Development of an Orange-Flavored Barley β-Glucan Beverage

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ABSTRACT

Barley β-glucan concentrate shows great potential as a functional food ingredient, but few product applications exist. The objectives of this study were to formulate a functional beverage utilizing barley β-glucan concentrate, and to make a sensory evaluation of beverage quality in comparison to pectin beverages and to assess shelf stability over 12 weeks. Three beverage treatments containing 0.3, 0.5, and 0.7% (w/w) barley β-glucan were developed in triplicate. Trained panelists found peely- and fruity-orange aroma and sweetness intensity to be similar ($P > 0.05$) for all beverages tested. Beverage sourness intensity differed among beverages ($P \leq 0.05$). Panelists evaluated beverages containing 0.3% hydrocolloid as similar ($P > 0.05$), whereas beverages with 0.5 and 0.7% β-glucan were more viscous ($P \leq 0.05$) than those with pectin at these levels. Acceptability of beverages was similar according to the consumer panel. Shelf stability studies showed no microbial growth and stable pH for all beverages over 12 weeks. Colorimeter values for most beverages decreased ($P \leq 0.05$) during the first week of storage, mostly stabilizing thereafter. With an increase in concentration, β-glucan beverages became lighter in color ($P \leq 0.05$) and cloudier, but these attributes for pectin beverages were not affected ($P > 0.05$). β-Glucan beverages exhibited cloud loss during the first three weeks of storage. β-Glucan can therefore be successfully utilized in the production of a functional beverage acceptable to consumers.

Mixed-linkage (1→3),(1→4)-β-D-glucan (β-glucan) is a soluble fiber component found predominantly in barley and oats. β-Glucan has demonstrated health-promoting properties, when included in the diet. These include cholesterol lowering (Klopfenstein and Hoseney 1987; Newman et al 1992; Wang et al 1992; Kahlon et al 1993; Wang et al 1997; Wood and Beer 1998) and regulation of blood glucose levels (Wood et al 1990; Braaten et al 1991; Wood et al 1994).

These developments led to the approval of a health claim for oats by the Food and Drug Administration (FDA) in the United States, indicating that oatmeal, whole oats, and oat products containing 0.75 g of β-glucan per serving may reduce the risk of heart disease (Federal Register 1997). Recommended consumption is 3 g of β-glucan per day to achieve such health benefits. This claim was later amended to include oat extracts containing up to 10% β-glucan (Federal Register 2002).

The nutritional benefits of β-glucan, along with its functional properties including thickening, stabilizing, emulsification, and gelation, make it a favorable nutraceutical ingredient for inclusion in the formulation and production of functional foods and beverages (Dawkins and Nnanna 1995; Burkus and Temelli 1999). β-Glucan has been isolated and concentrated from cereals using dry milling and sieving (Knuckles et al 1992; Sunberg and Aman 1994), dry milling, and air classification (Wu et al 1994) or alkaline extraction procedures (Wood et al 1989; Bhatty 1993, 1995; Dawkins and Nnanna 1993; Saulnier et al 1994; Temelli 1997). However, food product applications of β-glucan gum or development of β-glucan-enriched products remain limited in both research and commercial settings.

Beverages are excellent carriers for ingredients with nutraceutical potential such as soluble fiber or herbal extracts (Swientek 1998; Pszczola 1998). Being easily consumed along with a usual meal, a functional beverage (a beverage containing health-promoting nutraceutical ingredients) may enrich the meal and improve health. Barley β-glucan is particularly well suited for such an application, being capable of imparting a smooth mouthfeel to beverage products, while also making the beverage an excellent source of soluble dietary fiber. A barley β-glucan gum, with similar functionality, could potentially serve as an alternative to traditional beverage thickeners such as alginates, pectin, xanthan, and carboxymethylcellulose (Giese 1992). However, there are no reports on the utilization of barley β-glucan as an ingredient in the production of a functional beverage product. Therefore, the objectives of this study were to 1) develop a formulation and processing procedure for a functional beverage incorporating barley β-glucan; 2) evaluate β-glucan beverage quality and acceptability in comparison to pectin using trained and consumer panel sensory evaluation techniques; 3) examine the shelf stability of β-glucan beverages using instrumental techniques.

