Oscillation Measurements and Creep Test of Bread Prepared from Wheat-Lupin Flours and Wheat Flour-Lupin Fibre Dough's Blends

Abdelrahman R. Ahmed[1,2], I. Mohammed[1,3*] and B. Senge[1]

1 Institute for Food Technology and Food Chemistry, Department of Food Rheology, Technical University of Berlin, Sekr. KL-H1, Königin-Luise-Str. 22, D-14195 Berlin / Germany.

2 Faculty of Education, Home Economics Department, Ain Shams University, Cairo, Egypt.

3 Faculty of Agriculture, Food Science Department, Aleppo University, Syria

ABSTRACT

The effects of lupine flour or fibre supplementation (5, 10 and 15% of wheat flour) on the dynamic rheological properties of dough were studied. A linear viscoelastic behavior of module at the range of $10^{-4} \leq \gamma \leq 10^{-3}$ was found. The storage modulus (G′) is greater than the loss modulus (G′′).

INTRODUCTION

Lupine flour is widely considered an excellent raw material for supplementing different food products owing to its high protein content[1] and is largely used as eggs substitute, for example in cakes, pancakes, biscuits, or brioche[2], and has been added to spaghetti[3], pasta, crisps[4], and bread[5]. It has been also used as a butter substitute in cake, brioche, and croissant[2]. Lupine does not contain gluten, thus it is sometimes used as a functional ingredient in gluten-free foods[6]. Lupine kernel fiber has also a potential as a human food ingredient as it has been used in the production of palatable fiber-enriched baked goods and pasta[7]. Rheology is defined as a study of the deformation and flow of matter[8]. 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[9, 10], liquid food[11, 12], gels[13, 14], emulsions[15, 16] and pastes[17, 18]. Vast food materials show a rheological behaviour that classifies them in between the liquid and solid states; meaning that their characteristic varies 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. The aim of this study was to test the effects of lupin flour and lupin fibre supplementation on the dynamic rheological properties of dough.

MATERIALS AND METHODS

Materials

Local Egyptian breeds of lupine (*Lupinus albus L.* variety Giza) were obtained from the Agricultural Research Centre, Giza, Egypt. Lupine flours and hulls were obtained after grinding lupine grains in a laboratory hammer mill (Retsch - Germany) until they could pass through a 250 µm screen. Commercial wheat flour type 405 was obtained from Lidl Market (Berlin-Germany).

Methods

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 rheological properties of dough samples.

Amplitude sweep

The amplitude of relative strain was $10^{-4} \leq \gamma \leq 1$ 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.

RESULTS AND DISCUSSION

Oscillation measurements

Amplitude sweep

Figure (1) showed that a collection of storage and loss modulus and loss factor for lupine dough compared with wheat flour dough. In the double logarithmic representation of the deformation-dependent behavior of the studied dough is pronounced with a dominant LVR solid behavior (G '> G " or detect loss factor <1), followed by a decrease of both moduli and an increase in the Loss factor with structural break (tan δ = 1). The overall structure and macro-structure is experiencing a "break down ", will be completely destroyed. A sub-structure is not available. The destruction of deformation γ_z with G '= G is located at wheat flour-dough at 0.6, with 0.5 lupine flour-dough. Compared to the wheat flour dough should be noted that despite the higher protein content, the higher level structure and the

