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Rheological characterization of jet-cooked *Lesquerella fendleri* seed gum and cornstarch solutions☆

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Abstract

Lesquerella is a potential new seed crop that contains hydroxy fatty acid triglycerides and approximately 15% seed coat gums. The polysaccharide gum of the *Lesquerella fendleri* seed was isolated and jet-cooked with cornstarch in a series of laboratory experiments to investigate the viscoelastic properties of gum-modified starch solutions. The *Lesquerella* gum was combined with cornstarch at 1, 5, and 10% levels to produce a jet-cooked and drum dried material with potential application as a thickening or suspension agent. Flow curves were determined for 1% solutions of jet-cooked starch and gum combinations. All materials investigated were biodegradable and exhibited positive thixotropic behavior. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: New crops; Gums; Rheology; Viscosity modifier

1. Introduction

Lesquerella fendleri is an emerging new crop with a polysaccharide seed coat gum that exhibits positive thixotropic behavior in dilute solutions (Abbott et al., 1994). The seed oil contains a triglyceride composition with over 50% hydroxy fatty acids (Barclay et al., 1962; Mikolajcak et al., 1962; Roetheli et al., 1991; Abbott et al., 1997). As the production of *L. fendleri* increases to provide hydroxy fatty acids for the growing industrial market, the supply of seed coat gums will also increase. To develop new applications for the available *L. fendleri* seed coat gum, we investigated the treatment of gum and cornstarch solutions in a jet-cooking process and evaluated the rheological performance of the resulting material.

☆ Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

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2. Materials and methods

Food grade cornstarch, Buffalo 3401, was obtained from CPC International, Inc. (Argo, IL). The cornstarch density was reported to be 1.5 g ml^{-1} with a specific heat of 0.31 cal g^{-1} °C, and a moisture content of between 5 and 10%. *L. fendleri* seed coat gums were previously recovered from hexane extracted meal by water washing and freeze-drying (Carlson et al., 1992).

Solutions of cornstarch and *Lesquerella* gums were prepared separately in de-ionized water and sheared for 10 min in a Waring model CB-3 laboratory blender (Waring Products Corp., New York, NY) at a setting of medium. These cornstarch and *Lesquerella* solutions were then combined and mixed together in the laboratory blender for another 5 min to produce a homogeneous mixture with a total solids of 15% (w/v). Following this procedure, solutions were prepared from cornstarch and 1, 5, or 10% *Lesquerella* gum to produce feed material to the jet-cooker with different compositions while maintaining a constant total solids content of 15%.

A Penick and Ford (Penford Products Co., Cedar Rapids, IA) laboratory jet-cooker was used to process the gum and cornstarch solutions. The jet-cooker was equipped with a type B, size 300 Hydro-heater (Hydro-Thermal Corp., Milwaukee, WI), and a model SSQ Moyno feed pump (Robbing and Myers Inc., Chicago, IL). The jet-cooker was operated at a feed rate of 1.8 l min^{-1}. The temperature of the cooker was held at 140°C with 275 kPa steam. Jet-cooked product was collected in a stainless steel Dewar flask. Samples of feed and product were taken for viscosity determinations. A rotary double drum dryer equipped with 30.5 cm diameter and 45.7 cm long drums was used to dry the jet-cooked materials (Drum Dryer and Flaker Corp., North Liberty, IN). The drum dryer was operated at a speed of approximately 2 rpm and heated to 143°C with 310 kPa steam. Drum dried material was milled to a fine powder using a model 3379 laboratory mill (Thomas Corp., Philadelphia, PA) fitted with a 1 mm screen.

Rheological characterizations were performed with a controlled-stress rheometer (Model CSL2500, CarriMed, Dorking, UK) equipped with a 6 cm, 2° cone fixture and a Peltier plate which enabled the temperature in the chamber of the instrument to be controlled to ± 0.2°C.