MATERIALS AND METHODS

Materials

β-Glucan gum (85.63%, w/w, dry matter basis) was extracted from waxy, hull-less barley (Bly Blend, mix of two experimental barley cultivars, SB89528 and SB89497) at the POS Pilot Plant Corp. (Saskatoon, SK, Canada), according to Burkus and Temelli (1998) before this study. Lime peel pectin (Mexpectin RS 450, Grinsted, Denmark), sucrose, high-fructose corn syrup (HFCS) (Isosweet 100, Staley, Decatur, IL), citric and ascorbic acids were obtained from a local food ingredient supplier (UFL Foods, Edmonton, AB, Canada). β-Carotene colorant was supplied by Hoffman-LaRoche (10% CWS β-carotene, Parsippany, NJ). Natural orange flavorings (natural orange essence 3× enriched and cold-pressed Valencia terpeneless orange peel oil) were kindly provided by Firmenich Citrus Center (Safety Harbor, FL). Glass juice bottles (300 mL) were obtained from a local bottling company. Commercial products used in training sessions for the sensory panel were purchased from a local grocery store.

Beverage Formulation and Production

Beverage formulations (Table I) were developed using laboratory-scale trials and bench top sensory evaluation by the research group. Focus group discussion was also conducted with six individuals, according to the methods outlined by Morgan (1988), for consumer assistance and product evaluation during formulation development. Pilot plant production of the beverages was performed at the Food Processing Development Center (Leduc, AB, Canada) according to the processing procedure developed during laboratory-scale trials (Fig. 1). After pasteurization, beverages were immediately hot-filled into 300-mL bottles, capped, and placed into refrigerated storage after production.

Six beverage treatments were formulated with 0.3, 0.5, and 0.7% (w/w) β-glucan gum or pectin in triplicate. Pectin was selected for use in the control treatments because it is used quite extensively in beverage products.

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Sensory Evaluation

Standard sensory evaluation procedures were followed during recruitment, selection and training of sensory judges (15 staff and students of the University of Alberta), and during trained and consumer panel evaluations (ASTM 1979; Meilgaard et al 1991). To perform descriptive analysis, panelists were trained using repeated round table and individual evaluations of trial formulations of the pectin and β-glucan gum beverages, and reference samples.

Beverage and reference samples (25 mL) were presented to the trained sensory panel in capped glass jars at 5°C. Samples were kept in a cold water bath to maintain serving temperature. Samples were presented according to a random order, balanced design along with two unsalted crackers and room temperature distilled water for rinsing, a napkin, and score sheet on an off-white fiberglass tray. Panelists evaluated samples in standard sensory panel booths containing an attribute definition sheet, stop watch, and pencil. Panelists were rewarded for participation after each session.

Reference samples consisted of Minute Maid Original orange juice, Tang breakfast drink, and Lipton orange beverage prepared according to directions on package, and a 0.45% (w/w) pectin solution. Sweetener, hydrocolloid, acid, and flavor ingredients used in β-glucan beverage production were used to prepare solutions as well as added to references to alter sample sensory attributes for training purposes. Trained panelists evaluated peely-orange and fruity-orange aroma, sweetness and sourness intensity, and viscosity attributes for all six beverages. Panelists used a 15-cm line scale to evaluate product attributes. Attribute descriptors were presented at anchor points 1.25 cm from each end of line scale (none to extreme) for aroma and taste intensity and (not viscous to extremely viscous) for viscosity. Reference samples and scores on a 15-cm line were provided for sweetness, sourness, and viscosity attributes (Table II). Scores for reference samples were determined during training sessions (Meilgaard et al 1991).

Consumer evaluation was performed at the University of Alberta fitness facility. Panelists (105 university students and staff) were provided 50-mL beverage samples in clear plastic cups on off-white fibreglass trays, along with paper ballot, napkin, pencil, and distilled water in a styrofoam cup for rinsing. Consumers were rewarded for participation.

Consumer panelists evaluated beverage sweetness, sourness, orange flavor, thickness, and overall acceptability. Panelists used a nine-point hedonic scale (like extremely; like very much; like moderately; like slightly; neither like nor dislike; dislike slightly; dislike moderately; dislike very much; and dislike extremely) scoring 9 to 1, respectively, for evaluation of the beverages.

