

Effect of Extraction Conditions on Yield, Composition, and Viscosity Stability of Barley β -Glucan Gum

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ABSTRACT

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Cereal β -glucan can function as a thickener, but endogenous β -glucanase enzymes of the grain cleave β -glucan, reducing its viscosity. Although different extraction techniques have been developed, the viscosity stability of β -glucan gum has not been reported. The objective of this study was to investigate the effect of extraction treatments on the yield, purity, and viscosity stability of barley β -glucan (BBG) gum. A regular barley cultivar, Condor, and a waxy cultivar blend were extracted at pH 7–10 and 55°C for 0.5 hr. Four extraction conditions were evaluated: 1) extraction at high pH with no additional heat treatment; 2) boiling of extract; 3) prior refluxing of flour with 70% ethanol; and 4) treatment of extract with thermostable α -amylase for purification. Viscosity of extracts was monitored for ≥ 24 hr at 25°C. The highest β -glucan purities

were achieved with a boiled Condor extract at pH 7 (81.3% db, 4.1% yield) and with refluxed waxy barley extracted at pH 8 and treated with α -amylase and (79.3% db, 5.1% yield). Gums extracted without subsequent heat treatment or prior refluxing of flour had high protein (>17%) and starch (>24%) impurities, respectively. The viscosity of gums obtained without heating was unstable. Prior refluxing treatment was not sufficient to stabilize final extracts. Boiling extracts resulted in stable but low viscosity. Reflux followed by purification treatment produced the highest stable viscosity for 0.5% solutions of both Condor (64 mPa sec⁻¹, pH 7) and waxy (48.8 mPa sec⁻¹, pH 8) extracts. Stable BBG gum with high viscosity can be obtained using thermal treatments in combination with high pH. The potential use of such gums as thickeners in food systems needs to be assessed.

Research on isolation of β -glucan, which produced stable solutions, was pioneered by Preece and Mackenzie (1952). Key extraction methodologies for barley and oat β -glucan were developed by Wood et al (1977, 1978). More recently, Bhatti (1993) investigated the influence of different solvents on recovery and viscosity of barley and oat β -glucan gums. β -Glucan recovery from barley and oat bran was 80–85% and $\approx 55\%$ with NaOH and Na₂CO₃, respectively, but sodium carbonate extracts had viscosities that were more than three times higher. Dawkins and Nnanna (1993) reported that extraction at pH 9.2 and 50°C and pH 10 and 50–55°C produced the highest yield and purity of oat β -glucan. They later investigated the effects of concentration, temperature, NaCl, pH, and sucrose on the rheological properties of oat gum and compared its viscosity to other food-grade gums (Dawkins and Nnanna 1995). Oat β -glucan gum may have applications as a thickener and stabilizer in food products and, possibly, in biomedical applications. Earlier studies on barley β -glucan (BBG) primarily focused on estimation and characterization of β -glucan from the perspective of the needs of the brewing and feed industries.

Pilot plant studies to scale up β -glucan extraction procedures have been reported (Wood et al 1989, Bhatti 1995). Wood et al (1989) extracted β -glucan from oat bran that was deactivated by refluxing with 75% ethanol for 4 hr prior to extraction. Sodium carbonate was used to adjust to pH 10. The viscosity of the pilot plant gum was less than the viscosity of bench gum obtained under similar conditions, probably as a result of the high shear rates and enzyme activity of fungal or bacterial origin encountered under the pilot plant conditions (Wood et al 1989). Extract of deactivated bran obtained with 0.2M sodium acetate buffer had no viscosity loss after 1 hr, whereas extract of nontreated bran lost 24% of its original viscosity. The viscosity loss of deactivated bran extracts obtained at pH 10 was ascribed to nonenzymatic changes that probably involved phenolics. However, a 1-hr test of viscosity stability, as performed by Wood et al (1989), is a fairly short period. Products containing β -glucan as a thickener or stabilizer require viscosity stability over their shelf life. Viscosity stability tests that continue for at least 24 hr should give a better indication of enzyme stability for preliminary development.

