



Effect of galacto-oligosaccharide purity on water sorption and plasticization behavior

Alexa M. Lans, Yael Vodovotz*

The Ohio State University, Department of Food Science and Technology, 110 Parker Food Science and Technology Building, 2015 Fyffe Road, Columbus, OH 43210, United States

ARTICLE INFO

Keywords:

Galacto-oligosaccharides
Thermogravimetric analysis
Differential scanning calorimetry
Food powders

ABSTRACT

Galacto-oligosaccharides (GOS) can be produced with different purity levels that were hypothesized to alter water uptake and overall stability. Two purity GOS levels (55% and 90%) in commercially available mixtures were analyzed. Water was found to plasticize GOS (more effectively in the 55% compared to 90% GOS mixture), decreasing the glass transition temperature (T_g) causing the caking of powders and collapse of the amorphous structure. The critical a_w for the 55% GOS mixture was between a_w 0.23 and 0.33, corresponding to 3.7 and 5.9% moisture, and for the 90% GOS the critical a_w was between a_w 0.43 and 0.58, corresponding to 9.7 and 13.0% moisture. Differential thermogravimetric (DTG) curves demonstrated that water was more homogenous and difficult to remove as the T_g of GOS fell below storage temperature. DTG trends suggest that this analysis may be used to predict T_g of GOS mixtures, which is influenced by GOS purity level.

1. Introduction

Galacto-oligosaccharides (GOS) are non-digestible food ingredients that have been shown to increase populations of health-promoting species of gut bacteria and thus fall under the definition of prebiotics (Slavin, 2013). GOS have been used as popular food ingredients in Japan and Europe, due to their health benefits, and also favorable physiochemical properties including high solubility, colorless appearance, mild sweetness, high temperature and acid stability, and viscosity similar to high fructose corn syrup that can be used to improve body and mouth-feel (Tzortzis & Vulevic, 2009).

GOS are mainly produced through a transgalactosylation reaction of lactose using β -galactosidase enzymes (Tzortzis & Vulevic, 2009). The products of this reaction may then act as nucleophilic acceptors, potentially building complex mixtures of linear and branched oligosaccharides with degrees of polymerization (DP) ranging from 2 to 8, and a terminal glucose unit (Intanon et al., 2014; Tzortzis & Vulevic, 2009). β -galactosidase enzymes may be obtained from various enzyme sources, including microorganisms, plants and animals. Depending on the enzyme used, the final GOS mixture may vary in glycosidic linkages which may include β -(1 \rightarrow 3), β -(1 \rightarrow 4) and β -(1 \rightarrow 6) linkages (Intanon et al., 2014).

Since the transgalactosylation reaction competes with hydrolysis

during manufacturing of GOS, the final mixture almost always contains a considerable amount glucose and galactose, as well as unreacted lactose (Intanon et al., 2014; Torres, Gonçalves, Teixeira, & Rodrigues, 2010). Therefore, GOS mixtures may vary in purity, referring to the concentration of GOS in the mixture. Enzyme source and lactose concentration as well as reaction conditions such as pH, temperature, water activity, and buffer composition can all affect the purity the GOS mixture formed (Gosling, Stevens, Barber, Kentish, & Gras, 2010). Non-GOS impurities, including glucose, galactose, and lactose, may be removed by techniques such as ion-exchange chromatography, size-exclusion chromatography, nanofiltration, supercritical fluid extraction, and approaches based on selective fermentation techniques for a given microorganism (Torres et al., 2010).

GOS purity and DP may affect the prebiotic efficacy of GOS. *In vitro* studies have shown that some *Bifidobacterium* species may selectively catabolize GOS with a DP of three or four over lactose and other disaccharides (Gosling et al., 2010). Higher DP GOS may also be more resistant to fermentation in the gut, delivering a prebiotic effect in more distal locations in the intestine. However, controlling the DP to produce less pure GOS mixtures may be important to limit adverse side-effects of flatulence and laxation that are caused by osmotic pressure in the intestinal lumen after GOS consumption (Gosling et al., 2010). Increased costs are also associated with the additional processing steps required to

Abbreviations: GOS, galacto-oligosaccharides; DP, degree of polymerization; T_g, glass transition temperature; a_w , water activity; RH, relative humidity; DSC, differential scanning calorimetry; TGA, thermogravimetric analysis; DTG, derivative thermogravimetric analysis; FWHM, full width at half maximum; GAB, Guggenheim-Anderson-de Boer

* Corresponding author.

