Utilization of Sweet Lupin Hull Fibers in Formulating Novel Functional Bread

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ABSTRACT

A good correlation between fibers consumption and the reduction of coronary heart-related diseases and diabetes incidence has become evident. However, fibers intake is commonly lower than recommended. In consequence, the development of foods with high fiber content should be desirable. The aim of this paper is to investigate the possibility of using substituting wheat flour (WF) with 5, 10 and 15% sweet lupin hull fibers (SLHF) in formulating novel functional bread. The SLHF showed higher levels of ash, crude fat, total phenolic, flavonols and dietary fibers than the WF. The SLHF increased the water absorption and dough development time. Regarding dough stability, it appears that 5% SLHF exhibited higher stability and resistance to mechanical mixing values than the control, while it decreased as the substitute level increased from 10% to 15%. A linear viscoelastic behaviour of module at the range of $10^{-4}\leq\gamma\leq 10^{-3}$ was found. The storage modulus (G´) was greater than the loss modulus (G´´). The dough handling was not affected at any levels of supplementation with SLHF and dough surface of the wheat dough and its blends with 5, 10 and 15 % SLHF were classified as "normal". The crust of the control was lighter and less yellow than any of the other samples. For crumb colour, as the level of SLHF increased, the a* and b* values increased, indicating that a redder and more yellow crumb was obtained as a result of SLHF substitution. Supplementation WF with SLHF at level of 5 and 10 % gives parameter values at least as good as the control sample and 15 % produces acceptable bread in terms of weight, volume, crumb structure and colour. In addition, sensory evaluation showed that panelists judged these fiber-enriched breads as acceptable. Therefore, their use allows an increase of the daily intake of fibers without promoting negative effects on the rheological properties of doughs or quality and overall acceptability of the resulting breads. This study indicates that substituting wheat flour (WF) with SLHF at levels from 5 to 15% can be used in bread making in order to fortify the diet.

Keywords: sweet lupin hull fibers, wheat flour, farinograph, dynamic rheology, bread quality.

INTRODUCTION

The interest in foods rich in dietary fibers increased in the recent decades and this led to the development of a large market for fiber-rich products and ingredients (Drzikova*, et al.*, 2005). The specific properties of dietary fiber has been reported to play an important role in the prevention and treatment of various gastrointestinal disorders (hernia, duodenal ulcer, gall stones, appendicitis, constipation, hemorrhoids, colon carcinoma), obesity, atherosclerosis, coronary heart diseases, colorectal cancer and diabetes (De Escalada Pla*, et al.*, 2007). Addition of fibers to foods is an alternative way to compensate for the existent deficiency in the diet. Apart from the nutritional application, fiber can be used for technological purposes such as bulking agent or fat substitute in foods (Guillon & Champ, 2000).

The World Health Organization (WHO, 2003) currently recommends consumption of foods containing > 25 g (30-45 g) of total dietary fiber/day. In fact, WHO has identified dietary fiber as the only dietary ingredient with "Convincing Evidence" showing a protective effect against weight gain and obesity. Bread can be enriched with dietary fiber such as wheat bran, gums such as guar gum, modified celluloses and β-glucans. Wheat flour contains 1.5–2.5 % total arabinxylans, non-starch polysaccharides of cereal which is an important source of dietary fiber where one-third to half is water-extractable and the other is water-unextractable (Su*, et al.*, 2005).

Lupin hull fibers are a novel food ingredient that can be isolated from the endosperm of local Egyptian breeds of sweet lupin (*Lupinus albus L.* variety Giza). This legume has already gained legislative approval for use as human food in some countries, including Australia. Demonstration that sweet lupin hull fibers (SLHF) can be used to formulate food products with acceptable sensory properties is required to introduce this novel ingredient into the food supply system. This fiber is predominantly non starch polysaccharide in the form of thickened cell walls of the lupin seed endosperm, with some residual protein. The SLHF has been described as a powder that is pale in colour, low in odour and flavour, and suitable for use as a 'nonintrusive' fiber ingredient in foods such as baked goods and meat products (Johnson & Gray, 1993).

Rheology is defined as a study of the deformation and flow of matter (Bourne, 2002). The applications of rheology have expanded into food processing, food acceptability and handling. Many researches have been conducted to understand the rheology of various types of food such as food powder (Weert, *et al.*, 2001, Grabowski, *et al.*, 2008), liquid food (Sabato, 2004, Park, 2007), gels (Michon, *et al.*, 2004, Foegeding, 2007), emulsions (Robins, *et al.*, 2002, Corredig & Alexander, 2008) and pastes (Abu-Jdayil, *et al.*, 2002, Lim & Narsimhan, 2006). Fast food materials show a rheological behaviour that classifies them in between the liquid and solid states, meaning that their characteristics vary in both viscous and elastic behaviours. This behaviour, known as visco-elasticity, is caused by the entanglement of the long chain molecules with other molecules.

Nevertheless, there is a lack of published data on foods containing SLHF. The aim of the present study was to substitute WF with 5, 10 and 15% SLHF in formulating novel functional bread.

MATERIALS AND METHODS

Materials

Local Egyptian breeds of sweet lupin (*Lupinus albus L.* variety Giza) were obtained from the Agricultural Research Centre, Giza, Egypt. The hulls were removed from the seeds in a laboratory hammer mill (Retsch - Germany), grounded to give sweet lupin hull fibers (SLHF) then re-milled and sieved to pass through sieve 500 µm. Commercial wheat flour (WF) with extraction rate 72% was obtained from the local market. All other chemical reagents used in the experimental analysis were of analytical grade.

Methods

Chemical methods

Proximate composition

Proximate composition of WF, SLHF and their blends was carried out according to ICC Standard Methods (ICC, 2001). Moisture content was determined by drying the samples at 105°C to a constant weight. Ash content was determined by calcinations at 900°C. Nitrogen content was determined by using Kieldahl method with factor of 5.7 to determine protein content. The crude fat content was determined by defatting in the Soxhelt apparatus with hexane.

Starch content

Starch content was assessed using a polarimetric method according to Davidek, *et al.* (1981). All the measurements of analyzed samples were made in triplicate.

Dietary fiber content

The soluble (SDF), insoluble (IDF) and total dietary fiber (TDF) contents of SLHF, WF and their blends were determined by the enzymatic gravimetric method of Prosky, *et al.* (1988).