Bhatti (1995) used 1N NaOH as a solvent in pilot plant extraction of β -glucans from hull-less barley and oat bran and did not detect β -glucanase activity in any of the brans by flow-injection analysis (Aastrup and Jorgensen 1988). Bran was not inactivated, but the chosen analysis method may not have been sensitive enough to detect low-level activity. Conversely, Wood et al (1989) found increased enzyme activity in oat bran, possibly due to concentration of enzyme-rich outer layers. The high extraction pH used by Bhatti (1995) would denature proteins and enzymes (Hurrell and Finot 1985), and thus, enzyme degradation is less likely than chemical cleavage (McCleary and Codd 1991). Whatever the reason, the viscosities of barley and oat gums obtained by Bhatti (1995) were lower than that of oat gum isolated by Wood et al (1989). Bhatti (1995) did not report the stability of his extracts nor the thinning effect from high shear rates in pilot plant equipment.

Clearly, enzymatic hydrolysis may represent a major problem in production and further utilization of β -glucan. Glucanase enzymes may be native to barley or may originate from microorganisms. Brunswick et al (1987) found significantly ($P < 0.05$) higher activity of endo-(1 \rightarrow 3)- β -D-glucanase in imbibed barley compared to endo-(1 \rightarrow 3)(1 \rightarrow 4)- β -D-glucanase, in which enzyme activity was assessed by viscometry. Kilning at 60°C for 16 hr decreased endo-(1 \rightarrow 3)(1 \rightarrow 4)- β -D-glucanase activity by 70–80%, whereas endo-(1 \rightarrow 3)- β -D-glucanase activity was reduced by only 30%. Endo-(1 \rightarrow 3)- β -D-glucanase was stable at 60°C for 40 min, but when the temperature was increased to 70°C, its activity level was negligible (Ballance and Meredith 1976). Steaming and kiln-drying, which are common industrial practices used with oat to inactivate lipases and minimize rancidity, have not been investigated as potential methods for glucanase inactivation in barley. Enzymes of microbial origin may be more heat stable than endogenous barley glucanases (Wood et al 1989). Furthermore, despite initial inactivation of enzymes, post-contamination of extract or gum is possible. Conditions favorable for microbial growth are created when gum is dispersed in water. Probably, the most reliable method of detecting enzyme activity is measurement of changes in extract viscosity over time.

Anderson et al (1978) cited a range of conditions for inactivation of β -glucanase enzymes when using ethanol or isopropyl alcohol as solvents. In this study, ethanol was used because it does not represent a health risk, but it is expensive and requires special fire- and explosion-proof equipment and plants. Alternative methods of inactivating enzymes that result in a stable gum product of consistent yield, purity, and viscosity were sought.

The objectives of this study were to investigate the effects of different extraction conditions, such as high pH without heating,

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prior ethanol reflux, boiling of extract, and treatment with thermostable α -amylase on the yield, composition, stability of viscosity, and shear-thinning behavior of BBG gum.

MATERIALS AND METHODS

Two samples of hull-less barley were provided by J. Helm (Alberta Agriculture, Food and Rural Development, Lacombe, AB, Canada): cv. Condor (5.4% β -glucan, db) with normal starch and Bly Blend (7.0% β -glucan, db) with waxy starch. Bly Blend is a mixture of two experimental cultivars, SB89528 and SB89497. Whole kernels were crushed in a mill (model III Plus, Magic Mill, Salt Lake City, UT) and finely ground to <250 μ m in a sample mill (cyclone model 3010-30, Udy Corp., Fort Collins, CO). Sodium carbonate was from BDH (Toronto, ON, Canada) and ethanol (99.9%) was from Commercial Alcohols (Brampton, ON, Canada). Pure BBG (>99% purity specified) of low- (LV) and high-viscosity (HV) (1% [w/v] solutions at 5.9 and 114 centistokes and molecular weights of 137,000 and 327,000, respectively) were purchased from Megazyme (Bray, Ireland). Termamyl 120 LN, a thermostable α -amylase EC 3.2.1.1. from *Bacillus licheniformis* was provided by Novo Nordisk BioChem. (Toronto, ON, Canada). Distilled water was used.