E-mail addresses: lans.2@osu.edu (A.M. Lans), vodovotz.1@osu.edu (Y. Vodovotz).

<https://doi.org/10.1016/j.foodchem.2018.06.008>

Received 19 January 2018; Received in revised form 1 June 2018; Accepted 3 June 2018

Available online 05 June 2018

0308-8146/ © 2018 Elsevier Ltd. All rights reserved.

remove impurities (Playne & Crittenden, 2009).

Commercial GOS are sold as syrups or dry powders in an amorphous, metastable state (Torres et al., 2010). When the amorphous matrix exists in the glassy state, molecular mobility is limited, which lends to solid-like properties and a fairly stable product (Roos, 2002). However, when the amorphous materials reach glass transition temperature (T_g), molecular mobility is greatly increased, which causes transition to a more liquid, “rubbery” state (Torres, Bastos, Goncalves, Teixeira, & Rodrigues, 2011). In this state, stability is greatly decreased; stickiness, caking and softening of powders can occur, causing problems during manufacturing and storage (Palzer & Sommer, 2011). T_g is dependent on moisture content and water activity (a_w), or relative humidity (RH) divided by 100. Plasticizers such as water depress T_g , and a dramatic decrease in stability occurs above a critical moisture content and corresponding critical a_w (Roos, 2002).

Typically, T_g decreases as the molecular weight of compounds decrease, due to an increase in free volume, which leads to increased molecular mobility (Simatos, Champion, Lorient, Loupiac, & Roudaut, 2009). T_g is also related to other compositional factors such as degree of branching and interactions between compounds in a mixture (Hartel, Ergun, & Vogel, 2011). Blends of materials typically have T_g values intermediate between the T_g of each component in the mixture (Simatos et al., 2009). Due to their ability to form glassy matrices, GOS have been also shown to act as protective agents that stabilize lactic acid bacteria (Santos, Araujo-Andrade, Tymczyszyn, & Gómez-Zavaglia, 2014).

Torres et al. (2011) studied the water sorption and plasticization properties of a 97% GOS mixture. The GOS mixture showed a sigmoidal type isotherm, and lost its amorphous character above a_w 0.591 and 12.3% moisture (g water/g solids). Santos et al. (2014) reported water sorption effects on T_g of 75% and 97% GOS mixtures. However, sorption behavior of less pure GOS mixtures composed of other types of linkages, and detailed analyses of water populations associated with these GOS matrices as a result of increasing a_w , has not been explored. The major objective of this study was to determine the effect of a_w on physical stability of GOS products of varying purities, and to characterize water populations associated with the GOS matrix as a result of increasing a_w using thermogravimetric techniques. It was hypothesized that purity of GOS will alter water uptake and overall stability of the mixture. Characterization of relative sorption properties will allow for the prediction of stability and quality changes during processing and storage of GOS.

2. Materials and methods

The GOS products used in this study were Oligomate 55NP (Yakult Co., Tokyo, Japan) and Purimune GOS (GTC Nutrition, Golden, CO) powders. The sugar composition of the mixtures including the distribution of oligosaccharides for Oligomate 55NP in g/100 g solids as follows: monosaccharides- glucose 22.4 g, galactose 8.6 g; disaccharides- lactose 12.7 g, GOS 14.8 g; trisaccharides- GOS 34.4 g; tetrasaccharides and higher oligomers- GOS 7.3 g. The sugar composition of the mixtures including the configuration and distribution of oligosaccharides for Purimune GOS in g/100 g solids as follows: monosaccharides- glucose 0–1 g, galactose 0–0.5 g; disaccharides- lactose 7–10 g, GOS 16–21 g; trisaccharides- GOS 38–52 g; tetrasaccharides and higher oligomers- GOS 25–29 g. Total GOS is determined as the portion of the mixture that consists of non-lactose disaccharides, trisaccharides, tetrasaccharides and higher oligosaccharides on a dry weight basis (Spherix Consulting Inc., 2010). Manufacturing of Oligomate 55NP GOS uses β -galactosidases derived from *Sporobolomyces singularis* and *Kluyveromyces lactis*, while Purimune GOS is made from a β -galactosidase obtained from *Bacillus circulans* (GTC Nutrition, 2009; Spherix Consulting Inc., 2010). In this work, the Oligomate product is referred to as 55% GOS, while the Purimune product is denoted as 90% GOS.