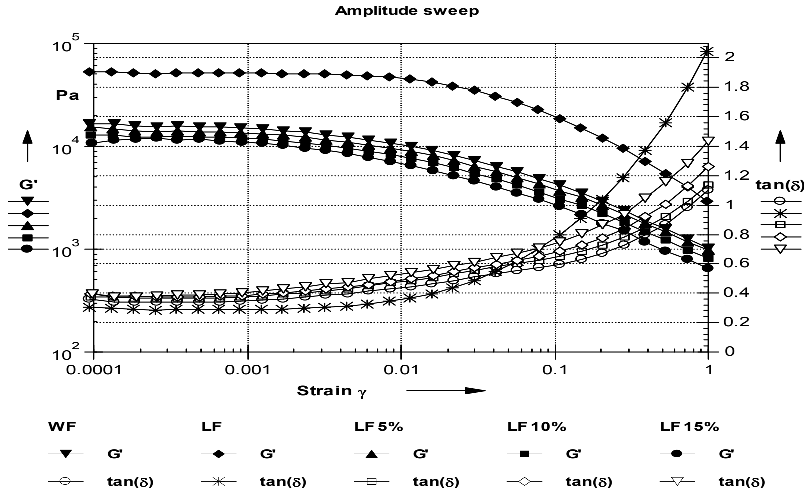

Figure (1): Amplitude sweep the flour mixture in dough (5, 10 and 15 % lupine flour)

relatively larger particulation in lupine-dough quickly leads to a structural instability of the dough, recognizable by the curve of tan δ. The module (G', G" and G*) with increasing lupine flour content in the mixtures in comparison to the wheat flour with a deformation of $\gamma = 10^{-3}$ decreased slightly. A stable structure in hibernation is determined based on the dominance of the wheat flour in the blends. This result was in agreement with earlier studies[19].

The addition of lupine fiber 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 wheat flour 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.[20] 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).

Frequency sweep measurements

To characterize the dough as the dispersed material systems, the frequency-dependent behavior of the wheat flour and lupine flour or fiber depending on the subsequent mixing ratios (5%, 10% and 15% lupine flour or fiber) was examined by oscillatory measurements.

The relations G', G" and tan δ with frequency sweep for pure wheat flour dough, composite flour dough's and pure lupine flour dough are presented in fig. (3). 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 module – the storage modulus and the loss modulus for pure wheat- and lupine flour 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. When the oscillation frequency increased from 0.1to approximately 1 Hz, the higher frequencies caused an increase of those values. Similar frequency dependence was noted by Pedersen et al.[21] for cookie doughs, but not confirmed with Rasper[22], who is reported that when higher frequencies are used,

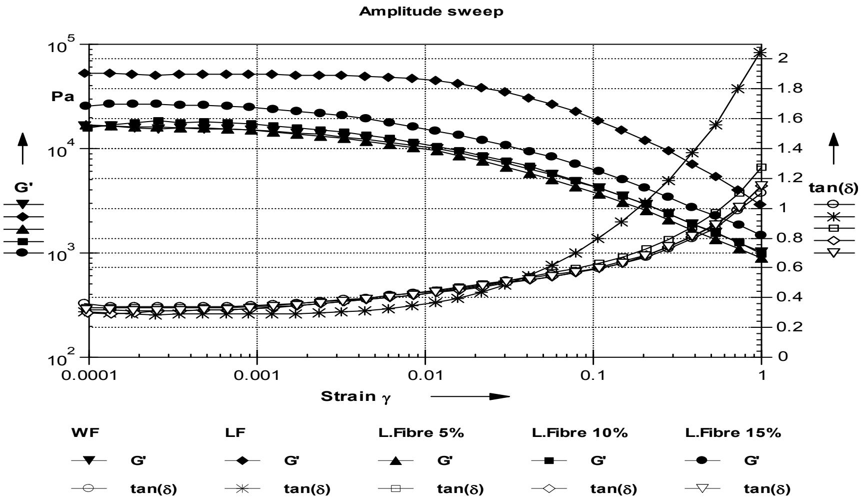

Figure (2): Amplitude sweep the flour mixture in dough (5, 10 and 15 % lupine fiber)

becomes greater than due to viscoelastic solid conversion to elastoviscous liquid.

In contrast, the additions of lupine fiber at different concentration (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 $\tan\delta$ decreased (Fig 4).

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 behavior of the lupine doughs. Therefore, $\tan\delta$ ($=G''/G'$) values for all dough formulations were lower than 1.

