Physico-chemical properties of BG, GNB and CSWB solutions isolated from the legumes

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콩류에서 분리된 BG, GNB, CSWB 용액의 이화학적 성질

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Abstract

Physico-chemical properties of black gram (BG), great northern bean (GNB), and California small white bean (CSWB) isolated from the legume were investigated. The ratio of galactose to arabinose (G/A) increased in the order CSWB < GNB < BG. Small-amplitude oscillatory tests indicated viscoelastic properties of BG, GNB, and CSWB ranging from solid-like, paste-like, and liquid-like behaviors, respectively. Small-strain oscillatory tests were conducted to assess the structure recovery of the AGs(arabinogalactans) after pre-shearing. G” values of BG and GNB increased, but those of CSWB remained constant after shearing.

1. Introduction

AGs, mainly isolated from legumes, are widely used as emulsifiers in the food industry (Castellani, et al., 2010). AGs are used to supplement beverages to enhance viscosity and provide pH stability. In humans, AGs are mainly fermented in the large intestine by gut microbiota, although the gastric phase is considered to be key in the digestion process (Mellinger, et al., 2008). Chemical and mechanical modification of AGs happens in the stomach. Acidity in the stomach directly promotes the release of arabinosyl units from the polysaccharides (Zhang, 2003). Depending on the AG type and concentration, the rheological properties may exhibit either Newtonian flow behavior (generally at high shear rates) or shear thinning flow behavior (generally at low shear rates) (Christian Sanchez, Renard, Robert, Schmitt, & Lefebvre, 2002). In this work, three different types of legumes－BG, GNB, CSWB－having different carbohydrate structures and compositions, were selected and characterized.

2. Experiment

2.1 Small amplitude oscillatory tests

For small shear amplitude oscillatory measurements, AG solutions with 1%, 2.5%, and 5% (w/v) concentrations were prepared. Two types of tests were conducted: strain sweep and frequency sweep tests. The strain sweep test was conducted to determine the linear viscoelastic region of the sample. During the test, a frequency of 1 rad/s was selected, whereas the strain was changed in the range of 0.1 – 20%. Based on the strain sweep test results, a frequency sweep test was performed with 3.0% strain amplitude over a frequency range of 0.1 – 100 rad/s. Results are expressed in terms of the storage (G’) and loss (G”) moduli, and the phase angle (δ) as a function of frequency. To investigate the effect of pre-shearing, different shear rates (0, 500, and 1000 s^{-1})were applied to the AG solutions for 10min. After the pre-shearing step, both storage and loss moduli were measured as afunction of time at a constant frequency of 1rad/s and a normal stress of 0.01Pa.

3. Results and discussion

3.1. Physico-chemical properties of AGs

3.1.1.Viscoelastic properties of the AG solutions determined by small shear amplitude oscillatory tests

Oscillatory tests of AG solutions yielded values for the storage modulus, G', loss modulus, G", and the phase angle, d. These three values provide an indication of the mechanical signature of the material and enable its classification into groups such as solid-like, paste, and liquid-like materials (Fevzioglu, Hamaker, & Campanella, 2012). BG solutions with a 5% concentration had G' values significantly higher than G" values, indicating a solid-like structure or gel-3D network (Fig. 1A). Differences between G' and G" values decreased when the concentration of the solution decreased. For 1% BG solutions, G' and G" were very close, indicating that these solutions behave more like pastes or high viscosity liquids. The cross-over observed in the GNB solutions with 1% and 2.5% concentrations could be defined as a critical gelling point of the solution (Yang, Campanella, Hamaker, Zhang, & Gu, 2013). Interestingly, the cross-over is affected by the concentration of the solution. Critical gelling points of 1%, 2.5%, and 5% GNB solutions were determined as approximately 2.5, 10, and 15 rad/sec, respectively (Fig. 1B). For instance, large changes in the storage and loss moduli with frequency are more indicative of liquid-like viscoelastic materials, which are very noticeable for the 1% GNB solution, followed by the 2.5% and 5% solutions, as illustrated in Fig. 1B. The CSWB solutions exhibited significantly higher G" than G' values at all frequencies, suggesting that CSWB solutions exhibited liquid-like behavior (Fig. 1C).

3.2.2. Influence of pre-shear treatment on structure recovery of AGs

AG solutions were pre-sheared at different shear rates (0, 500, and 1000 s-1)for10minfollowedbymeasurementofG" as a function of time at an angular frequency of 1 rad/s. This time sweep test for 5% solutions of BG, GNB, and CSWB is illustrated in Fig. 2. G" values of the BG solution drastically increased when the pre-shearing rate increased with respect to the un-sheared solution. Changes of G" over time increased slightly after the application of the pre-shear treatment. Increasing G" values upon the application of shearing would indicate a structural building process of the dispersed AG molecules in the solution (Li, et al., 2009).

4. Conclusion

BG, GNB, and CSWB with different chemical structures exhibited a variety of physico-chemical properties. The physico-chemical properties of the AG solutions were affected by the ratio of galactose and arabinose. The frequency sweep test indicated that various structures of AGs can form gel-3D networks, pastes, or liquid solutions. The composition and chemical structure of the AG had a large influence on the viscosity and viscoelastic properties of solutions formed with those AG molecules. The effect of different pre-shearing treatments on a solution's structure recovery was measured by a small strain oscillatory test as a function of time. G" values of solutions formed with AGs from BG increased after a high pre-shearing treatment, but the G" values of solutions prepared with AGs from GNB and CSWB were nearly constant. This result indicates that an intensive pre-shearing treatment involving high shear rates was able to promote particle-particle interaction and an increase in the elastic properties of the sample (G').