Extraction of β -Glucan

The extraction procedure was modified from that of Wood et al (1978). Barley was ground to pass through a 250- μ m mesh screen. The flour-to-water ratio was 1:12. Four thermal treatments were used: 1) extraction at pH 9 and 10, achieved by addition of a few milliliters of 20% (w/v) Na_2CO_3 to untreated flour followed by addition of water and adjustment of pH before extraction and no thermal treatment of the extract (no heat gums); 2) barley flour refluxed twice with 70% ethanol (2 \times 1 hr) (refluxed gums); 3) extracts from untreated flour, immediately after starch separation, were boiled for 1 hr at the pH of extraction (boiled gums); and 4) extracts of refluxed flour were treated with thermostable α -amylase for 1 hr at 98°C to eliminate starch impurities (purified gums).

The four experimental treatments were performed with waxy barley at 55°C and various pH levels (Burkus 1996), whereas for Condor pH (7.0) and temperature (55°C) were kept constant (Temelli 1997). Gums were classified based on 1% (w/w) solution viscosity: LV at 1–20 mPa sec⁻¹ and HV at >100 mPa sec⁻¹.

TABLE I
Composition and Viscosity of Waxy Barley Gums Obtained at High pH with no Additional Heat Treatment and 55°C^a

Extraction pH	Yield (%)	β -Glucan (%)	Starch (%)	Proteins (%)	Viscosity ^b (mPa sec ⁻¹)
9	4.4b	57.8a	7.6a	17.7b	150.1a
10	4.9a	44.6b	8.7a	27.2a	131.1b

^a Means in the same column followed by the same letter are not significantly different ($P > 0.05$).

^b 1% (w/w) solution measured at a fixed speed of 16 rpm.

TABLE II
Composition and Viscosity of Refluxed Waxy Barley Gums Extracted at Different pH levels and 55°C^a

Extraction pH	Yield (%)	β -Glucan (%)	Starch (%)	Protein (%)	Pentosans (%)	Viscosity ^b (mPa sec ⁻¹)
5	6.6c	52.5d	24.7	2.1	5.3	8.9c
6	6.5c	54.2c	26.1	2.3	4.1	8.8c
7	5.8d	57.5b	27.1	3.4	4.6	13.3b
8	6.7c	59.5a	25.5	4.7	4.3	20.8a
9	7.6b	60.3a	25.9	4.7	4.8	21.4a
10	8.4a	54.7c	25.6	6.9	6.3	15.7b

^a Means in the same column followed by the same letter are not significantly different ($P > 0.05$).

^b 0.5% (w/w) solution measured at a fixed speed of 64 rpm.

Viscosity Measurements

Viscosity measurements were done on a viscometer (Rotoviscometer model RV-3, Gebruder Haake, Berlin, Germany) at shear rates approximately that of eating (20–50 sec⁻¹) (Glicksman 1982). The viscometer was equipped with a MK 500 measuring head and NV viscosity sensor system (8-mL cup) with tempering vessel to maintain a constant temperature of 25 \pm 0.2°C. Pseudoplastic behavior, as described by the power law model, was determined by conducting flow curve or consecutive fixed-speed tests. Shear rates for flow curve analysis were \geq 41 sec⁻¹, as determined automatically by the viscometer to be the reliable range for measurements, and the shear rate range for fixed-speed tests was 12–80 sec⁻¹.

Gums were dissolved in distilled water by bringing them to a boil, and the hydrated mixture was stirred at \approx 77°C for 1 hr on a multiposition, hot-plate stirrer (model 51450, Cole Parmer Instrument Co., Chicago, IL). The solutions were cooled on the stirrer for 1 hr, and concentration was adjusted with distilled water. Choice of concentration (1% for LV and 0.5% for HV gums) was dictated by the reliable measurement range of the viscometer. Viscosity was measured immediately after preparation of solutions.