Phenolic compounds

Total extract yield

The dry SLHF were extracted according to Mohdaly, *et al.* (2010), using methanol 10:1, solvent: dry sample ratio. Extraction was carried out using a shaking incubator at room temperature for 24 hr followed by filtration through Whatman No.1 filter paper. The residues were re-extracted under the same conditions. The combined filtrate was evaporated in a rotary evaporator under vacuum at 40ºC. The extracts obtained after evaporation of organic solvent were weighed to determine the extract yield.

Total phenolic content

Total phenolic content of WF, SLHF and their blends were determined by the Folin–Ciocalteu micro-method (Arabshahi & Urooj, 2007). A 20 µL aliquot of the extract solution (1 mg/ml) was mixed with 1.16 mL of distilled water and 100 µL of Folin–Ciocalteu's reagent followed by 300 µL of 200 g L^{-1} Na_2CO_3 solution. The mixture was incubated in a shaking incubator at 40°C for 30 min and its absorbance at 760 nm was measured. Gallic acid was used as standard for the calibration curve. Total phenolic content expressed as gallic acid equivalent (GAE) was calculated using the following linear equation based on the calibration curve:

$$Ab = 0.98C + 9.925 * 10^{-3} \ (R^2 = 0.9996)$$

where Ab is the absorbance and C is the concentration (mg GAE g^{-1} dry weight (DW)).

Total flavonoid content

Total flavonoid content was determined by the method of Ordoñez, *et al.* (2006). To 0.5 ml of each extract solution (1 mg/ml), 0.5 mL aliquot of 20 g L^{-1} $AlCl_3$ ethanolic solution was added. After 1 hr at room temperature, the absorbance at 420 nm was measured. A yellow colour indicated the presence of flavonoids. Extract samples were evaluated at a final concentration of 0.1 mg ml^{-1}. Total flavonoid content expressed as quercetin equivalent (QE) was calculated using the following equation based on the calibration curve:

$C = 0.0255 * Ab$ ($R^2 = 0.9812$)

where *Ab* is the absorbance and *C* is the concentration (mg QE g^{-1} DW).

Total flavonol content

Total flavonol content was determined by the method of Kumaran & Joel Karunakaran, (2007). To 2 mL of extract solution, 2 mL of 20 g L^{-1} $AlCl_3$ ethanolic solution and 3 mL of 50 g L^{-1} sodium acetate solution were added. The absorbance at 440 nm was measured after 2.5 hrs at 20°C. Extracts were evaluated at a final concentration of 0.1mg mL^{-1}. Total flavonol content expressed as QE was calculated using the same equation of flavonoids.

Antioxidant activity of extracts

Because of the differences among the various test systems available, the results of a single method can provide only a limited assessment of the antioxidant properties of a substance (Sacchetti, *et al.*, 2005). For this reason, the antioxidant activity of the extracts obtained from WF, SLHF and their blends was determined through two complementary assay procedures:

1,1-Diphenyl-2-picryl-hydrazyl (DPPH·)

The DPPH assay according to Lee, *et al.* (2003) was utilised with some modifications. The stock reagent solution (1 x 10^{-3} mol L^{-1}) was prepared by dissolving 22 mg of DPPH in 50 mL of methanol and stored at −20 °C until use. The working solution (6 x 10^{-5} mol L^{-1}) was prepared by mixing 6 mL of stock solution with 100 mL of methanol to obtain an absorbance value of 0.8±0.02 at 515 nm, as measured using a spectrophotometer. Extract solutions of different concentrations (0.1 mL of each) were vortexed for 30 s with 3.9 mL of DPPH solution and left to react for 30 min, after which the absorbance at 515 nm was recorded. A control sample (with no added extract) was also analysed. Scavenging activity was calculated as follows:

DPPH radical-scavenging activity (%) =

$[(Ab_{control} - Ab_{sample})/ Ab_{control}] * 100$

where *Ab* is the absorbance at 515 nm.

2,2-Azino-bis-3-ethylbenzothiazoline-6-sulphonic Acid (ABTS)

For the ABTS assay, the method of Re, *et al.* (1999) was adopted. The stock solutions were 7 mmol L^{-1} ABTS solution and 2.4 mmol L^{-1} potassium persulphate solutions. The working solution was prepared by mixing the two stock solutions in equal quantities and allowing them to react for 12–16 hr at room temperature in the dark. Then one mL of the resulting $ABTS^{\bullet+}$ solution was diluted with 60 mL of methanol to obtain an absorbance of 0.706 ± 0.001 units at 734 nm, as measured using a spectrophotometer. The $ABTS^{\bullet+}$ solution was freshly prepared for each assay. Extract solutions of different concentrations (1 mL of each) were allowed to react with 1 mL of $ABTS^{\bullet+}$ solution for 7 min, after which the absorbance at 734 nm was recorded. A control sample (with no added extract) was also analysed. Scavenging activity was calculated as follows:

ABTS radical-scavenging activity (%) =

$[(Ab_{control} - Ab_{sample})/Ab_{control}] * 100$

where $Ab_{control}$ is the absorbance of ABTS radical + methanol

Ab_{sample} is the absorbance of ABTS radical + extract

Physical Methods

Farinograph measurements

The dough mixing of SLHF, WF and their blends were studied using farinograph instrument (Brabender, Duisburg, Germany). The measurements were conducted according to the constant flour weight procedure of ICC (2001) and all measurements were made at room temperature (25 ºC). From the farinogram curves, water absorption (percentage of water required to yield dough consistency of 500 farinograph unit (FU), dough development time (DDT, time to reach maximum consistency), stability (time during dough consistency is at 500 FU) and degree of softening (difference in FU) between the line of the consistency and the medium line of the torque curve 12 min after development time), were determined.