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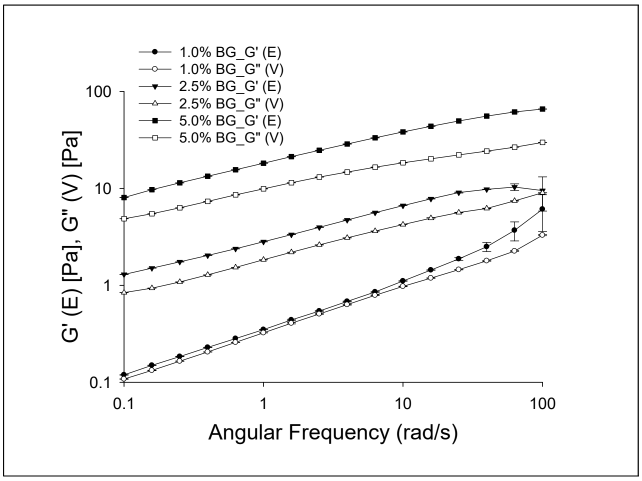
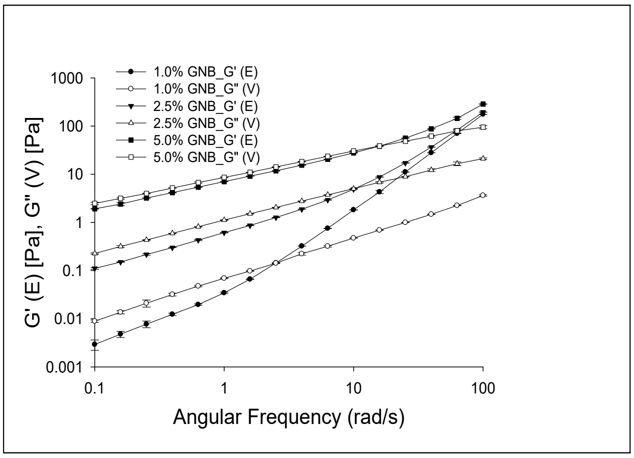
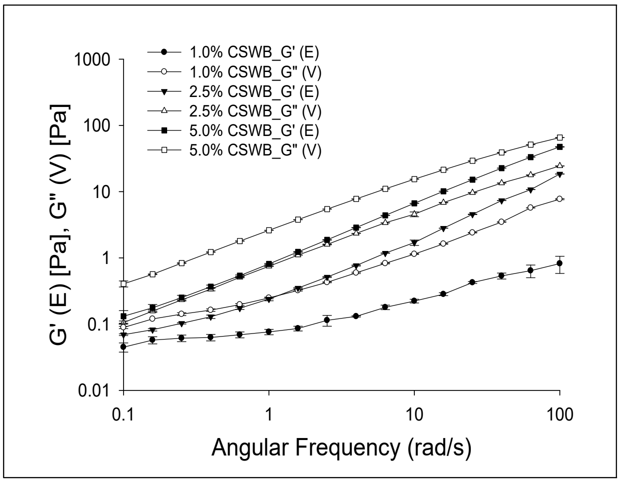


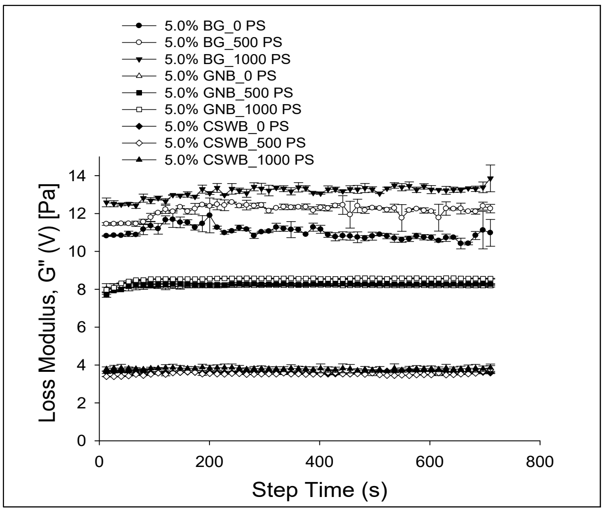
[Fig. 1A] Viscoelastic properties of 1%, 2.5%, and 5% of (A) BG, solutions. Changes in storage, *G'*, and loss, *G"*, moduli as functions of the log of the angular frequency are shown. The error bars show the standard deviation of duplicates (n = 2).



[Fig. 1B] Viscoelastic properties of 1%, 2.5%, and 5% of (B) GNB, solutions. Changes in storage, *G'*, and loss, *G"*, moduli as functions of the log of the angular frequency are shown. The error bars show the standard deviation of duplicates (n = 2).



[Fig. 1C] Viscoelastic properties of 1%, 2.5%, and 5% of (C) CSWGB, solutions. Changes in storage, *G'*, and loss, *G"*, moduli as functions of the log of the angular frequency are shown. The error bars show the standard deviation of duplicates (n = 2).



[Fig. 2] Frequency-sweep plots for 5% BG, GNB, and CSWB solutions with different pre-shearing (PS). The range of PS used was 0–1000 s-1. The error bars show the standard deviation of duplicates (n = 2).