Viscosity stability of extracts was tested by measuring viscosity over time. For this purpose, extractions were performed according to the treatments described, but β -glucan was not isolated by precipitation with ethanol. Thus, the point where proteins were separated from the extract was considered time = 0, and viscosity was measured. Extracts were stored at room temperature, and aliquots were removed for viscosity measurement over time. Extracts were split into two parts. One part was kept at pH 4.5, as for protein precipitation, and one part was adjusted back to the conditions of extraction pH.

Chemical Analysis

β -Glucan and moisture contents of gum samples were determined according to McCleary and Glennie-Holmes (1985). Starch and pentosans were quantitated by the method of Holm et al (1986) and Hashimoto et al (1987), respectively. Proteins were analyzed with a nitrogen analyzer (FP-428, Leco Corp., St. Joseph, MI). Ash content was determined according to Approved Method 08-01 (AACC 1995). Results are reported on a dry matter basis.

Statistical Analysis

Extractions under each condition and chemical analyses of each extract were done twice. Viscosity measurements were performed three times for each sample. Analysis of variance of the results was performed using the GLM procedure (version 6, SAS Institute, Cary, NC). Multiple comparison of the means was performed by least significant difference tests at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Yield, Composition, and Viscosity of Gums

The composition and viscosity of gums processed under various conditions are presented in Tables I–IV. Although waxy barley gums obtained at high pH with no additional heat treatment had high viscosity (Table I), the extract could not be separated from the protein fraction adequately, despite centrifugation at 17,600 \times g. Consequently, the β -glucan content of gums was low, dropping to 44.6%, and protein contamination was high, reaching 27.2%, at pH 10 and 55°C. High protein levels were also reported by Temelli (1997) for Condor gum extracted under similar conditions. Increasing centrifugal force to 21,000 \times g did not improve protein separation. Forces higher than 8,000 \times g are rarely applied in industrial production, thus this method was excluded as a potential step for scaling up production of BBG gums.

When waxy barley flour was refluxed with ethanol prior to extraction (Table II), the viscosity of samples extracted at pH 8 and 9 was >50% higher than that of samples extracted at pH \leq 7. These high pH samples also had significantly ($P \leq 0.05$) higher purity. However, despite higher viscosity, the β -glucan content of gums

was substantially lower compared to samples obtained at pH 8 from flour that had not been refluxed (59.5 vs. 72.0%, respectively, as found in preliminary extractions). This was the result of a high starch content, probably from gelatinization during refluxing (Table II). Therefore, reducing starch content by hydrolysis with thermostable α -amylase, as described by Bhatti (1995), was undertaken.

When extracts were boiled to deactivate enzymes, high viscosity was achieved for gums extracted at pH 9 and 10 (Table III). Even though the highest β -glucan content (76.6%) was achieved at pH 8 (data not shown), its viscosity was relatively low (56.9 mPa sec⁻¹ for 1% solution), probably indicating some enzymatic hydrolysis. In a separate test, a gum extracted at pH 8.6 was treated either by boiling for 1 hr or holding at 90°C for 30 min. The gum obtained after heating at 90°C had 45% higher viscosity, indicating the β -glucan extract was not stable at boiling temperatures.

Purification of the extract from refluxed flour with thermostable α -amylase resulted in a significant ($P \leq 0.05$) improvement in the purity of gums (69.4–79.3% β -glucan) (Table III). Starch content decreased from $\approx 25\%$ in refluxed gums to $<2\%$ in purified gums, whereas protein content increased by $>60\%$ compared to refluxed gums. Despite the harsh thermal treatment (1 hr at 98°C), the viscosity of pH 8 and 9 gums was significantly ($P \leq 0.05$) higher after purification treatment. Purification treatment at a lower temperature might improve viscosity even further, because the concentration of β -glucan in the gums would be increased without the risk of thermal degradation.