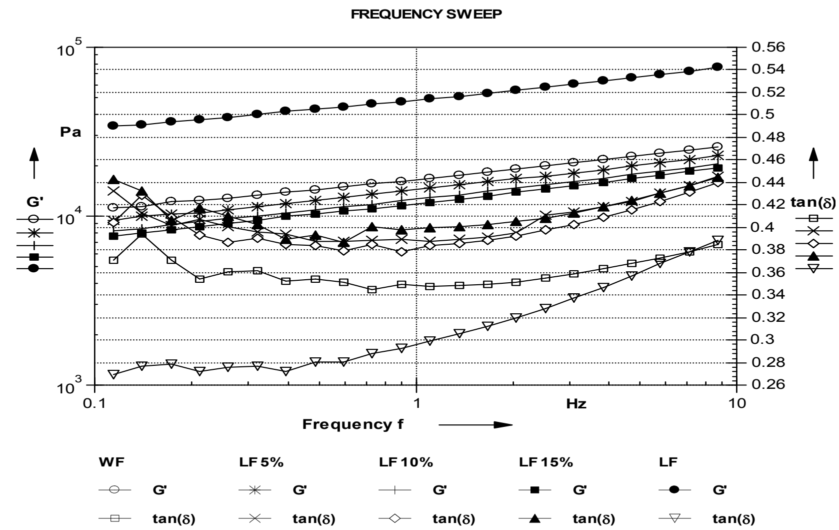

Figure (3): Frequency sweep the flour mixture in dough (5, 10 and 15 % lupine flour)

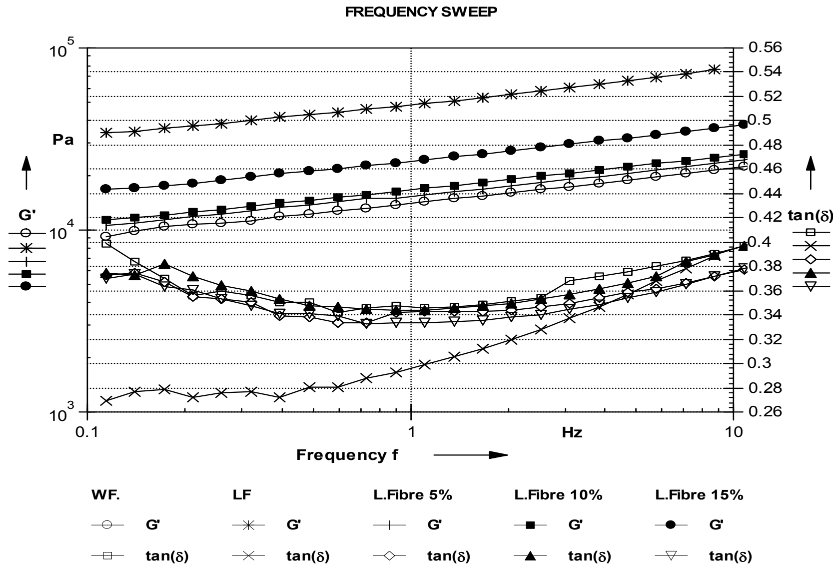

Figure (4): Frequency sweep the flour mixture in dough (5, 10 and 15 % lupine fiber)

<u>Creep tests</u>

The creep test was done to compare the properties of the materials science different flours and their mixtures at constant measuring conditions. This measured approach within the framework of classical dough investigation evaluated only partially. There are proven higher viscoelastic properties of the wheat dough. Is clearly an example this (old) conventional method has the great difference in the structural properties seen between wheat flour and lupine dough. Compared to the lupine dough, the dough with wheat flour had optimal viscoelastic material. Fig. (5,6) showed that the wheat flour values compared to the lupine flour dough, the higher of maximum deformation and creep compliance as well as having equal weight of the restoring force. The elastic deformation units to the wheat flour dough almost twice as large compared to the viscous friction. With increasing concentration of lupine flour in the dough system (flour mixtures) increases the maximum deformation and elastic recovery (from 1.01 to 1.64) when lupine flour was add at 15 %. While, with increasing concentration of lupine fiber in the dough system (flour mixtures) decreases the maximum deformation and elastic recovery (from 1.01 to 0.58) when lupine fiber was add at 15 % fig. (5, 6).