Thixotropic loop experiments were conducted over the shear rate range 0.8–250 s^{-1}. The upward and downward cycles of the loop were kept equal, with a total cycle time of 4 min. Small-amplitude, oscillatory frequency sweeps were conducted using a constant applied strain of 30% over an angular frequency range 0.1–100 rad s^{-1}. The strain amplitude was selected to provide a measurable level of torque for each material across the frequency range of interest. A torque sweep was conducted prior to the small-amplitude oscillatory frequency sweep experiments to determine the linear viscoelastic range. This strain amplitude was found to be within the linear viscoelastic range for each of the solutions tested. Experiments were replicated to provide agreement within 10% relative standard deviation.

3. Results and discussion

Samples of cornstarch, *Lesquerella* gum, and jet-cooked solutions were subjected to rheological evaluations to measure the extent of network formation. Data for the first cycle of thixotropic loop experiments on mixtures of cornstarch with 5 and 10% *Lesquerella* gum are presented in Figs. 1 and 2, respectively. Both materials exhibited similar positive thixotropic responses before and after jet-cooking. The cornstarch solution containing 5% *Lesquerella* gum displayed an increase in viscosity of nearly two orders of magnitude after jet-cooking (Fig. 1). The cornstarch solution containing 10% *Lesquerella* gum also displayed an increase in viscosity after jet-cooking but not as great as the 5% solution (Fig. 2). One possible explanation for this behavior is that the jet-cooking operation disrupts the developing gel network, which limits the viscosity in the jet-cooked product. Subsequent additions of gums in the feed material do not substantially contribute to an increased product viscosity. The greatest change in viscosity between feed and product material is then observed with the lower level of gums.

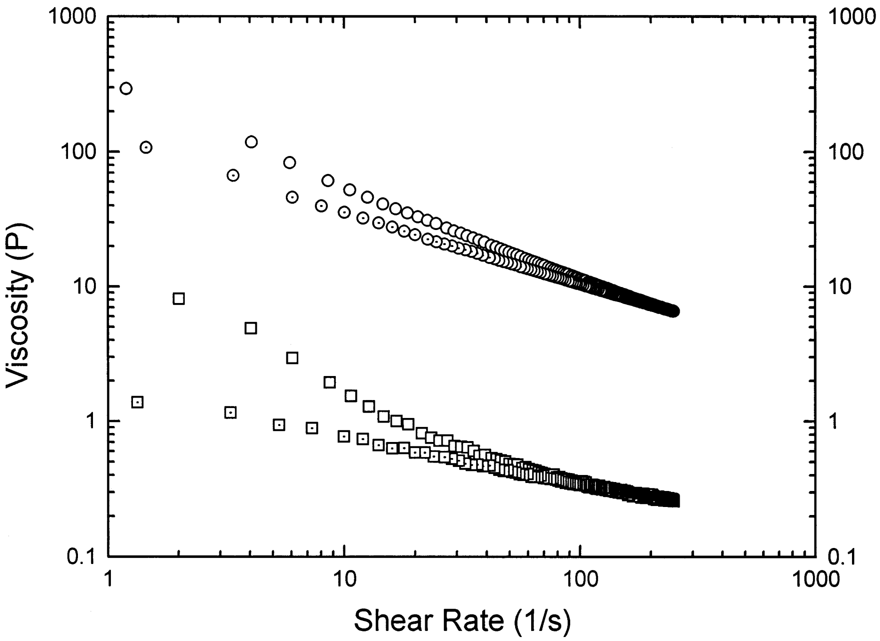

Fig. 1. Thixotropic loop measurements for cornstarch and 5% *Lesquerella* gum solutions determined at 25°C before and after jet-cooking. Feed, □ up cycle, ⊡ down cycle; product, ○ up cycle, ⊙ down cycle.