Boiling and purification treatments were compared statistically (Table III). Total yield and β -glucan content were not significantly ($P > 0.05$) affected by pH within either treatment, although β -glucan content tended to decrease with increasing pH. However, viscosity of boiled gums increased significantly, whereas viscosity of purified gums decreased significantly ($P \leq 0.05$) at higher pH. The recovery of β -glucan (g of β -glucan in gum from 100 g of flour/g of β -glucan in 100 g of flour) was 49.1 and 49.5% for boiled

pH 9 and 10 gums, respectively, which was lower than that of purified pH 8 (53.1%) and 9 (53.3%) gums. Recovery (58.5%) of β -glucan was highest for purified pH 10 gum, but its viscosity was $>36\%$ lower than that of purified pH 8 and 9 gums.

β -Glucan content of Condor gums obtained with no additional heat treatment, boiling, or purification was similar ($P > 0.05$), even though boiled gum had slightly higher (81.3%) purity (Table IV). Refluxed gum had significantly ($P \leq 0.05$) lower purity (60.3%) due to high starch contamination. β -Glucan yield (g of β -glucan/100 g of flour) was also reduced after refluxing.

Viscosity Stability of Gums

The viscosity stability of gums was assessed by determining changes in viscosity over time. The drop in viscosity over time indicated β -glucanase activity that was not detected by the β -glucanase (malt and microbial) assay kit (Megazyme). The main contributor to the viscosity of a BBG gum is β -glucan. Small amounts of pentosans also contribute to gum viscosity, whereas the influence of residual protein is negligible (Bhatti et al 1991).

Figure 1 shows the change in the viscosity of waxy barley extracts obtained at pH 9 and 10 with no heat treatment over time. Apparent β -glucanase activity was inhibited when the pH was returned to its basic extraction value (b, Fig. 1) but remained high when acidic pH was maintained at 4.5 (a, Fig. 1) after protein separation. Presumably, pH 4.5 is closer to the optimal pH for enzyme activity. This agrees with the findings of Wood et al (1978), who also found enzyme activity in BBG gum after extraction at pH 10.

The change in viscosity of boiled waxy barley extracts over time is shown in Fig. 2. The viscosity of the pH 9 extract was stable for three days when maintained at pH 9 after extraction. However, when the extract was held at pH 4.5 after centrifugation, its viscosity dropped, although slowly. Because it was close to stable for 19 hr, this may be due to microbial contamination. Loss of vis-

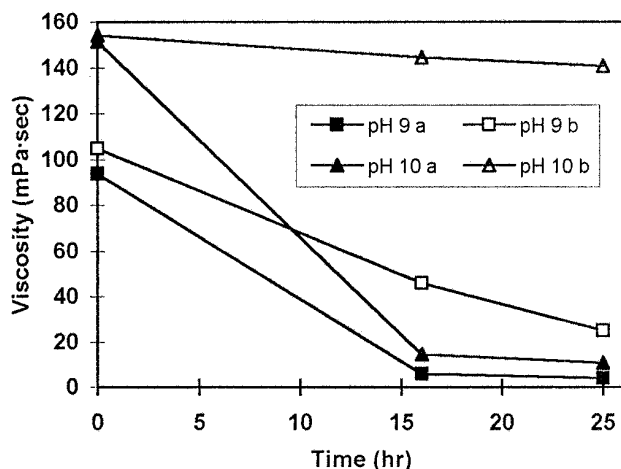


Fig. 1. Viscosity stability of waxy barley extracts obtained at pH 9 and 10 and 55°C with no additional heat treatment. Viscosity was determined at 16 rpm at pH 4.5 (a) and extraction pH (b).