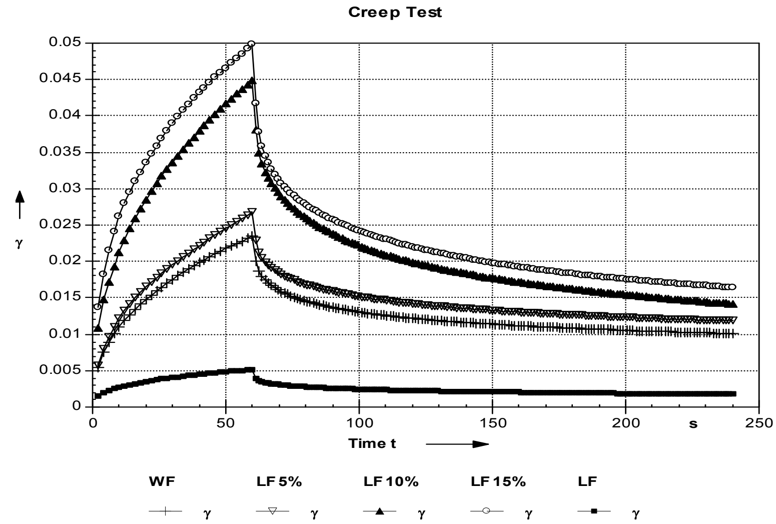

Figure (5): Frequency sweep the flour mixture in dough (5, 10 and 15 % lupine flour)

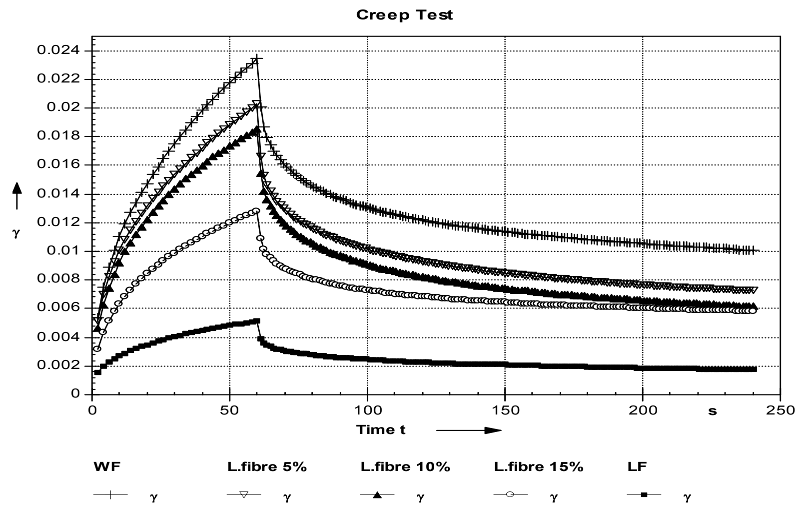

Figure (6): Frequency sweep the flour mixture in dough (5, 10 and 15 % lupine fiber)

CONCLUSION

The rheological properties of dough and their phase change behaviors were discussed. The value of modulus increased with an increase in frequency for pure wheat- and lupine flour dough as well as for composite flour dough. The results showed that rheological properties of all dough's were characterized as dispersion system and indicated the distinctive elastic behavior ($G' > G''$). Increasing of lupine proportion in the mixtures caused increasing of G' and G''-level. The flow-ability was very low for pure lupine flour dough sample compared to pure wheat flour dough. The flow-ability decreased with increasing the lupine flour concentration in blend-dough. Despite all this, the addition of lupine fiber to the wheat flour did not significantly affect on the properties of dough. Moreover, the nutritional values have been improved by the addition of lupine. In general, it is clear that the addition of lupine flour up to 15% is not affected on the working properties of the dough.

REFERENCES

1. Sironi, E., F. Sessa, and M. Duranti (2005), “A simple procedure of lupin seed protein fractionation for selective food applications”, *European Food Research and Technology,* **221**, 145-150.

2. Tronc, E. (1999), “Lupin flour: a new ingredient for human food”, *Grains Legumes,* **25**, 24-29.

3. Rayas-Duarte, P., C. M. Mock, and L. D. Satterlee (1996), “Quality of spaghetti containing buckwheat, amaranth, and lupin flours”, *Cereal Chemistry,* **73**, 381-387.