Rheometer measurements

A rheometer UDS 200 from Paar Physica (GmbH measurement technique Stuttgart) with temperature control with a plate-plate system (measurement system MP 31) was used for measuring the dynamic rheological properties of dough samples according to Mohammed (2011). Operation, including temperature control and data handling, was conducted using PC-based software. Each time, a sample was taken of a given blend (WF + SLHF), containing 100 g of flour and combined with a specific amount of water, equivalent to the water absorption resulting from farinograph test. The consistency of the sample obtained at that level of dough moisture permitted its placement by hand within the measurement system of the rheometer. The dough was kneaded for 5 min using a mixer with a spiral blade. Next, 10 g dough was transferred onto the lower plate of the rheometer and pressed down with the upper plate, 25 mm in diameter, until a gap of 2 mm was obtained. The excess of the sample, protruding beyond the edge of the upper plate, was trimmed off, while drops of fluid silicon oil were placed around the uncovered surface of the sample to protect the sample from loss of moisture during the test. In this condition, the sample was left to rest for 1 min. That period permitted the relaxation of normal stresses generated in the course of compression of the sample. All the following rheological tests were made at a constant temperature of the lower plate (25 °C), controlled by means of an external thermostatic bath:

Amplitude sweep

The amplitude of relative strain was $10^{-4} \leq \gamma$ (deformation) ≤ 1 and fell within the linear viscoelastic region for all samples. The limits of the region were determined based on an experiment in which increasing stress was applied, at constant oscillation frequency of 1 Hz.

Frequency sweep

Applying oscillation frequencies within the range from 0.1 to 20 Hz at constant strain $\gamma = 10^{-3}$. Each logarithmic frequency decade corresponded to 30 measurement points.

Creep test

The cycle of dynamic tests was followed by a 10-min period of relaxation. Then, the dough sample was subjected to the creep test, applying a constant shear stress of 50 Pa for 60 s on the sample and allowing the sample to recover the strain in 180 s after removal of load.

Technological Methods

Pan bread preparation

Bread was prepared according to ICC (2001) as follows: 500 g (WF or WF supplemented with 5, 10 or 15 % SLHF), were first dry-mixed in the mixer bowl for 1 min. Next, 1 % sugar, 1.2 % salt, 3 % fresh compressed yeast, previously dissolved in water, were added followed by the addition of water up to 500 FU consistency and the dough kneading process was continued for a total of 5 min and placed in baking pans then in a proofing cabinet at 30°C and 75-80 % relative humidity.

After 45 min fermentation, the dough was punched down to remove gases, proofed for further 45 min and baked at 240°C for 30 min. During baking, some water was vaporized in the oven to avoid any extreme dryness of the bread crust. Each baking test was conducted in triplicate.

Bread evaluation

Loaf measurements

Bread mass was weighed after 3 hrs at room temperature. The volume (cm^3) was measured by rapeseed replacement method as described in the AACC (1983). The specific volume was obtained by dividing the volume of loaves by their weights.

Colour measurements

Crumb and crust colour of fresh bread was measured with a Minolta Colourimeter (CR 200 Japan). Colour readings were expressed by Hunter values for L*, a* and b* corresponding to lightness, redness, and yellowness, respectively.

Sensory evaluation

Evaluation of the baked loaves quality characteristics was carried out following cooling to room temperature for 2 hr. Sensory evaluation was performed by ten panelists who were graduate students and staff members of the Department of Rheology, Institute of Food Technology and Food Chemistry, Technical University, Berlin. Loaves were randomly assigned to each panelist. The panelists were asked to evaluate each loaf for appearance, crumb texture, crumb grain, crust colour, taste, odour and overall acceptability. A 10 point scale was used where 10 "excellent and 1 "extremely unsatisfactory (Mohammed, *et al.*, 2012).

Statistical Methods

Analysis of variance (ANOVA) was carried out using SAS program (Statistical Analysis System version. 9.1) SAS Institute Inc. (SAS, 2004). Mean ± standard deviation (SD) of mean was used.

RESULTS AND DISCUSSION

Chemical composition

The proximate chemical compositions of WF, SLHF and their blends substituted with different levels of SLHF (5, 10 and 15%) are given in Table (1). The SLHF showed higher levels of ash, crude fat and dietary fiber than the WF. Conversely, WF showed higher levels of moisture, crude protein and starch.

The hull constitutes a considerable part of the lupin seeds (ca. 20 %) with a high content of dietary fiber (50–54 %) of good functionality (Gorecka, *et al.*, 2000). Compared to other leguminous crops, lupin seeds have a large proportion of hulls, which can be used as a source of valuable health promoting ingredients, including those with antioxidant properties. Mean dietary fiber increased with increasing amount of SLHF added to be 6.83, 10.95 and 15.08 % for substituting WF with SLHF at 5, 10 and 15 %, respectively on dry weight basis.

Phenolic compounds and antioxidants activity

Table (2) shows the extract yield, total polyphenol content and antioxidant activity of WF, SLHF and their blends. It was noted that SLHF had total phenolic, and flavonol contents higher than that found in WF. A slight difference was observed between WF and SLHF in flavonoid content. The same trend was observed with the antioxidant activity for SLHF in DPPH and ABTS tests. These results are similar to those obtained by Lampart-Szczapa, *et al.* (2003) who studied the antioxidant properties of lupin flour and hulls using the rancimat and oxidograph tests and they found that lupin tannin content and antioxidant activity were concentrated in the flours and hulls.

Phenolic compounds ubiquitous in plants are key phytochemical drivers of the health and functional foods and nutraceutical industry. Research with polyphenol compounds from various crops has created a growing market for polyphenol-rich ingredients, estimated to be worth around $ 99 million in Europe in 2003 (Nutraingredients, 2005).

Rheological properties

Farinograph measurements

Fig. (1) shows farinograms of WF and its blends with SLHF. The water absorption of WF was 56.1 % according to the ICC method, and the resulting dough has a development time of 2.5 min,

Table 1: Chemical composition of WF, SLHF and their blends (5, 10 and 15 % substitution of WF with SLHF)

Constituents (%)*	WF	SLHF	SLHF level in blends		
			5%	10%	15%
Moisture	11.27 ± 0.09	8.76 ± 0.06	11.14 ± 0.08	11.02 ± 0.07	10.89 ± 0.16
Crude protein	12.1 ± 0.20	4.8 ± 0.26	11.74 ± 0.23	11.37 ± 0.25	11.01 ± 0.29
Total ash	0.40 ± 0.02	2.57 ± 0.18	0.51 ± 0.12	0.62 ± 0.06	0.73 ± 0.44
Crude fat	1.62 ± 0.19	2.1 ± 0.11	1.64 ± 0.17	1.67 ± 0.14	1.69 ± 0.18
Starch	69.8 ± 1.96	0.20 ± 0.04	66.32 ± 1.91	62.84 ± 1.86	59.36 ± 3.82
S. D. F**	1.1 ± 0.09	43.7 ± 2.19	3.23 ± 0.15	5.36 ± 0.32	7.49 ± 0.45
I. D. F***	1.6 ± 0.23	41.5 ± 1.12	3.60 ± 0.25	5.59 ± 0.27	7.59 ± 0.34
T. D. F****	2.7 ± 0.15	85.20 ± 4.38	6.83 ± 0.32	10.95 ± 0.53	15.08 ± 0.75