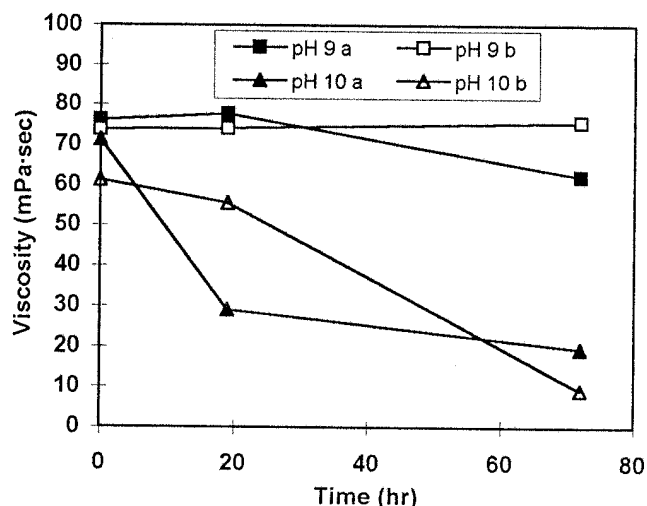


Fig. 2. Viscosity stability of boiled waxy barley extracts obtained at pH 9 and 10 and 55°C. Viscosity was determined at 32 rpm at pH 4.5 (a) and extraction pH (b).

TABLE III
Composition and Viscosity of Boiled Waxy Barley Gums and Gums Extracted with Refluxing and Purification Treatment at Different pH Levels and 55°C^a

Treatment	Extraction pH	Yield (%)	β -Glucan (%)	Starch (%)	Protein (%)	Pentosans (%)	Ash (%)	Viscosity ^b (mPa sec ⁻¹)
Boiled	9	5.0b	69.4b	12.0	6.1	6.6	2.2	25.0e
	10	5.0b	68.6b	12.6	5.2	6.3	1.7	30.5c
Purified	8	5.1ab	79.3a	1.7	8.4	6.8	2.0	48.8a
	9	5.2ab	77.9a	1.1	9.3	7.3	2.5	44.3b
	10	5.7a	77.5a	1.2	10.6	7.2	2.2	28.2d

^a Means in the same column followed by the same letter are not significantly different ($P > 0.05$).

^b 0.5% (w/w) solution measured at a fixed speed of 16 rpm.

cosity in the pH 10 extract over the same time period was substantial. Higher ionic strength and high pH could have led to cleavage of (1→3) bonds in β -glucan molecules (McCleary and Codd 1991). Extracts obtained at lower pH levels of 8 and 8.6 were tested for stability as well but lost about half their viscosity in 24 hr. After three days, acidic samples developed an off-odor.

In refluxed waxy barley extracts (Fig. 3), pH 7 extracts were apparently more stable than pH 9 extracts. This might be due to chemical cleavage of polysaccharide linkages caused by phenolic compounds in alkaline solution (Arbin et al 1980). These phenolics could be extracted by refluxing with ethanol (Wood et al 1989). Microbial enzymes, which are present on the outer layers of the grain, may have survived the inactivation procedure (Wood and Weisz 1987). Subsequent microbial contamination also cannot be excluded.

When waxy barley extracts treated with thermostable α -amylase after refluxing were studied for enzyme activity, no change in viscosity was detected for 24 hr for both pH 8 and 9 (Fig. 4). After 72 hr, samples extracted at pH 8 lost some viscosity, probably due to growth of sporogenic microorganisms or microbial contamination, because the pH of sample a increased from 4.5 to 6.2. In addition, slight off-odor formation was apparent. Samples extracted at pH 9 had stable viscosity for 72 hr. Higher pH in combination with extraction temperature (55°C) probably contributed to better digestion of

proteins (Hurrell and Finot 1985), and spores could not recover. Stability of Condor extracts obtained at pH 7 and 55°C (Fig. 5) agreed with the observed trends for waxy barley extracts. Only reflux with purification treatment resulted in a high, stable viscosity. Ethanol refluxing alone was insufficient to stabilize Condor gum, in contrast to the stable waxy refluxed gum obtained at pH 7. Boiled Condor gum had stable but low viscosity. During extraction at pH 7, which is close to the optimum for enzyme activity, β -glucanase enzymes probably quickly degraded β -glucan, and boiling was applied too late. Viscosity of Condor extracts obtained at pH 10 and 45°C (data not shown) exhibited trends similar to Condor pH 7 and 55°C gums, with stabilization at the lower level (18.3 mPa sec⁻¹) for refluxed and purified gum. Again, the high extraction pH was