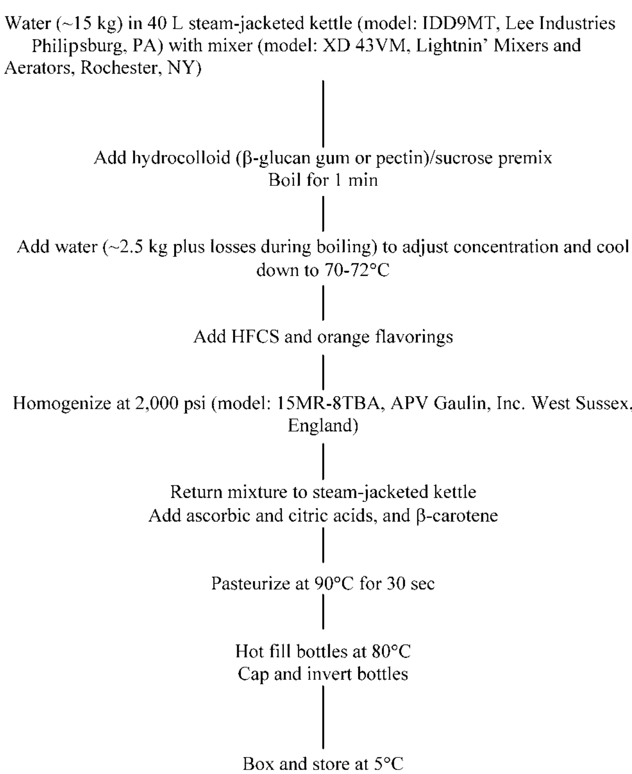

Fig. 1. Pilot plant production of β-glucan and pectin beverages.

Shelf Stability

β-Glucan and pectin beverages were stored immediately after production for 12 weeks at 5°C. Instrumental measures for examination of storage stability were performed weekly for 8 weeks and at 12 weeks. Beverage viscosity at 5°C was determined using a Haake rotational viscometer (RV-1 Rotational Viscometer, Haake, Germany). Two 8-mL samples of each beverage were used for viscosity determination. Product pH was obtained using a pH meter (model 220, Corning Labware and Equipment, Corning, NY), and total aerobic plate counts were determined according to standard pour plate methods (Speck 1979). *L*, *a*, and *b* color values were determined using a colorimeter (Hunter Associates Laboratory, Fairfax, VA). Duplicate 5-g samples of each beverage were placed in a plastic petri dish and color was measured. Cloud stability was determined by measuring product absorbance with a spectrophotometer (HP 8452A, Hewlett Packard, Boise, ID) set at 660 nm (Versteeg et al 1980). Duplicate measures were taken for all samples of the three replicates produced.

Statistical Analysis

Production of each beverage formulation followed by their evaluation by the trained panel was performed in triplicate. Consumers performed a single evaluation of 0.5% (w/w) pectin and β-glucan gum formulations. Instrumental measurements during storage stability study were performed in duplicate for all three replicates of beverage production. Analysis of variance of the results was performed using the SAS general linear model procedure (v. 7, SAS Institute Cary, NC). Multiple comparison of the means was performed by Student-Newman-Keuls (SNK) test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Beverage Formulation and Production

The beverage formulation developed and used in pilot plant production is shown in Table I. The production procedure is outlined in Fig. 1. β-Glucan gum or pectin was premixed with sucrose to prevent clumping of the polysaccharide during addition to water. Gum particles were separated by such premixing, leading to ease of mixing with water and faster processing.

The water added after the boiling step served two purposes: to add volume withheld for cooling and to account for water lost during boiling of mixture. Cooling by this method was necessary because the steam-jacketed kettle did not have cooling capabilities. Acid ingredients and β-carotene were added as late as possible in the

TABLE I
Beverage Formulations

Ingredients	Concentration (w/w)
Water	89.4, 89.2, or 89.0%[a]
β-Glucan gum or pectin	0.3, 0.5, or 0.7%
Sucrose	5.0%
High fructose corn syrup	5.0%
Citric acid	0.27%
Ascorbic acid	0.03%
β-Carotene	10 ppm
Natural orange essence	0.01%
Terpeneless orange peel oil	0.0005%

[a] 89.4, 89.2, and 89.0% water used for 0.3, 0.5, and 0.7% β-glucan or pectin, respectively.

process to minimize β-carotene degradation and to minimize the exposure of β-glucan polymers to low pH at elevated temperatures. By minimizing this exposure, β-glucan polymers were preserved and the viscosity was maintained by avoiding any potential acid-catalyzed hydrolysis of the glycosidic linkages at elevated temperatures used during processing. This helped to maintain potential health benefits as well as the body and mouthfeel of the beverages produced because viscosity is very important in the health-promoting properties and functionality of β-glucan (Wang et al 1992).

