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Effect of processing treatments and storage conditions on stability of fruit juice based beverages enriched with dietary fibers alone and in mixture with xanthan gum

Émilie Paquet [a, b], Raza Hussain [a, b], Laurent Bazinet [a, b], Joseph Makhlouf [b], Simone Lemieux [b], Sylvie L. Turgeon [a, b, *]

[a] *STELA Dairy Research Centre, Laval University, Québec, Qc, Canada G1V 0A6*
[b] *Institute of Nutrition and Functional Foods (INAF), Laval University, Québec, Qc, Canada G1V 0A6*

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ABSTRACT

The present work aims to study the synergistic effect between xanthan gum (X) with a range of hydrocolloids such as barley β-glucan (Bg), guar gum (G), and konjac-mannan (K) on the viscosity of heat-treated fruit juice based beverages. The protective effect of X on the stability of Bg, G, and K in a fruit juice based beverage during processing and storage (0–16 weeks at 4 °C or 20 °C) was also evaluated. The results showed that pasteurization stabilized viscosity and turbidity of beverages enriched in Bg and BgX. However, the viscosity of pasteurized beverages enriched in K and G varied with storage time. In general, addition of X showed a complete protective effect against degradation at 4 °C for K (KX) whereas it provides no protection at all for G (GX). Viscosity and turbidity of beverages prepared with Bg and BgX increased significantly while those with G and K decreased slightly over time. Viscosity and turbidity changes are rapid when beverages are stored at 20 °C. We clearly evidenced that processing and storage treatments along with proper formulation are crucial to ensure technological stability of dietary fibers and X proved to be efficient to stabilize other fibers.

1. Introduction

Importance of preventing type 2 diabetes is highlighted worldwide by the substantial increase in the prevalence of diabetes mellitus in recent years (Lam & LeRoith, 2012). In 1998, the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) recommended that the food industries should make attempts to lower the glycemic response of food products (Livesey, Taylor, Hulshof, & Howlett, 2008). To achieve this aim, food enrichment in soluble dietary fibers could be used. Presently, guar gum (G) (Brennan, Merts, Monro, Woolnough, & Brennan, 2008), cereal β-glucans (Bg) (Gao, Wang, Wu, Ming, & Zhao, 2012) and konjac-mannan (K) (Chearskul et al., 2007) are some fibers known to attenuate blood glucose and insulin responses. The beneficial physiological effect of soluble dietary fibers seems to be closely related to the increase in the viscosity of gastro-intestinal tract's contents that in turn reduces the rate of gastric emptying and nutrient absorption by profusely increasing the unstirred layer in the small intestine (Kumar, Sinha, Makkar, de Boeck, & Becker, 2012).

Induction of viscosity by dietary fibers and their bioactivity are influenced by several intrinsic (structural features, concentration, average molecular weight, molecular weight distribution, solubility) and extrinsic (pH, temperature, processing steps, food matrix characteristics) factors. Accordingly, a particular attention must be given to processing and storage treatments to ensure integrity of the functional ingredients. A study on processed oat solid foods (isocaloric crisp bread, granola, porridge, and pasta containing 4 g of β-glucan) has demonstrated that the highest efficacy in attenuating the Peak Blood Glucose Response (PBGR) is obtained with porridge and granola that present the highest peak molecular weight and viscosity (Regand, Tosh, Wolever, & Wood, 2009). It seems that Bg glycosidic bounds would be more stable during high-temperature short-time treatments than lower temperatures; β-glucanases from wheat flour remain active at the latter conditions (Rakha, Aman, & Andersson, 2011). For G and K, physiological

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* Corresponding author. STELA Dairy Research Centre and Institute of Nutrition and Functional Foods (INAF), Laval University, Québec, Qc, Canada G1V 0A6. Tel.: +1 418 656 2131x4970; fax: +1 418 656 3353.

E-mail address: Sylvie.Turgeon@fsaa.ulaval.ca (S.L. Turgeon).

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Table 1
Composition of beverages.

Beverages	Abbreviation	Ratio (FPS:X)	[PS] total (g/100 g)
Control	C	–	–
Barley β-glucan	Bg	–	1.040
Barley β-glucan/xanthan gum	BgX	80:20[a]	1.300
Konjac-mannan	K	–	0.288
Konjac-mannan/xanthan gum	KX	90:10	0.320
Guar gum	G	–	0.235
Guar gum/xanthan gum	GX	50:50[b]	0.470
Xanthan gum	X	–	0.260

FPS: functional polysaccharides; X: xanthan gum.

[a] Ghotra et al. (2009).

[b] Casas et al. (2000).

effects have also been related to their induced viscosity (Galmarini, Baeza, Sanchez, Zamora, & Chirife, 2011; Tatirat & Charoenrein, 2011) but only few experiments established the effect of technological treatments. In addition, it is important to mention that studies have mainly been performed with solid foods rather than liquid foods where no industrial treatment was applied.

Xanthan gum (X) is widely used in food industries because of its excellent stability over a broad range of pH values and temperatures (Katzbauer, 1998). Furthermore, it interacts synergistically with oat and barley Bg (Ghotra, Vasanthan, & Temelli, 2009; Paquet, Turgeon, & Lemieux, 2010), G (BeMiller, 2009) and K (Hosseini-Parvar, Matia-Merino, Goh, Razavi, & Mortazavi, 2010). Very recently, a synergistic and viscosifying effect of X and oat Bg mixtures in heat-treated fruit juices was reported elsewhere (Paquin, Bedard, Lemieux, Tajchakavit, & Turgeon, 2013). Juices enriched with Bg experienced a dramatic decrease in viscosity during heat processing (pasteurization) while juices supplemented with a mixture of Bg and X remained stable and effectively reduced the human glycemic response.