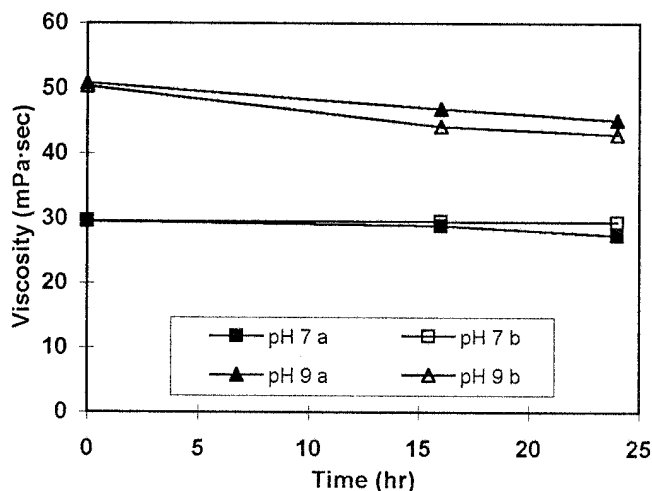


Fig. 3. Viscosity stability of refluxed waxy barley extracts obtained at pH 7 and 9 and 55°C. Viscosity was determined at 32 rpm at pH 4.5 (a) and extraction pH (b).

TABLE IV

Yield and β -Glucan Composition of Gums Extracted from Condor Flour at pH 7 and 55°C with Different Heat Treatments^a

Treatment	Gum Yield (%)	β -Glucan (%)
No heat	3.8b	78.0a
Boiled	4.1ab	81.3a
Refluxed	4.3a	60.3b
Purified	3.2c	78.8a

^a Means in the same column followed by the same letter are not significantly different ($P > 0.05$).

TABLE V

Power Law Model Parameters for Pseudoplastic Behavior of High- (HV) and Low-Viscosity (LV) Pure Commercial Gum and Boiled Waxy Barley Gum Obtained at pH 9 and 55°C

Gum	Concentration (% w/w)	Shear Rate Range (sec ⁻¹)	Consistency Coefficient (c)	Flow Behavior Index (n)	R ²
HV pure gum	0.5	41–68	0.35	0.904	0.9993
HV pure gum	1.0	12–80	4.03	0.803	0.9989
LV pure gum	1.0	118–1,359	0.10	0.999	0.9993
Boiled gum	1.0	41–118	2.55	0.860	0.9998
Boiled gum	0.5	41–723	0.33	0.885	0.9982
Boiled gum	0.25	561–2,876	0.04	1.002	0.9982

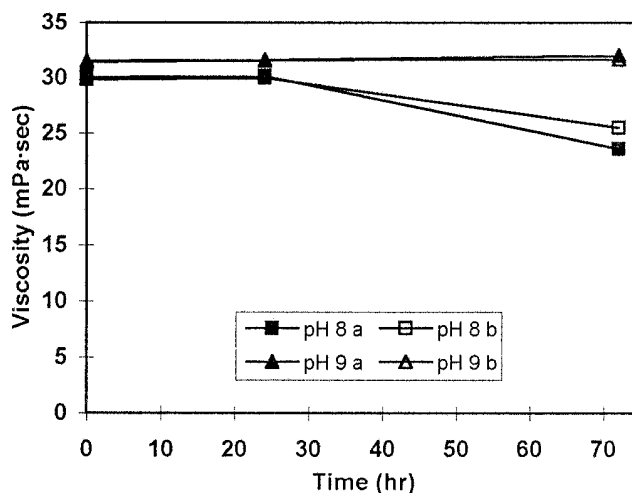


Fig. 4. Viscosity stability of purified waxy barley extracts obtained at pH 8 and 9 and 55°C. Viscosity was determined at 32 rpm at pH 4.5 (a) and extraction pH (b).