*Mean of three replicates ± SD on dry weight basis (DW), **S. D. F. = Soluble dietary fiber,

***I. D. F. = Insoluble dietary fiber, ****T. D. F. = Total dietary fiber

Table 2: Extract yield, total polyphenol content and antioxidant activity of WF, SLHF and their blends (5, 10 and 15 % substitution of WF with SLHF).

Parameters*	WF	SLHF	SLHF level in blends		
			5%	10%	15%
Extract Yield (%)	13.7 ± 3.99	16.1 ± 0.46	14.2 ± 0.52	15.1 ± 0.96	15.4 ± 0.46
Total Phenolic (µg GAE/g DW)	43.63 ± 3.52	126.63 ± 2.57	47.73 ± 2.08	51.92 ± 2.05	56.07 ± 1.79
Total Flavonoids (µg QE/g DW)	6.33 ± 0.15	7.63 ± 0.06	6.63 ± 1.47	7.00 ± 0.95	7.30 ± 0.72
Total Flavonols (µg QE/g DW)	30.53 ± 6.13	32.03 ± 3.97	30.57 ± 3.38	29.5 ± 6.94	28.50 ± 7.18
Antioxidants activity					
DPPH (%)	3.31 ± 0.35	3.75 ± 1.64	3.98 ± 0.25	4.15 ± 0.54	4.76 ± 0.68
ABTS (%)	26.7 ± 0.21	27.54 ± 0.40	27.45 ± 1.09	28.90 ± 0.29	29.83 ± 0.00

*Mean ± SD.

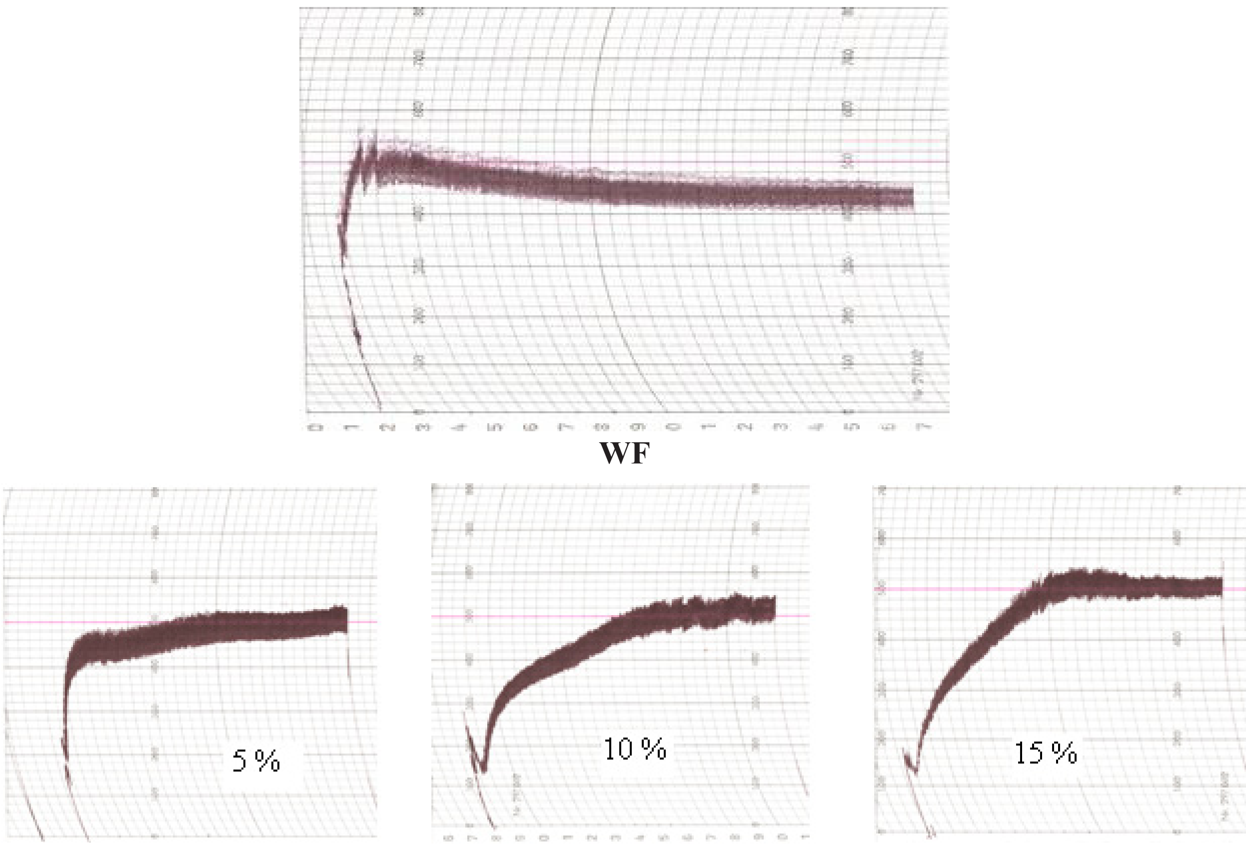

Fig. 1: Farinogram data of WF and its blends (5, 10 and 15 % substitution of WF with SLHF).

a stability of 5.5 min and softening of 58 FU. A slight drop in dough consistency with 491 FU was registered with the wheat dough.

Substitution of WF with SLHF (Fig. 1) increased the water required for optimum bread making absorption from 56.1 % for WF to 68.5 % for the 15 % substitution of WF with SLHF. These results confirmed by Sudha, *et al.* (2012) who studied the effects of wheat and oat brans as sources rich in insoluble dietary fiber and soluble dietary fiber in the formulation of instant vermicelli and study its influence on the rheological characteristics and product quality. The incorporation of wheat and oat brans from (0 to 20 %) in the blends increased the water absorption significantly from 58.3 to 64.1 %.