Hence, due to limited studies on this subject matter, for the first time, this work aimed to verify the stability of dietary fibers alone and in mixture with X in a fruit based beverage after an industrial pasteurization treatment and during storage.

2. Material and methods

2.1. Material

X (TIC Pretested® Ticaxan®) was obtained from TIC GUMS, Philadelphia, MD, USA; moisture 9.5 g/100 g and protein 6.0 g/100 g. Three readily available commercial dietary fibers were used: barley Bg (Barliv™, Cargill, Wayzata, MN, USA; β-glucan 72.2 g/100 g, moisture 4.5 g/100 g and protein < 2.0 g/100 g), G (TIC Pretested® GuarNT® Flavor Free 4000, TIC GUMS, Philadelphia, MD, USA; moisture 10.2 g/100 g and protein 4.5 g/100 g) and K (TIC Pretested® Ticagel® Konjac High Viscosity, TIC GUMS, Philadelphia, MD, USA; moisture g/100 g and protein < 2.0 g/100 g).

Clarified apple concentrate (70.4 °Brix) was a gift from Industries Lassonde, Rougemont, QC, Canada. The choice of apple juice was made on the basis of its clarity as it allows the observation of destabilization phenomena (precipitate formation, color change and opalescence).

2.2. Beverage formulation

The composition of each beverage prepared is presented in Table 1. The beverages without addition of dietary fibers were named as control throughout in this paper. Ratio and final concentration of dietary fibers and X have been chosen in order to have a similar targeted viscosity of 0.18 Pa s at 37 °C (body temperature) and 30 s^{-1} (related to the hypothetic shear rate in gastro-intestinal tract) (Wood, 2004). This viscosity setting has been established on previous work. These results showed that beverages enriched in polysaccharides under these conditions presented the desired hypoglycaemic effect as well as acceptable organoleptic characteristics (Paquin et al., 2013). Selected ratios are those mentioned in the literature to present the highest synergistic effect except for the mixture with K and X (KX). Preferential ratio for this mixture is 50:50 (Alvarez-Mancenido, Landin, Lacik, & Martinez-Pacheco, 2008; Fitzsimons, Tobin, & Morris, 2008) but at this point, a gel was formed after heat treatment. Afterward, ratio of 90:10 (90% K: 10% X) was used to ensure liquid behavior of the beverages.

In addition, beverages enriched with dietary fibers alone were also studied at the concentration level used in the mixture. For the beverage enriched with X alone, the selected concentration was the highest used in the mixture (Table 1). For all batches, three repetitions (batches) of the eight beverages (30 L) were made except that of beverages (K, KX, G and GX) for which a repetition was discarded as the apple juice concentrate was different so consequently only two repetitions were carried out.

2.3. Beverage preparation

First, stock solutions of Bg, K, G and X were prepared with different polysaccharide concentration (2, 0.8, 0.8 and 1.5 g/100 g) used for each beverage respectively. Weighed quantity of K, G and X was dissolved in deionized water at room temperature using an axial flow impeller (A-100, Cole–Parmer, Vernon Hills, IL, USA; diameter of 69 mm, pitch of 38 mm) at 1500 rpm (K and G) or 600 rpm (X) for 2 h. To ensure complete solubilization of Bg, deionized water was preheated at 90 ± 2 °C. Bg was subsequently hydrated using mixer (at 1500 rpm with the same paddle) at this temperature for 10 min in a double wall cooker (Lee Industries Inc., Philipsburg, PA, USA) and then cooled to room temperature. In order to ensure the final concentration, deionized water was added after the cooling process to compensate water evaporation during hydration (as measured by weight). After hydration, stock solutions were stored at 4 ± 2 °C over night (~18 h). The following day, polysaccharides along with weighed quantities of apple juice concentrate in appropriate volume of deionized water (until desired volume of beverages and to adjust the degree Brix (°Bx) at 10.6) were blended, stirred at 1200 rpm (for 15 min) with four inches three palm helix paddles (EVIP25M, Lightnin Mixers & Aerators, Rochester, NY, USA) to obtain proper homogenization at room temperature.

2.4. Pasteurization and storage procedures

Beverages were pasteurized using a tubular heat exchanger (UHT/HTST Lab-25 HV, MicroThermic Inc., Raleigh, NC, USA) at 98 ± 2 °C for 30 s, cooled at 20 ± 4 °C and bottled in 300 mL polyethylene terephthalate (PET) bottles. To study the pasteurization effect, 4.8 L of each beverages batch were not heat-treated. However, in order to ensure their preservation, they were supplemented with 260 mg/kg of each sodium benzoate and potassium sorbate. After this process, heat-treated and untreated beverages were stored in equal quantity at 4 and 20 ± 2 °C.

2.5. Rheological measurements

Pasteurization effect on beverage's viscosity was evaluated over time (one week) using viscosity profiles of the heat-treated and untreated beverages. These rheological measurements were performed at 37 ± 1 °C (body temperature) with a shear-rate