Sensory Evaluation

The results of the trained panel sensory evaluation of barley β-glucan and pectin beverages are shown in Table II. Peely-orange and fruity-orange aroma and sweetness intensity of β-glucan and pectin beverages were similar ($P > 0.05$). Therefore, the type of hydrocolloid and concentration did not affect these sensory attributes. No suppression of flavor intensity with increasing gum concentration was observed. This is contrary to what was expected because others have reported that, with increasing hydrocolloid concentration, the intensity of both basic tastes and aromatic flavors decreases (Vaisey et al 1969; Moskowitz and Arabie 1970; Pangborn et al 1972; Pangborn and Szczesniak 1974; Malkki et al 1993). However, Pangborn et al (1972) reported that a viscosity of ≈16 mPa·sec was required to significantly alter sweetness. All beverages, except the 0.7% β-glucan beverages, had a viscosity of <16 mPa·sec. Malkki et al (1993) also found that oat gum had less of an effect on taste intensities than other hydrocolloids. It is hypothesized that the neutral charge of β-glucan presents less opportunity for binding of flavor components and therefore less sensory suppression. This explains the lack of flavor suppression seen with increasing concentrations for both hydrocolloids.

Beverage sourness intensity differed ($P \leq 0.05$) among beverages. Pectin beverages were slightly more sour than beverages formulated with β-glucan gum at each gum concentration, but this difference was not significant ($P > 0.05$). The pectin originating from lime peels contributes to the sour taste or acidity of the beverages because of the acidic nature of lime fruit. On the other hand, β-glucan solutions are slightly alkaline (pH 7.6 for 1.0% β-glucan solution) because β-glucan is extracted from barley at alkaline conditions. Thus, β-glucan gum does not contribute to beverage acidity and sourness intensity. In addition, there was a slight drop in sourness intensity with increasing gum concentration. The beverage containing 0.3% pectin (lowest viscosity) was significantly more sour ($P \leq 0.05$) than that containing 0.7% β-glucan (highest viscosity). This is in agreement with the results of Pangborn et al (1972), who showed that sourness, when compared to other tastes, was affected the most with increasing hydrocolloid concentration.

Trained panelists also determined that there were significant differences in the viscosity of the beverages (Table II). As expected, the viscosity of beverages increased ($P \leq 0.05$) with gum concentration. Beverages containing 0.3% β-glucan gum and pectin had similar viscosity ($P > 0.05$). However, beverages containing 0.5 and 0.7% β-glucan were significantly more viscous ($P \leq 0.05$) than those with pectin at the same level. Less β-glucan gum is required to produce beverages with similar viscosity to pectin at concentrations ≥0.5% (w/w). β-Glucan beverages contain less soluble fiber than pectin beverages of the same viscosity. On the other hand, if more β-glucan gum is desired for a higher fiber claim but not the increase in viscosity (which would adversely affect consumer acceptability), extraction conditions used for the isolation of β-glucan from barley may be manipulated to obtain a lower viscosity β-glucan gum for the desired functionality (Burkus and Temelli 1998). However, it is important to note that high viscosity is critical for health benefits. For example, Wood et al (2000) have demonstrated the link between oat β-glucan viscosity and glycemic index.

The target market for a β-glucan functional beverage is composed of individuals who take an active role in their own health improvement through dietary and lifestyle choices. They want a refreshing beverage that offers more than what is currently available in beverage products. The consumer evaluation performed at the University of Alberta physical fitness facility assumed that individuals described by the target market would be found there.

The consumer panel found β-glucan and pectin beverages to be similar ($P > 0.05$) in the acceptability of attributes evaluated (sweetness, sourness, orange flavor, and thickness) and overall acceptability. For all attributes evaluated, mean scores ranged between 6 (like slightly) and 7 (like moderately) for both beverages.