Rosell, *et al.* (2001) reported that the differences in water absorption is mainly caused by the greater number of hydroxyl groups that exist in the fiber structure and allow more water interaction through hydrogen bonding. It could be noted that water absorption increased with increasing amount of SLHF. The observed effect agreed with the increased water absorption found by Sosulski & Wu (1988) when they added field pea hulls, wheat, corn and wild oat brans to the bread dough formula.

The highest development time values were obtained in doughs with SLHF (5, 10 and 15 %) (Fig. 1). Similar results were expressed by Daglioglu & Gundogdu (1999) who studied the effect of stabilized rice bran in bread making. Regarding dough stability, it appears that the dough sample containing 5 % SLHF exhibited higher stability and resistance to mechanical mixing values than the control, while it decreased as the substitute level increases from 10 % to 15 %. In general, the stability value is an index of the dough strength, with higher values indicating stronger dough. The increase in the stability time was related to the amount of substitution.

Rheometer measurements

Fundamental rheometry is capable of describing the oscillation physical properties of a material over a wide range of strains and strain rates. The mechanical tests conducted within the linear viscoelastic region (LVR) are useful for understanding the dough properties in terms of physical and chemical structure. The rheological properties of the dough reflect its machine properties during processing and the quality of the end product (Mani, *et al.*, 1992).

Following a strain sweep at 1 Hz within the LVR was selected for additional testing.

Amplitude sweep measurements

The amplitude sweep is used to determine the linear viscoelastic region of the matrix. The addition of SLHF caused a shift of curves G' (Storage modulus) and G" (Loss modulus) towards higher values, while curve tan δ (Loss factor) moved towards lower values. The data indicate that the additions applied caused an increase in WF dough elasticity (G') and viscosity (G"), the increase in elasticity dominating over that in viscosity, as a result of which tan δ decreased. Likewise, Lamacchia, *et al.* (2010) studying doughs with a constant addition of water (30 %), recorded significantly higher values of G' and G" for oat whole meal dough than for wheat (semolina) dough. Also, oat whole meal dough, compared to wheat dough, was characterized by significantly higher values of tan δ.

Fig. (2) shows a compilation of storage modulus and tan δ of the three dough preparations compared to the wheat dough. The storage and loss modulus level of the flour mixture had increased differences among themselves in compared to the WF-dough. Linear viscoelastic region (LVR) for

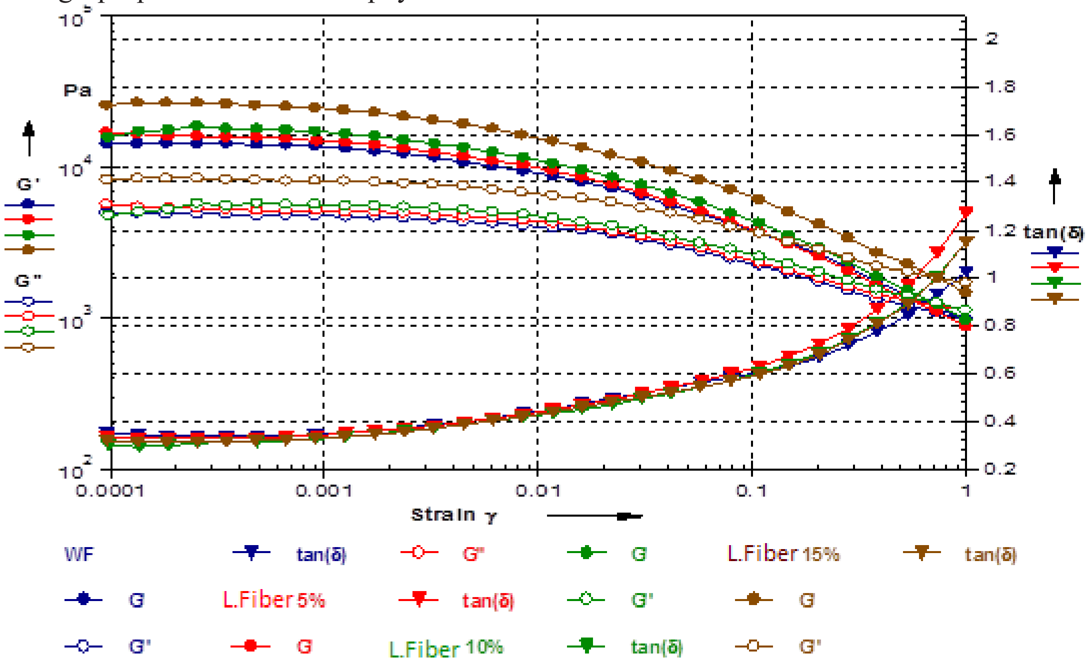

Fig. 2: Amplitude sweep of WF and its blends (5, 10 and 15 % substitution of WF with SLHF)

the mixtures with deformation was of $10^{-4} \leq \gamma \leq 10^{-3}$. The moduli (G' and G") increased slightly with increasing SLHF content in the mixtures in comparison to the WF with a deformation of $\gamma = 10^{-3}$. A stable structure in hibernation is determined based on the dominance of the WF in the blends.

Frequency sweep measurements

To characterize the dough as the dispersed material system, the frequency-dependent behaviour of the WF and SLHF depending on the subsequent mixing ratios (5, 10 and 15 % substitution of WF with SLHF) was examined by oscillatory measurements. Fig. (3) shows a comparison of the measured data of WF dough with different concentrations of (5, 10 and 15 % substitution of WF with SLHF). Also, it shows the storage G' and loss modulus G" and loss factor.

The presented data indicate that increase of oscillation frequency within the range from 0.1 to 20 Hz caused an increase in the values of the dynamic moduli the storage modulus and the loss modulus for pure wheat dough as well as for composite flour dough. Whereas, the values of the tangent of the phase angle, being the ratio of G"/ G', decreased gently while the oscillation frequency increased from 0.1 to approximately 1 Hz, the higher frequencies caused an increase of those values. Substitution of WF with different concentration of SLHF (5, 10 and 15 %) had a similar effect on the run of the mechanical spectra of wheat dough. Increase in the percentage share of the additions caused a shift of curves G' and G" towards higher values. The data indicate that the additions applied caused an increase in tested dough elasticity (G') and viscosity (G"), the increase in elasticity dominating over viscosity as a result of tan δ decreased.

