.2 ^a	0.17 ^b
WSF 1.0%	0.85 ^b	2.2 ^a	0.17 ^b
WSF 1.5%	0.88 ^b	1.9 ^a	0.17 ^b
GSF 0.5%	1.14 ^c	2.3 ^a	0.15 ^c
GSF 1.0%	1.23 ^c	2.2 ^a	0.15 ^c
GSF 1.5%	1.32 ^c	2.2 ^a	0.15 ^c

Each result is the average of three repetitions. Values followed by the same letter in the same column are not significantly different.

^a WSF Whole soybean flour, GSF germinated soybean flour.

^b Compression force to 50%

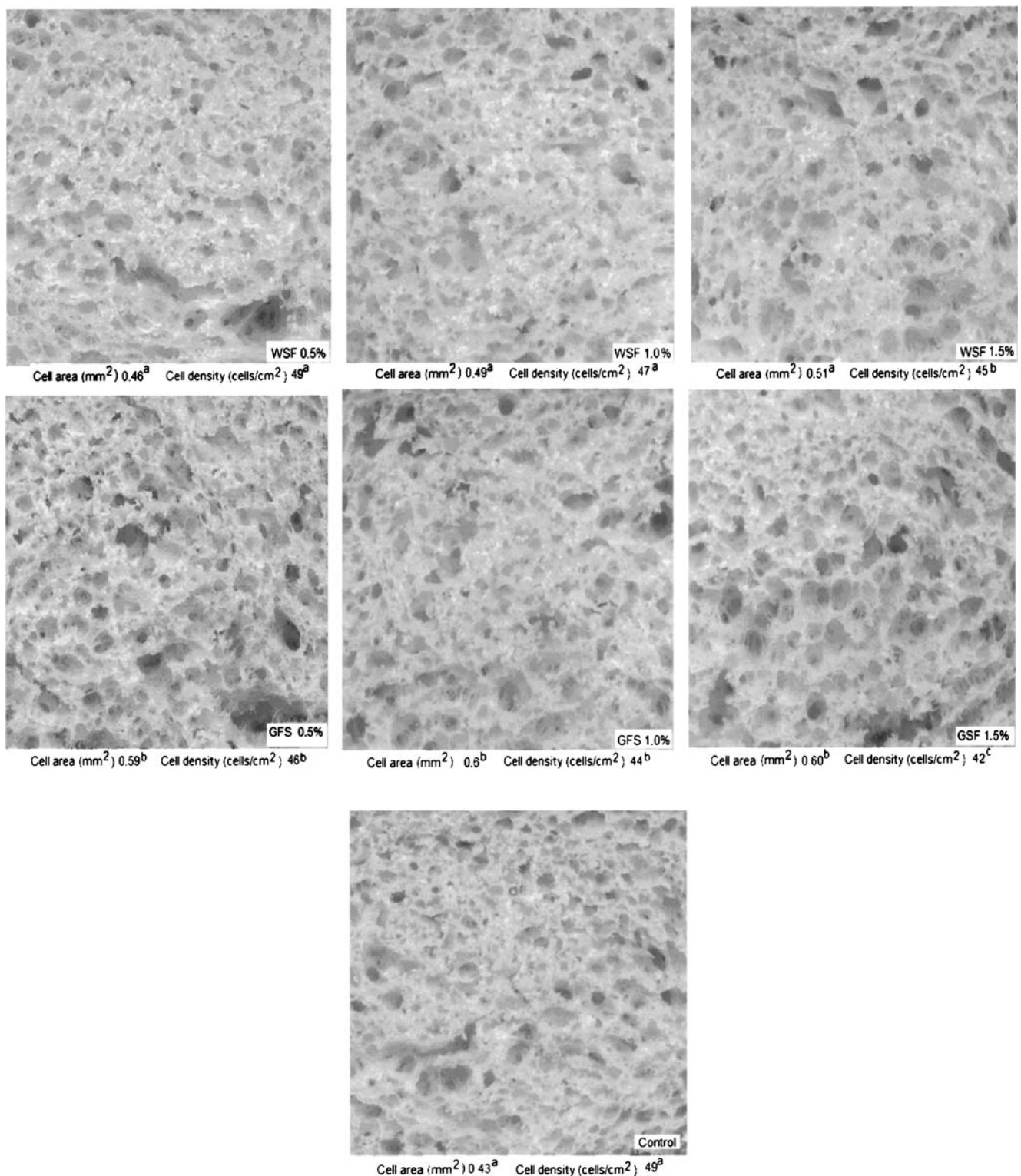
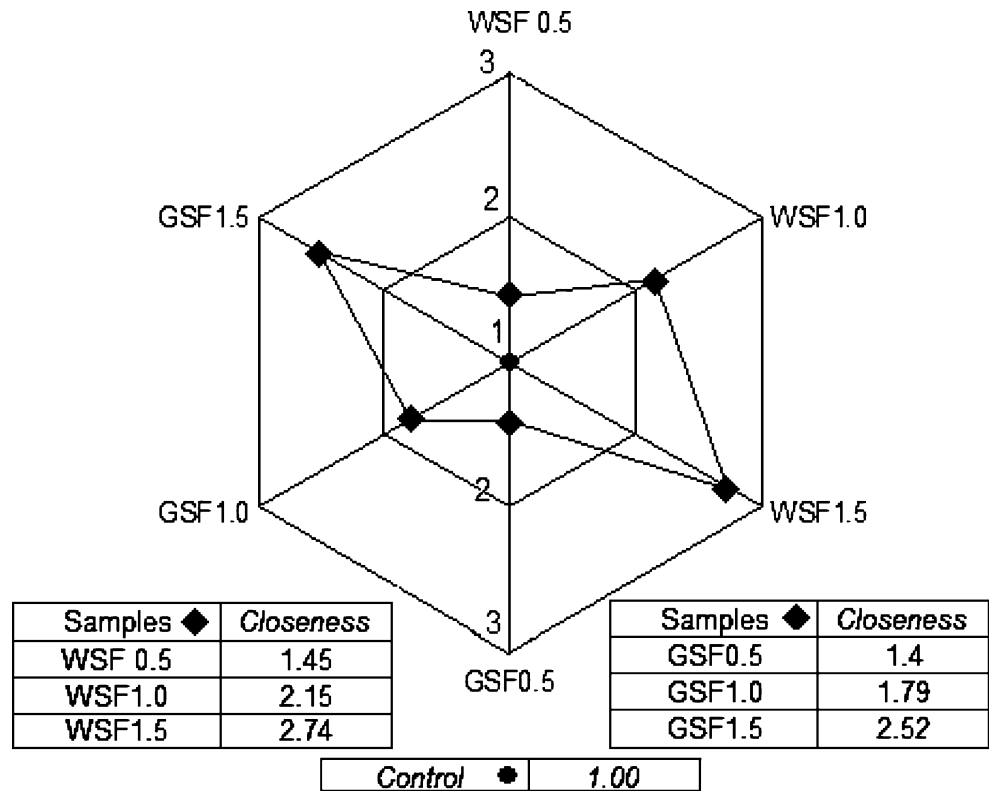