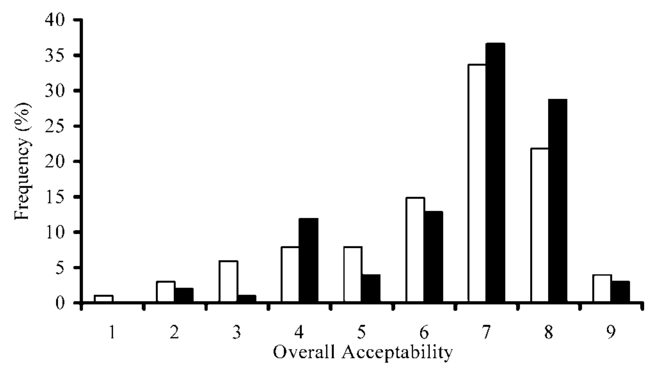

Fig. 2. Frequency distribution of overall acceptability for consumer panel scores (on a 9-point hedonic scale) for beverages with 0.5% (w/w) β-glucan (□) and pectin (■) beverages.

TABLE II
Reference Sample Scores and Mean Sensory Scores for Sensory Analysis of β-Glucan and Pectin Beverages by Trained Panel

Beverage	Peely-Orange Aroma[a]	Fruity-Orange Aroma[a]	Sweetness[a]	Sourness[a]	Viscosity[b]
β-Glucan					
0.3%	4.4a[c]	5.7a	7.3a	2.7ab	2.8e
0.5%	4.4a	6.6a	7.8a	2.4ab	4.1c
0.7%	4.4a	6.2a	7.3a	2.1b	6.1a
Pectin					
0.3%	4.9a	6.1a	7.1a	3.0a	2.6e
0.5%	5.0a	6.3a	7.7a	2.8ab	3.4d
0.7%	4.6a	6.6a	7.6a	2.7ab	4.7b
Reference samples			9.0[d]	5.0[e]	4.5[f]

[a] Anchor descriptors on 15-cm line scale (none to extreme).
[b] Anchor descriptors on 15-cm line scale (not viscous to extremely viscous).
[c] Values followed by the same letter in the same column are not significantly different ($P > 0.05$).
[d] Tang breakfast drink.
[e] Minute Maid Original orange juice.
[f] 0.45% (w/w) pectin solution.

The 0.5% (w/w) β-glucan and pectin beverages scored 6.3 and 6.7, respectively, on the nine-point hedonic scale (1 [dislike extremely], 9 [like extremely]) for overall acceptability. The similarity of the beverages as evaluated by the consumer panel agrees with the lack of difference found during trained panel evaluations. Although the trained panel found a significant difference ($P \leq 0.05$) between the viscosity of 0.5% β-glucan and pectin beverages, this difference was not detected by the consumer panel (acceptability of thickness was 6.2 and 6.4, respectively). Figure 2 shows the frequency distribution for the overall acceptability by the consumer panel. The data indicate that the majority of panelists scored the 0.5% β-glucan and pectin beverages 7 and 8 on the 9-point hedonic scale.

A 300-mL bottle of the 0.5% β-glucan beverage would provide 1.5 g of β-glucan. Therefore, the consumption of two bottles of this beverage per day would provide the recommended amount of 3 g of β-glucan, based on the FDA approved health claim for oats. However, this beverage was developed with barley β-glucan concentrate, which is currently not covered under the FDA approved claim, although a petition has been recently filed with the FDA for barley products to be eligible as a source of β-glucan.

Shelf Stability

The *L*, *a*, and *b* colorimeter values measuring beverage white, red, and yellow color components, respectively, for most β-glucan and pectin beverages decreased significantly ($P \leq 0.05$) during the first week of storage (data not shown). After the first week, however, colorimeter values for all beverages, except the *a* value for the 0.7% β-glucan beverage, stabilized ($P > 0.05$). The decreases in colorimeter values observed during the first week may be due to the precipitation of insoluble material present in the beverages or changes in the β-carotene colorant. Visually, however, the changes reported by colorimeter measurements were not noticeable.

It is also important to note that the increasing levels of β-glucan gum affected the *L* value or beverage whiteness. Increased β-glucan gum concentration resulted in a lighter product ($P \leq 0.05$) that was cloudier in appearance. However, *L* value was not affected by pectin concentrations ($P > 0.05$).

Beverage remained stable at pH 2.67–2.81 for all batches produced throughout the storage period. Total aerobic plate counts were also stable, showing no colony formation on initial plate counts, and no microbial growth in the beverages throughout the storage period. The pasteurization treatment applied (90°C/30 sec) and the acidic nature of the beverage were adequate in preventing the growth of spoilage organisms. This eliminated the need for the addition of preservatives. This keeps the ingredient list more consumer friendly.