Frequency sweep experiments showed that for all tested dough formulations, the elastic (or storage) modulus, G', was greater than the viscous (or loss) modulus, G", in the whole range of frequencies and both moduli slightly increased with frequency which suggests a solid elastic-like behaviour of the lupin doughs. Therefore, tan δ values for all dough formulations were lower than 1.

Creep tests

The creep test is to compare the properties (1-point – measurements) of the materials science of different flours and their mixtures at constant measuring conditions. This measured approach within the framework of classical dough investigation evaluated only partially.

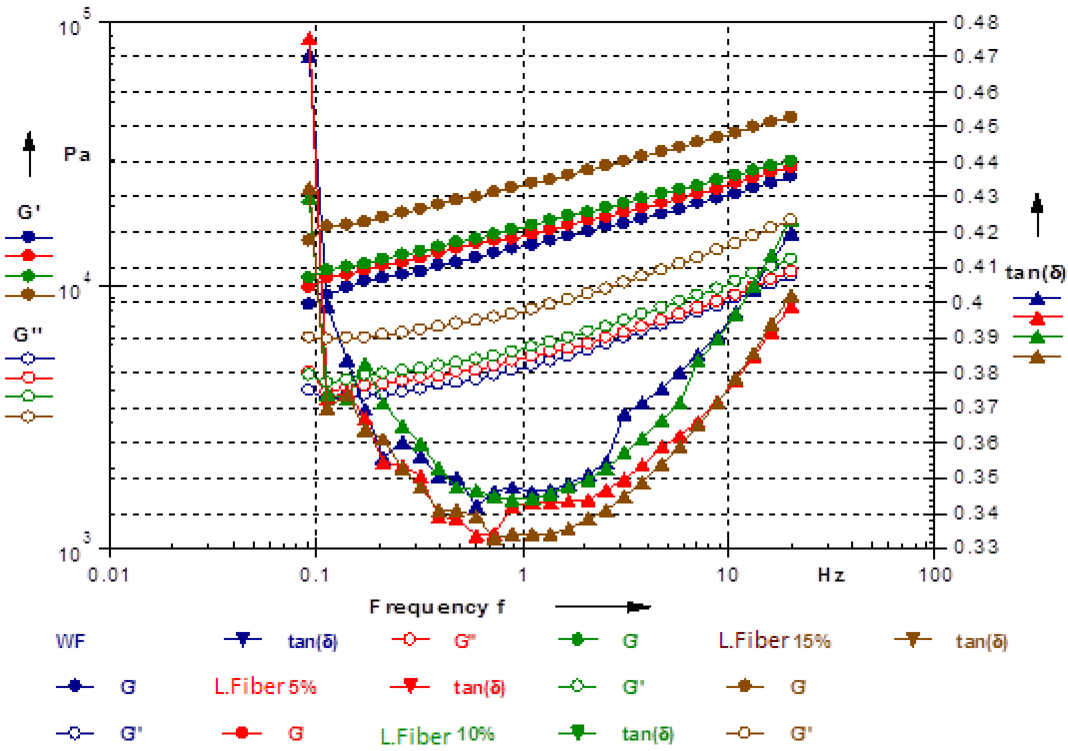

Fig. 3: Frequency sweep of WF and its blends (5, 10 and 15 % substitution of WF with SLHF).

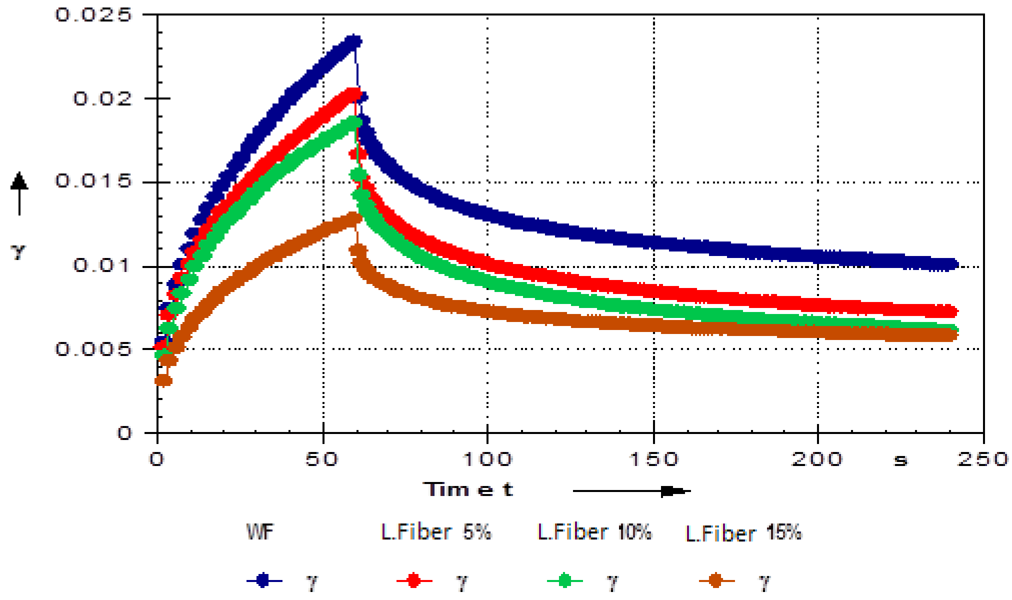

Fig. 4: Creep test of WF and its blends (5, 10 and 15 % substitution of WF with SLHF).

There are proven higher viscoelastic properties of the wheat dough. It is clearly an example this (old) conventional method has the great difference in the structural properties seen between WF dough and its blends with SLHF. Zero shear viscosity and shear modulus show minima, which for better flow properties of the dough suggesting. The greater of zero shear viscosity and the shear modulus, the lower of the fluidity of the dough (tendency for stiffness) was found (Fig. 4). The elastic deformation units of WF dough almost twice as large as compared to the viscous friction. With increasing of SLHF concentration in the dough system (flour mixtures), decreases the maximum deformation and elastic recovery (from 1.01 to 0.58) when WF substituted with 15% SLHF.