2.1. Moisture sorption isotherms

1 L polypropylene jars (Fisher Scientific, Hampton, New Hampshire) were filled with saturated salt solutions with equilibrium RH values ranging from 11 to 84% RH. Approximately 0.5 g of powdered GOS samples were placed on disposable aluminum pans and stored in the jars, which were sealed with a screw cap. Jars were kept in an incubator held at 25 °C. Samples were weighed each day until weight change was 0.001 g or less. Equilibration took approximately 2–14 days, with samples at lower RH taking less time to reach equilibrium. Three independent samples for each GOS product were equilibrated at each RH.

2.2. Differential scanning calorimetry measurements

Samples after equilibration, as well as the original dry powdered samples, were analyzed with a Differential Scanning Calorimeter (DSC) (Model Q100, TA Instruments) equipped with a refrigerated cooling system (TA Instruments, New Castle, DE, USA). The instrument was calibrated using an Indium standard. Approximately 10–15 mg of samples was loaded on aluminum DSC pans (PerkinElmer Instruments, Waltham, MA, USA) that were hermetically sealed with O-rings to avoid moisture loss during scanning. An empty pan with an O-ring was used as a reference.

The DSC method varied depending on the moisture content of the sample. Original dry samples and samples equilibrated at low RH were exposed to a thermal cycling method to delete thermal history and determine a true T_g . Samples were equilibrated at -20 °C, heated at 10 °C/min to 150 °C, held isothermally for three minutes, cooled at 10 °C/min to -20 °C, held isothermally for three minutes, and heated a second time to the initial heating temperature. The T_g onset ($T_{g\text{onset}}$), midpoint ($T_{g\text{mid}}$), and endset ($T_{g\text{end}}$) values were analyzed from the second heating cycle using TA Universal Analysis software (TA Instruments, New Castle, DE, USA). Samples equilibrated at higher RH that had transitioned into the rubbery state were exposed to only one heating cycle. Intermediate moisture samples were equilibrated to -50 °C and heated at 10 °C/min to 150 °C. High moisture samples were equilibrated to -80 °C and heated at 10 °C/min to 150 °C. These processes were repeated twice for each sample, for a total of six replicates per GOS at each equilibrium RH. T_g values are reported as the average of all six replicates.

2.3. Moisture determination by thermogravimetric analysis

Total water content and distribution of water within the equilibrated samples and samples in their original dry powder form were measured with a Thermogravimetric Analyzer (Model Q500, TA Instruments, New Castle, DE, USA). 10–15 mg of samples were loaded onto platinum TGA pans and heated from 25 to 180 °C at 10 °C/min. Moisture content was determined as percentage weight loss from initial temperature to the temperature of the first derivative peak weight loss (Gu, Ahn-Jarvis, & Vodovotz, 2015). The derivative weight loss was the rate loss (%) as a function of temperature (DTG). Total moisture content and DTG were obtained using TA Universal Analysis software (TA Instruments, New Castle, DE, USA). These processes were repeated twice for each sample, for a total of six replicates per GOS at each equilibrium RH. Moisture content is reported as the average of all six replicates. Fitting procedures of the DTG curves were performed using PeakFit version 4.12 (Systat Software, Inc, Richmond, CA, USA). Peak temperatures and the full width at half maximum (FWHM) values obtained are reported as the average of all six replicates.

To construct the sorption isotherms, moisture content (%) obtained by TGA was converted to a dry basis, and plotted against a_w (equilibrium RH/100). Sorption isotherm curves were fit to the Guggenheim-Andeson-de Boer (GAB) and Peleg models (Eqs. (1) and (2)) using the curve fitting tool in MatLab 8.5 (The MathWorks, Inc., Natick, MA).

Download English Version:

<https://daneshyari.com/en/article/7584201>

Download Persian Version:

<https://daneshyari.com/article/7584201>

[Daneshyari.com](https://daneshyari.com)