Fig. 2 Effect of the addition of WSF and GSF on crumb characteristics. *WSF* Whole soybean flour, *GFS* germinated soybean flour. Results are the average of three repetitions. Values followed by the same letter are not significantly different

the addition of the different types and concentrations of soybean flours (data not shown). All samples presented a value among 0.48 to 0.50, which means a non-circular cell. Crumb cell area increased when GSF was used in the bread

formulation, whereas the density of cells decreased. Addition of WSF did not have significant effect ($p > 0.05$) on these parameters as well as on the structural characteristics of crumb when varying the concentration of the soybean flours.

Fig. 3 Results of sensorial analysis (closeness to the reference standard test). *WSF* Whole soybean flour, *GSF* germinated soybean flour. Dots represent the scale of closeness; 1 no difference, 2 small difference, 3 medium difference among samples and the control sample. *Rhombus* represents how far each sample from the standard is



The bigger cell area and the smaller cell density observed on GSF samples gives information about a coarser crumb grain structure as compared to control and WSF samples.

Sensorial Analysis

Figure 3 shows that as the percentage of soybean flour was raised in the bread formulations, the panelists considered that the samples were different to the control bread. However, only 10% of these panelists reported a significant difference ($p > 0.5$) among samples, whereas 60% of them did not find any differences between the control bread and the one added with 0.5% of GSF. Statistical analysis showed that all breads were different ($p < 0.05$), except those prepared with 0.5% of WSF and GSF. Breads prepared with GSF got closer to the control sample as compared to the WSF results. In the likeability rating test (Fig. 4), 80% of the panelists considered that the samples prepared with GSF at 0.5 or 1.0% were better than the control bread ($p < 0.05$), and only the bread added with 1.5% WSF was not acceptable. All the other formulations were still satisfactory.

Conclusions

The addition of GSF to wheat flour slightly changes the mixing properties of dough, but had an improving effect on the overall bread quality. Adding GSF resulted in a higher

specific volume, a whiter, firmer, and more resilient crumb, but in a coarser grain as compared to bread baked with WSF. This makes GSF to be considered as a possible natural baking additive. The improving effects caused by the use of GSF may be caused by an increment of the enzyme activities

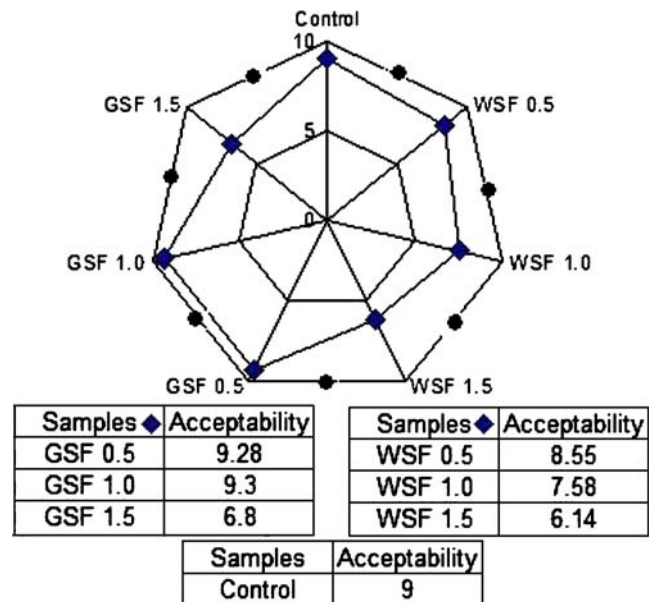


Fig. 4 Results of sensorial analysis (acceptability test). *WSF* Whole soybean flour, *GSF* germinated soybean flour. *External line with dots* represents the maximum value for acceptability (10). *Rhombus* represents how close each sample from the maximum acceptability value is

as well as the influence of soy carbohydrates. This indicates that additional studies concerning enzymes and soy carbohydrates on rheological properties, as well as the effect of breadmaking formulation ingredients, should be done to understand how GSF affects bread characteristics.

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