Bread Characteristics

The effect of SLHF incorporation on the wheat dough handling and fresh pan bread characteristics are shown in Fig. (5) and Tables (3-5).

The dough handling was not affected at any levels of supplementation and the dough surface of the wheat dough and its blends with SLHF (5, 10 and 15 % substitution of WF with SLHF) were classified as “normal”.

The effect of the SLHF on the fresh bread characteristics is summarized in Tables (3-5). The volume and specific volume of the control bread sample were higher than that of samples incorporating SLHF. This effect is probably related to the decreased visco-elasticity of dough resulting from substitution of WF with SLHF. As the level of SLHF supplementation increased (5–15 %), the loaf volume and specific volume of the corresponding fortified breads gradually decreased.

Doxastakis, *et al.* (2002) reported a decrease

Table 3: Loaf characteristics of WF and its blends with SLHF (5, 10 and 15 % substitution of WF with SLHF)*.

Sample	Loaf height cm	Loaf weight g	Loaf volume cm^3	Specific volume cm^3/g
WF	9.5 ± 0.73	470.8 ± 23	1900 ± 54	4.04 ± 0.4
L-fiber 5 %	9.3 ± 0.54	496.9 ± 12	1755 ± 26	3.53 ± 0.12
L-fiber 10 %	9.0 ± 0.56	503.6 ± 15	1700 ± 48	3.38 ± 0.13
L-fiber 15 %	8.5 ± 0.34	508.5 ± 18	1680 ± 38	3.3 ± 0.18

*Mean ± SD.

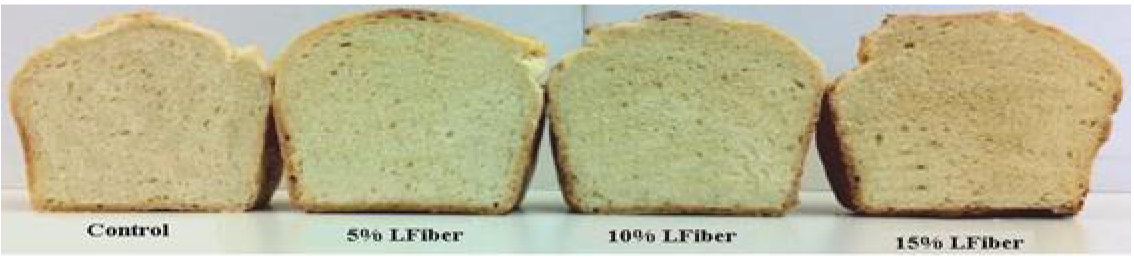

Fig. 5: External and internal appearance of pan bread from WF and its blends with SLHF (5, 10 and 15 % substitution of WF with SLHF).

in bread volume with increasing levels of lupin or soy flour and attributed this decrease to the dilution of the wheat gluten by the legume protein. It appears, therefore, that the decrease in bread volume resulting from substitution of WF with SLHF is most likely due to the combined effects of gluten dilution and mechanical disruption of the gluten network structure by the fiber particles. In addition, examination of the loaf internal structure revealed that the crumb of the SLHF supplementing bread contained a small number of gas cells compared to the control (Fig. 5).

Concerning loaf weight, as can be observed in Table (3) the loaf weight of samples incorporating SLHF was higher than that of the control bread sample. This effect is probably related to the increased water retention of dough resulting from substitution of WF with SLHF. As the level of SLHF supplementation increased (5–15 %), the loaf weight of the corresponding fortified breads gradually increased. The water retention capacity was to some extent enhanced by substitution of WF with SLHF in bread formulations. Additionally SLHF-enriched breads had slightly higher moisture content than the control due to a higher water addition during bread making and capacity of SLHF to retain more water than gluten. On the other hand, the loaf height of samples incorporating SLHF was lower than that of the control bread sample. This effect is probably related to the decreased elasticity of dough resulting from substitution of WF with SLHF. The control bread exhibited good crumb structure than the SLHF enriched breads, indicating that SLHF addition exhibited a more resistant to deformation crumb (Fig. 5). This behaviour is reasonable considering that the control sample was prepared with WF only that resulted in a stronger and more organized gluten network, due to its higher content of the gluten proteins. Substitution of WF with SLHF brought a marked increase in crumb hardness probably as a result of the thickening of the crumb walls surrounding the air cells and the strengthening of the crumb structure by the protein or fiber particles.

All colour data were expressed by Hunter L*, a*, and b* values corresponding to lightness, redness, and yellowness, respectively. The crust colour of samples was affected by the replacement of WF with SLHF (Table 4). In general, as SLHF level increased, the crust colour became darker as measured by the colourimeter. The crust of the control was lighter and less yellow than any of the other samples. For crumb colour, as the level of SLHF increased, the a* and b* values increased, indicating that a redder and more yellow crumb was obtained as a result of substitution of WF with SLHF.

The darkening of bread containing SLHF might have been attributed to an increase in Maillard reac-

Table 4: Colour measurements of pan bread from WF and its blends with SLHF (5, 10 and 15 % substitution of WF with SLHF)*.

Colour parameters	Crust			Crumb		
	L*	a*	b*	L*	a*	b*
WF	97.53 ± 3.79	1.24 ± 0.69	4.92 ± 2.74	100.62 ± 3.74	0.90 ± 0.60	2.31 ± 1.58
L-fiber 5 %	90.11 ± 6.66	1.69 ± 2.02	9.36 ± 5.15	99.77 ± 1.93	1.79 ± 0.70	5.50 ± 3.10
L-fiber 10 %	88.16 ± 8.29	2.57 ± 2.12	9.59 ± 1.74	96.9 ± 3.36	4.33 ± 0.46	13.47 ± 1.25
L-fiber 15 %	82.98 ± 7.58	3.61 ± 2.22	14.12 ± 3.22	96.8 ± 3.71	4.19 ± 0.59	13.60 ± 1.74

*Mean ± SD of 10 different points on crust and crumb.

tion taking place during baking. In the Maillard reaction, reducing carbohydrates react with free amino acid side chain of protein mainly lysine and lead to amino acid–sugar reaction products (polymerized protein and brown pigments). This reaction may compromise the nutritional value of foods through the blocking and destruction of essential amino nutrients (Hurrell, 1990). Colour of WF bread was light brown which increased significantly upon increasing the level of substitution of SLHF.

