Gelation of oxidised cereal beta-glucan extracts

Author:
Anand Mohan
Cereal Technology Division
Department of Food and Environmental Sciences
anand.mohan@helsinki.fi

Introduction

Cereal β-glucan, which occurs in plant cell walls, is the major component of soluble dietary fiber in oat and barley. Soluble fibers with a high solution viscosity, which is positively correlated to molecular weight (MW), lower the serum glucose and cholesterol levels. The relevant health claims on β-glucan as a functional food have been allowed by regulatory authorities, including the EFSA and the US FDA. In most processed-food systems, the native hydrolytic enzymes are inactivated, but oxidative degradation of this non-starch polysaccharide can, however, adversely affect the claimed health benefits. (Kivelä 2011). Although the physiological benefits are positively correlated with the viscosity of β-glucan, the relationship with its gelling capacity is not fully understood.

The scope of the Master's thesis included (1) the study of gelation characteristics of oxidised solutions of oat and barley β-glucan, and (2) correlating the results obtained by dynamic light scattering (DLS) microrheology with conventional rheology.

Methods

Native oat and barley β-glucans (OBG and BBG) were extracted, purified and oxidised, as per the procedure outlined in **Fig. 1**.

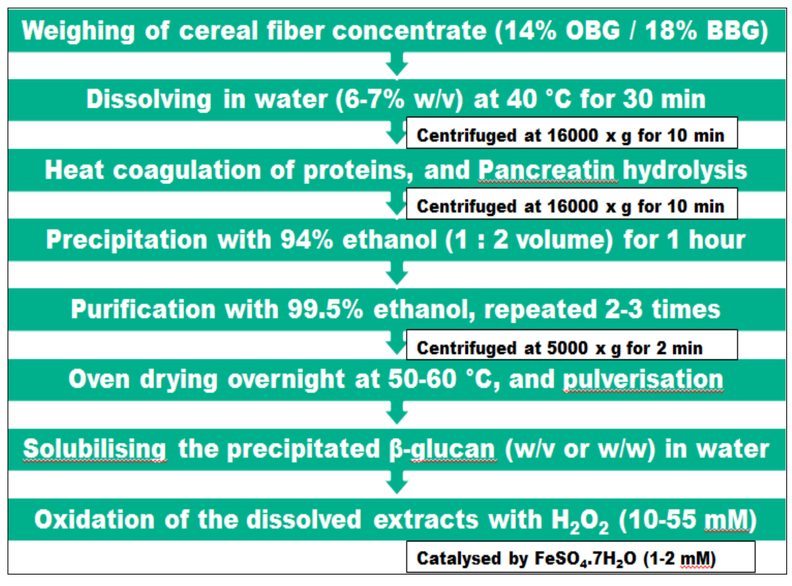

Fig. 1: Extraction and oxidation of β-glucan.

Rheological (RheoStress 600, Thermo Haake) and microrheological (Zetasizer Nano – ZS, Malvern) investigations were conducted on β-glucan solutions, 1-8 days after oxidising.

Results

Moduli curves of high-concentration BBG (4.0% w/w) illustrates the transformation in its viscoelastic characteristics on oxidation (**Fig. 2)**. Initially G″ was dominating on G′, and both the moduli increased with ω. Gelation was observed in the oxidised samples after a week, since G′ became partially independent of frequency and predominated over G″. Contrastingly in the non-oxidised samples, G′ exceeded G″ initially, but there was an early cross-over and the viscous modulus prevailed at higher frequencies.

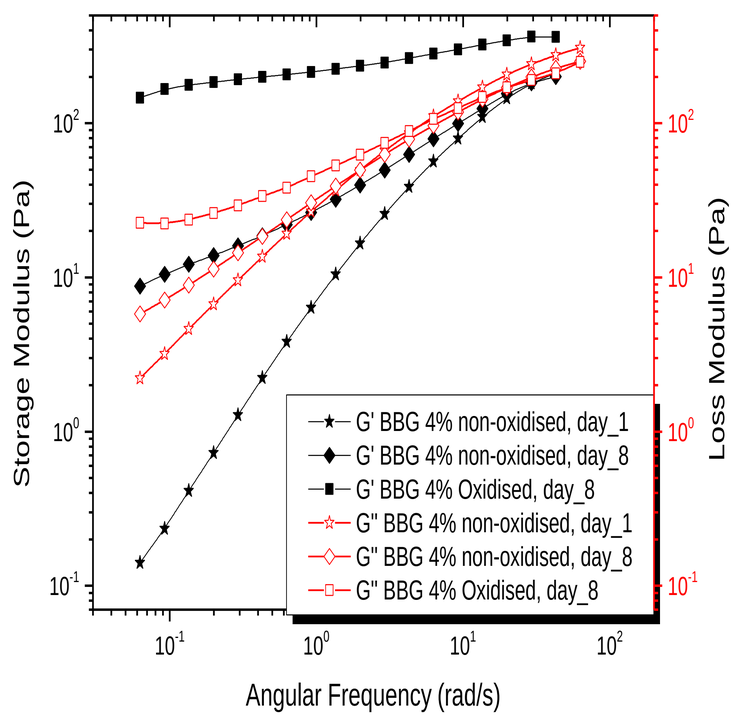

Fig. 2: Storage (G′) and viscous (G″) modulus plotted against angular frequency (ω), for oxidised BBG and control samples.