4. Lampart-Szczapa, E., W. Obuchowski, K. Czaczyk, B. Pastuszewska, and L. Buraczewska (1997), “Effect of lupine flour on the quality and oligosaccharides of pasta and crisps”, *Food / Nahrung,* **41**, 219-223.

5. Dervas, G., G. Doxastakis, S. Hadjisavva-Zinoviadi, and N. Triantafillakos (1999), “Lupin flour addition to wheat flour doughs and effect on rheological properties”, *Food Chemistry,* **66**, 67-73.

6. Scarafoni, A., A. Ronchi, and M. Duranti (2009), “A real-time PCR method for the detection and quantification of lupin flour in wheat flour-based matrices”, *Food Chemistry,* **115**, 1088-1093.

7. Smith, S., R. Choy, S. Johnson, R. Hall, A. Wildeboer-Veloo, and G. Welling (2006), “Lupin kernel fiber consumption modifies fecal microbiota in healthy men as determined by rRNA gene fluorescent <i>in situ</i> hybridization”, *European Journal of Nutrition,* **45**, 335-341.

8. Bourne, M. (2002), Physics and Texture. *In “*Food Texture and Viscosity: Concept and Measurement” M. Bourne, editor. Academic Press, New York. 59-106.

9. Weert, X., C. J. Lawrence, M. J. Adams, and B. J. Briscoe (2001), “Screw extrusion of food powders: prediction and performance”, *Chemical Engineering Science,* **56**, 1933-1949.

10. Grabowski, J. A., V. D. Truong, and C. R. Daubert (2008), “Nutritional and rheological characterization of spray driednext term sweetpotato previous termpowdernext term”, *LWT - Food Science and Technology,* **41**, 206-216.

11. Sabato, S. F. (2004), “Rheology of irradiated honey from Parana region”, *Radiation Physics and Chemistry,* **71**, 101-104.

12. Park, Y. W. (2007), “Rheological characteristics of goat and sheep milk”, *Small Ruminant Research,* **68**, 73-87.

13. Michon, C., C. Chapuis, V. Langendorff, P. Boulenguer, and G. Cuvelier (2004), “Strain-hardening properties of physical weak gels of biopolymers”, *Food Hydrocolloids,* **18** 999-1005.

14. Foegeding, E. A. (2007), “Rheology and sensory texture of biopolymer gels”, *Current Opinion in Colloid & Interface Science,* **12**, 242-250.

15. Robins, M. M., A. D. Watson, and P. J. Wilde (2002), “Emulsions - creaming and

rheology" *Current Opinion in Colloid & Interface Science,* **7,** 419-425.

16. Corredig, M., and M. Alexander (2008), "Food emulsions studied by DWS: recent advances" *Trends in Food Science & Technology,* **19**, 67-75.

17. Abu-Jdayil, B., K. Al-Malah, and H. Asoud (2002), "Rheological characterization of milled sesame (tehineh)" *Food Hydrocolloids,* **16**, 55-61.

18. Lim, H. S., and G. Narsimhan (2006), "Pasting and rheological behavior of soy protein-based pudding" *LWT - Food Science and Technology,* **39**, 344-350.

19. Letang, C., M. Piau, and C. Verdier (1999), "Characterization of wheat flour_water doughs. Part I: Rheometry and microstructure", *Journal of Food Engineering,* **41**, 121-132.

20. Lamacchia, C., S. Chillo, S. Lamparelli, N. Suriano, E. La Notte, and M. A. Del Nobile (2010), "Amaranth, quinoa and oat doughs: Mechanical and rheological behaviour, polymeric protein size distribution and extractability", *Journal of Food Engineering,* **96**, 97-106.

21. Pedersen, L., K. Kaack, M. N. Bergs'e, and J. Adler-Nissen (2004), "Rheological properties of biscuit dough from different cultivars, and relationship to baking characteristics" *Journal of Cereal Science,* **39**, 37-46.

22. Rasper, V. F. (1993), "Dough rheology and physical testing of dough." *In* Advances in Baking technology. B. S. Kamel and C. E. Stauffer, editors. VCH Publishers, New York. 107-129.