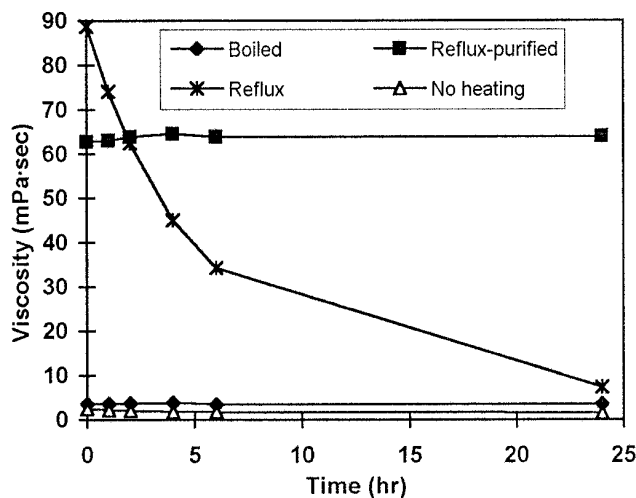


Fig. 5. Effect of different extraction treatments on viscosity stability of barley cv. Condor at extraction pH 7 and 55°C.

presumably responsible for the degradation of β -glucan. In addition, flour was wetted in distilled water for a few minutes, producing a pH \approx 6.3 prior to its adjustment to extraction pH, and viscosity was quickly depleted during this time, indicating high β -glucanase activity in Condor flour.

These results demonstrate the importance of degradation, mostly enzymatic, which should be taken into account in fortification of food products with barley β -glucan in the form of barley flour, bran, etc. The resultant lowered viscosity would reduce any viscosity-related health benefits. However, LV β -glucan might have uses in other food applications, and it certainly could be used at higher concentrations to achieve desired viscosity levels. However, it is unknown whether a high concentration of LV β -glucan leads to the same health benefits as lower concentrations of HV β -glucan.

Effect of Shear on Gum Viscosities

HV and LV pure gums and waxy boiled gum extracted at pH 9 and 55°C were examined over the shear rate ranges shown in Table V, and the power law model was applied to describe their pseudoplastic behavior. Model parameters are presented in Table V. The behavior of LV pure gum was essentially Newtonian, as was 0.25% solution of waxy boiled gum, whereas 0.5 and 1% solutions of both waxy boiled gum and HV pure gum behaved as pseudoplastic liquids, having a flow behavior index value <1 . The values of flow behavior index (n) for 1% HV gums are comparable to those reported by Bhatti (1995) for 1% barley and oat gum solutions (0.81–0.89). Consistency coefficient (c) values for boiled and HV pure gums were higher than those determined by Bhatti (1995) (2.55 and 4 vs. 0.096–0.76). Gum solutions, which are close to Newtonian ($n = 1$), have a slippery mouthfeel (Szczeniak and Farkas 1962) and may be used as a fat replacer. The apparent viscosity of waxy boiled gum, determined as a flow curve on the Haake viscometer, was not measured in the shear rate range of values close to the eating range (20–50 sec⁻¹) but was measured in the range 41–118 sec⁻¹ because of slow equilibration of the measuring spring in HV solutions. Consecutive fixed-speed measurements applied for HV pure gum better represent expected mouthfeel and are recommended for future work.

CONCLUSIONS

The production of stable HV β -glucan gums from barley requires inactivation of enzymes, either by ethanol refluxing of flour before extraction or thermal treatment of extract. Gums obtained from refluxed flour do not have a high β -glucan content and should be further purified by thermostable α -amylase, preferably at temperatures below the boiling point. The maximum β -glucan content of gum (79.3%) was achieved by extraction of refluxed waxy flour at pH 8 and 55°C and application of the purification treatment. Gum yield was 5.1% of waxy barley flour. The viscosity of a 0.5% aqueous solution at pH 4.5 of this gum was 48.8 mPa sec⁻¹. Similarly, high, stable viscosity of gum from Condor flour was achieved after treatment with thermostable α -amylase. The yield of this gum was 3.2%, with 78.8% purity and viscosity of 64 mPa sec⁻¹ for 0.5% solution. Boiling after extraction yielded stable but LV gum. If HV is not the major goal, LV gums can be extracted without any special treatment and stabilized afterward. Production of a stable barley β -glucan gum without refluxing is possible and needs further development. The HV BBG gums with high flow behavior index values have potential as fat replacers and thickeners in food systems.

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