Thixotropy was conspicuous in the gelling BBG solutions **(Fig. 3)**. At the beginning, the viscosity curves with ascending shear overlap with those obtained with descending shear but after a week's storage, hysteresis between the up and the down curves was appreciable, particularly for the oxidised samples.

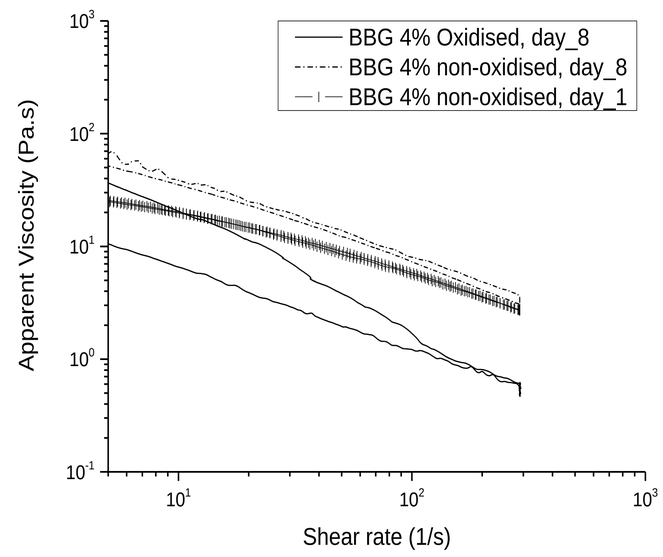

Fig. 3: Thixotropic loops for oxidised BBG and control samples.

In microrheology of dilute BBG solutions (0.2% w/v), η* of the oxidised samples first decreased, but surged after a week with a shear-thinning slope **(Fig. 4)**. Besides, G′ gained in strength and became less dependent on ω, as also seen in the bulk rheology of high-conc. BBG (**Fig. 2)**.

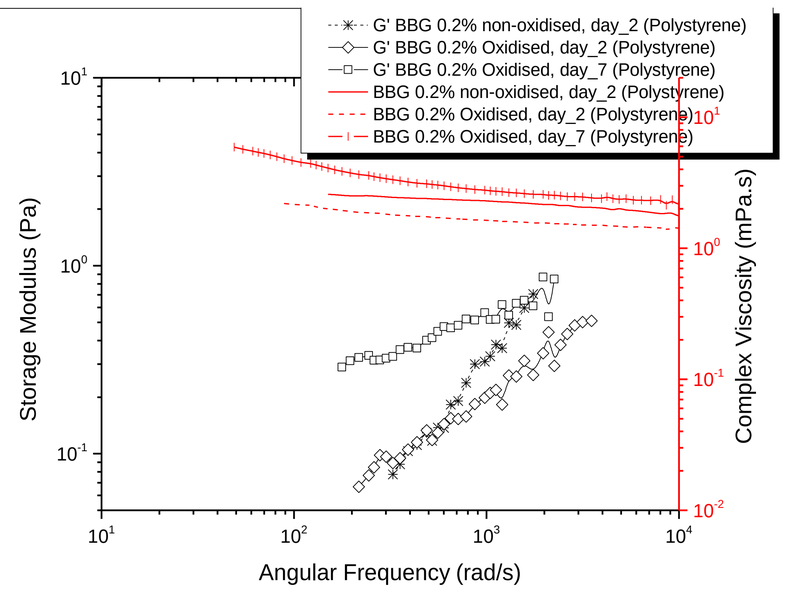

Fig. 4: Microrheology assessment with polystyrene probes in BBG.

Discussion

The low-MW BBG extract in the present study, which further depolymerised on oxidation, gelled more convincingly (**Fig. 2)** than the very high-MW OBG extract which somewhat forfeited its viscoelasticity due to oxidative degradation (results not shown for oat). This is also indicated in the microrheology data that are obtainable at a much higher frequency range **(Fig. 4)**. In a study of the gelling properties of BBG extracts (8% w/v) that were acid-hydrolysed to different molecular weights, Vaikousi *et al*, 2004, also noted that the least amount of time was required by the lower MW polymers to acquire a gel structure. In addition to the effect of MW, the higher cellotriose / cellotetraose (DP3/DP4) ratio in BBG was also hypothesied to facilitate gelation. Furthermore, hysteresis due to rotational shear was more prominent in the gelling BBG **(Fig. 3)** than in OBG solutions.

Moschakis *et al*, 2012, observed an overlap in the values of G′, G″ and η* for 2-5.0% (w/w) BBG extracts, obtained by rheology and direct imaging-based microrheology techniques. However, the different concentration regimes for bulk rheology and DLS microrheology in the present study make such an overlap unlikely.

Conclusion

Oxidised barley β-glucan showed the highest tendency for gel formation in oscillatory and rotational rheology, and also in microrheology experiments. This reaffirms that in cereal β-glucans, a low molecular weight and a high DP3/DP4 ratio is more conducive for gelation.

References

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Vaikousi H, Biliaderis CG, Izydorczyk MS. 2004. *J Cereal Sci 39(1):119-37.*

UNIVERSITY OF HELSINKI
FACULTY OF AGRICULTURE AND FORESTRY