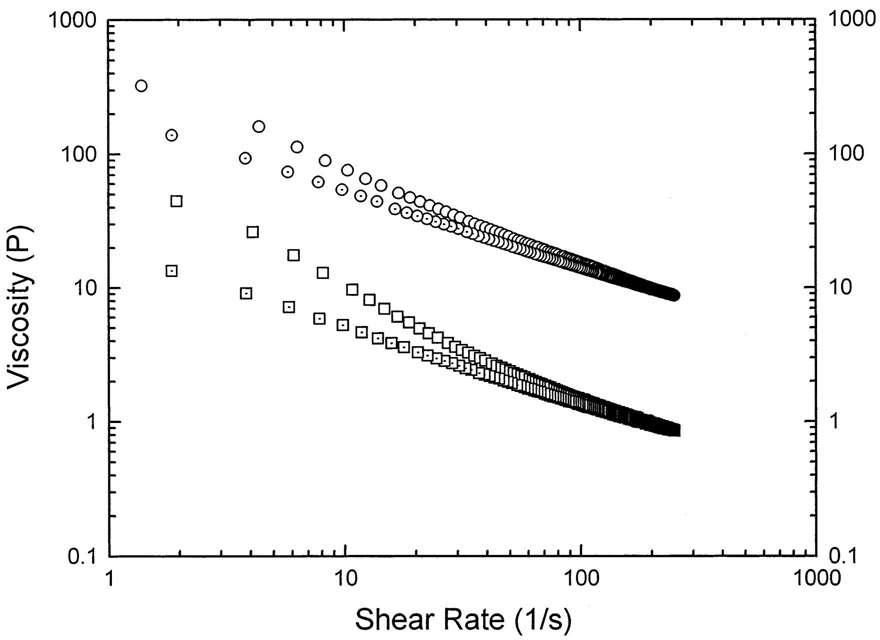

Fig. 2. Thixotropic loop measurements for cornstarch and 10% *Lesquerella* gum solutions determined at 25°C before and after jet-cooking. Feed, □ up cycle, ⊡ down cycle; product, ○ up cycle, ⊙ down cycle.

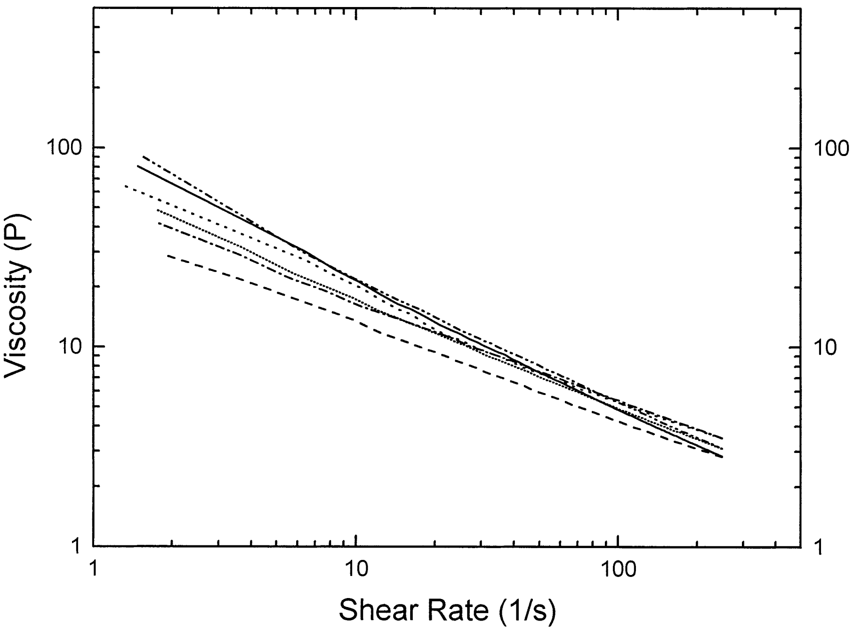

Fig. 3. Thixotropic loop determinations for 1% solutions of drum dried, jet-cooked mixtures of cornstarch and *Lesquerella* gum determined at 25°C. *Lesquerella* gum (0%), — up cycle, - - - down cycle; 1% *Lesquerella* gum,. . .up cycle, ▂ · ▂ down cycle; 10% *Lesquerella* gum, ▂· ·▂ up cycle, … down cycle.

Feed solutions prepared from cornstarch only, as a control, and cornstarch containing 1% *Lesquerella* gum were also subjected to thixotropic loop experiments, but the solids did not remain suspended in solution. These data were not considered reliable and were not reported (Chhabra, 1993).