Some of the beverages, especially those with a higher hydrocolloid content (0.7%, w/w) exhibited a slight decrease in viscosity throughout storage (Fig. 3). Viscosity was stable in all other formulations. β-Glucan gum was stable within the low pH environment of a beverage formulation, maintaining its consistency for 12 weeks. Any acid-catalyzed hydrolysis of β-glucan polymers that may have occurred at elevated pasteurization temperatures did not continue during the refrigerated storage period. The order of beverages from least viscous to most viscous, as evaluated by the trained sensory panel, agrees with instrumental measures of viscosity performed during the shelf-stability evaluation.

The β-glucan beverages exhibited cloud loss, measured as a decrease in absorbance at 660 nm, during the first three weeks (Fig. 4), but stabilized after week three. The pectin beverages exhibited very little cloud loss. A small amount of precipitate was visible at the bottom of the β-glucan gum beverages, which was easily resuspended when shaken. This precipitate was also visible in β-glucan solutions in water and is not due to precipitation caused by other ingredient interactions within the beverage formulation. The precipitate is assumed to be insoluble protein and fiber components present in the β-glucan gum at low levels. The insoluble material, being temporarily stabilized in the viscous network of the barley β-glucan solution, contributes to beverage cloudiness. Thus, the precipitation of this material is a factor in the loss of beverage cloudiness. This may also explain the decreases observed in colorimeter values for beverages during the first week of storage.

The cloudiness of β-glucan beverages increased with increasing gum concentration. This increase was not observed in the pectin beverages. Therefore, β-glucan gum may also be useful as a clouding agent in functional beverage products. This is also supported by the increase in beverage whiteness (*L*) value, observed with increasing concentrations of β-glucan gum.

CONCLUSIONS

Barley β-glucan gum was stable in the acidic environment of an orange-flavored beverage during processing and refrigerated storage. The ability of β-glucan to increase viscosity when added to water makes it an excellent thickener for beverage applications. β-Glucan gum did not significantly alter the sensory attributes of beverage products or differ from pectin, except for sourness and viscosity. Increased β-glucan gum decreased sourness intensity scores significantly at 0.7% when compared with 0.3% pectin, and increased beverage thickness more than pectin at concentrations ≥0.5%. Increasing β-glucan gum concentration also increased beverage cloud. An orange-flavored β-glucan-enriched beverage was successfully produced that was acceptable to consumers and stable over a 12-week storage period. β-Glucan, therefore, exhibits excellent potential as a nutraceutical ingredient for functional beverages, displaying both beneficial nutritional and physical functionality.

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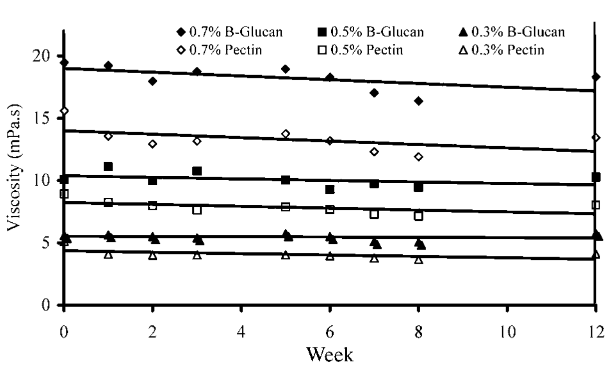

Fig. 3. Viscosity of β-glucan and pectin beverages during 12 weeks of storage at 5°C.

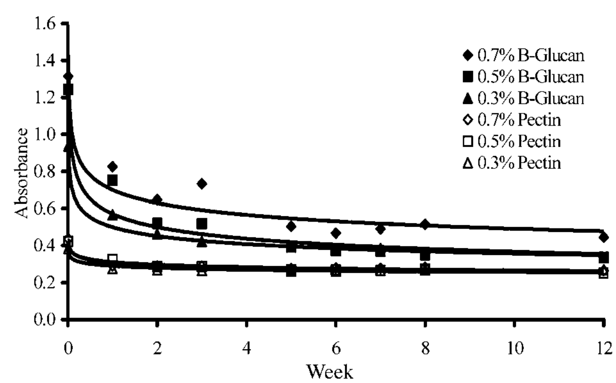

Fig. 4. Absorbance values at 660 nm, as a measure of cloud stability of β-glucan and pectin beverages during 12 weeks of storage at 5°C.

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