Most people who have tried bread from WF - SLHF mixes have found the texture, taste and frequently the colour to be appealing (Table 5). Substitution of WF with SLHF at 5, 10 or 15 % leads to reduce bread making potential degree and the reduction depends on the substituent level. However, substitution at 5 and 10 % SLHF gives parameter values at least as good as the control sample and produces acceptable bread in terms of weight, volume, crumb structure and colour. The blend with <10 % shows a substantial decrease in all values measured. A potential market for SLHF will appear in the nearest future.

CONCLUSION

In conclusion, the SLHF showed higher levels of ash, crude fat and dietary fiber than the WF. Conversely, WF showed higher levels of moisture, crude protein and starch. Mean dietary fiber increased with increasing amount of SLHF added for substituting WF with SLHF at 5, 10 and 15 %, on dry weight basis. The results of oscillation tests showed that the moduli (G' and G") decreased slightly with increasing SLHF content in the mixtures in comparison to the WF with a deformation of $\gamma = 10^{-3}$. A stable dough structure in hibernation is determined based on the dominance of the WF in the blends. The addition of SLHF caused a shift of curves G' and G" towards higher values, while curve tan δ moved towards lower values. The data indicate that the additions applied caused an increase in WF dough elasticity (G') and viscosity (G").

The dough surface of the wheat dough and the blend with 5, 10 and 15 % SLHF were classified as "normal". The volume of the control bread sample was higher than that of samples incorporating SLHF. This effect is probably related to the decreased elasticity of dough resulting from lupin addition.

The crust colour of samples was affected by the replacement of WF with SLHF. In general, as SLHF level increased, the crust colour became darker as measured by the colourimeter. Substitution of WF with SLHF at 5, 10 or 15 % leads to reduced bread making potential degree of reduction depends on the substituent level. However, substitution WF with SLHF at 5 and 10 % gives parameter values at least as good as the control sample and 15% produces acceptable bread in terms of weight, volume, crumb structure and colour. Development of such functional foods would be beneficial to improve the nutritional status of consumer. Finally, it can be concluded that SLHF can be used successfully in bakery products.

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Table 5: Sensory evaluation of pan bread from WF and its blends with SLHF (5, 10 and 15 % substitution of WF with SLHF)*.

Sample	Appearance	Crumb texture	Crumb grain	Crust colour	Taste	Odour	Overall acceptability
WF	8.3 ± 1.42	8.4 ± 1.65	8.2 ± 1.03	8.3 ± 1.49	8.3 ± 0.95	8.7 ± 1.16	8.4 ± 1.35
L-fiber 5 %	8.2 ± 1.14	8.1 ± 1.29	7.2 ± 1.75	8.5 ± 1.51	7.7 ± 1.49	8.2 ± 0.92	7.7 ± 1.70
L-fiber 10 %	7.8 ± 1.23	7.8 ± 1.40	6.4 ± 1.84	7.9 ± 1.73	7.6 ± 1.43	7.8 ± 1.40	7.6 ± 1.17
L-fiber 15 %	7.1 ± 1.91	7.1 ± 1.97	6.0 ± 2.31	7.8 ± 1.75	7.6 ± 1.26	7.8 ± 1.03	7.1 ± 1.52

*Mean ± SD of ten panelists

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استخدام ألياف قشر الترمس الحلو في إنتاج خبز جديد ذي خصائص وظيفية

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هناك علاقة واضحة بين تناول الألياف والحد من الأمراض المرتبطة بالقلب وحدوث مرض السكري. ومع ذلك، فإن تناول الألياف هو عادة أقل من الكمية الموصى بها. ونتيجة لذلك، تتجه الكثير من البحوث الي زيادة محتوي الألياف في الاغذية. الهدف من هذا البحث هو دراسة إمكانية إستخدام ألياف قشر الترمس الحلو عند مستوي (٥ ، ١٠ و ١٥٪ من دقيق القمح) في إنتاج خبز جديد ذي خصائص وظيفية. أظهرت النتائج أن محتوي الرماد والدهن والفينولات والفلافونولات الكلية والالياف الغذائية في ألياف قشر الترمس أعلي عنها في دقيق القمح. كما أوضحت أن إضافة ألياف قشر الترمس أدت إلي زيادة نسبة الماء الممتص وزمن تكوين العجينة وكذلك زيادة درجة ثبات العجينة والمقاومة للخلط لاعلي درجة عند إضافتها بنسبة ٥٪ ولكنها انخفضت عند زيادة النسبة الي ١٠ أو ١٥٪. كما بينت الاختبارات الريولوجية الديناميكية أن سلوك العجينة (viscoelastic behav-iour) كان خطياَ في مدي تشويه $١٠^{-٤} \leq \gamma \leq ١٠^{-٣}$. وأن معامل التخزين (G´) أكبر من معامل الفقد (G´´). لم يتأثر قوام العجينة عند أي نسبة إضافة لألياف قشر الترمس وكان سطح العجينة طبيعيا. وكان لون القصرة للخبز المصنع من دقيق القمح (العينة الكنترول) أقل دكانة واصفرارا من باقي العينات. بالنسبة للون اللبابة فبزيادة نسبة إضافة ألياف قشر الترمس تزيد قيمة كل من a* و b* ، مما يدل على أن لون لبابة الخبز أكثر احمرارا و أصفرارا نتيجة إستبدال دقيق القمح بألياف قشر الترمس. كما أظهر التقييم الحسي أن استخدام ألياف قشر الترمس بنسبة ٥ أو ١٠ ٪ أعطي خبزاً جيداً يقارب العينة الكنترول وأن نسبة ١٥٪ تنتج خبزاً مقبولاً من حيث الوزن والحجم وقوام اللبابة واللون. بالإضافة إلى ذلك، أشار المحكمون إلي أن إستخدام ألياف قشر الترمس في إنتاج الخبز يعتبر أمراً مقبولاً. وبالتالي، فإن استخدامها يسمح بزيادة الاستهلاك اليومي من الألياف دون حدوث آثار سلبية على الخصائص الريولوجية للعجائن أو الجودة والقبول العام للخبز الناتج. ولذا تشير الدراسة إلى إمكانية إستخدام ألياف قشر الترمس الحلو بنسب ٥-١٥٪ في صنع الخبز من أجل تحسين النظام الغذائي.