The jet-cooked products were drum dried, milled, and redissolved in de-ionized water to a 1% solids concentration and characterized by thixotropic loop experiments and by small-amplitude oscillatory sweeps (Figs. 3 and 4). Fig. 3 shows the results for the first cycle of thixotropic loop experiments for samples of cornstarch, cornstarch with 1% *Lesquerella* gum and cornstarch with 10% *Lesquerella* gum. The addition of *Lesquerella* gum did not appreciably change the behavior of the jet-cooked material. This may be the result of drum drying the material, which could lead to degradation of the cross-links or modification of the gums. The addition of *Lesquerella* gum appears to have slightly diminished the positive thixotropic response as the up and down curves for the *Lesquerella* containing materials are bounded above and below by the control (Fig. 3).

Fig. 4 displays the results of oscillatory sweeps performed on solutions of these same materials. In each case, the viscous or loss modulus is the dominant response over the frequency range investigated. Cornstarch with 1% *Lesquerella* gum shows greater deviation between the loss and storage modulus at the lower frequencies while cornstarch with 10% *Lesquerella* gum shows greater deviation at the higher frequencies. It is interesting to note that the values for the loss and storage modulus of the control is bounded above and below by cornstarch with 10% *Lesquerella* gum.

During the course of this study, we observed microbial or fungal growth in solutions of cornstarch and gums left open to the atmosphere at ambient temperatures. This indicates that under aerobic conditions these jet-cooked materials are biodegradable (Kawai, 1995).

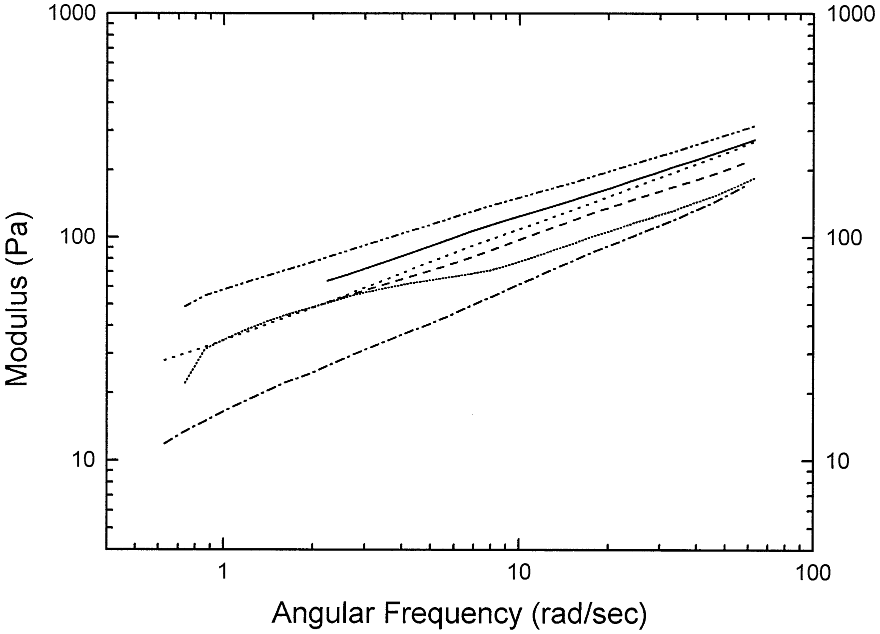

Fig. 4. Response of drum dried, jet-cooked mixtures of cornstarch and *Lesquerella* gum to oscillatory shear in 1% solutions at 25°C in terms of storage modulus, G', and loss modulus, G''. Cornstarch with 0% *Lesquerella* gum, - - - G', — G''; cornstarch with 1% *Lesquerella* gum, – · – G', · · · G''; cornstarch with 10% *Lesquerella* gum, … G', –· · – G''.

4. Conclusions

Mixtures of cornstarch jet-cooked with 1, 5, and 10% *Lesquerella* gum produced materials with positive thixotropic properties and with a higher viscosity than mixtures of the same materials prior to jet-cooking. All of these materials were biodegradable and offer potential as viscosity modifiers in edible and industrial applications.

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