# Rheological Characteristics of Cold Thickened Beverages Containing Xanthan Gum–Based Food Thickeners Used for Dysphagia Diets

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**ABSTRACT**
Cold beverages are commonly thickened with commercial gum-based food thickeners for consumption by patients with dysphagia. In this study, the rheological properties of a thickened water and five thickened beverages (orange juice, apple juice, grape juice, whole milk, and a sport drink) that were prepared with four commercial instant xanthan gum–based thickeners (coded A-D) were investigated at a 3% thickener concentration. All thickened samples showed high shear-thinning behavior with yield stress at the serving temperature of 8°C. The magnitudes of apparent viscosity ($\eta_{a,50}$), consistency index (K), storage modulus (G′), and loss modulus (G″) of the thickened beverages, except for water, with food thickener A were significantly higher compared with other thickeners (B, C, and D) ($P<0.05$). The largest increases in K values for thickened beverages were observed at 1-hour storage, and at longer times their K values, except for milk, remained approximately constant. Rheological parameters demonstrated statistically significant differences in flow and dynamic behaviors between the cold thickened beverages prepared with the xanthan gum–based food thickeners ($P<0.05$), indicating that their rheological properties are strongly influenced by the dispersing medium, the type of food thickener, and storage time. In particular, appropriately selecting a commercial food thickener for preparing thickened beverages seems to be of importance for managing dysphagia.
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DYSPHAGIA IS DEFINED AS A DISORDER OF THE swallowing mechanism and can be caused by stroke, cancer, or neuromuscular disorders, among other conditions. Patients with dysphagia can be at risk for aspiration pneumonia and other respiratory problems. One possible method to manage dysphagia is the use of thickened fluids prepared with a food thickener.[1,2] Thickened fluids alter the variables of the swallow reflex, allowing more time for the complex series of events to occur to move the bolus to the stomach without compromising airway closure.[3] Therefore, commercially available food thickeners have been widely used as additives in beverages for patients with dysphagia to elicit the optimal swallow response because of ease of preparation, convenience, reasonable cost, and the suspending ability of the thickened fluids.[4,5]

Thickened beverages prepared with food thickeners exhibit rheological properties depending on the thickener brand, medium for preparation, thickener concentration, temperature, and time between preparation and service.[1,6-12] In particular, it is necessary to determine the rheological properties of cold thickened beverages as a function of time during refrigerated storage because various cold thickened beverages prepared with food thickeners can produce different rheological patterns during storage in a refrigerator before serving. Therefore, it is of considerable practical importance to predict the rheological properties of cold thickened beverages at different conditions to manage dysphagia properly. However, no study has been conducted regarding the rheological properties of cold thickened beverages as a function of storage time in a refrigerator.

Commercial instant food thickeners generally consist of modified starches and gums.[7] In the present study, xanthan gum–based food thickeners were investigated for preparing thickened beverages because they are commonly used in diet modification for patients with dysphagia because of their palatability and smooth texture when compared with starch-based thickeners.[13] It is very important that palatable thickened beverages are offered to patients with dysphagia to increase likelihood of reaching hydration targets and improve quality of life.[14]

Although extensive literature is available on the rheological properties of thickened beverages with starch-based food thickeners, there is less-reported research on cold thickened beverages with xanthan gum–based food thickeners. In addition, no attempt has been made to study the effect of dispersing media, type of food thickener, or storage time on the rheological properties of various cold thickened beverages containing xanthan gum–based food thickeners. In particular, little comprehensive information is available on viscoelastic properties of various thickened beverages with different xanthan gum–based thickeners using nondestructive dynamic oscillatory measurements.

This study was designed to investigate the effect on the rheological properties of thickened beverages prepared with commercial xanthan gum–based food thickeners in cold beverages. The principal objectives of this study were to investigate the steady flow and dynamic viscoelastic properties of various cold thickened beverages prepared with xanthan gum–based food thickeners as a function of dispersing media, type of food thickener, and storage time, and to compare the rheological differences among the various cold beverages and food thickeners in beverage-thickener mixture systems.

## METHODS

### Materials and Sample Preparation

Four commercially available instant food thickeners (thickeners A, B, C, and D) were selected: thickener A (composite of xanthan gum [XG], guar gum [GG], and dextrin), thickener B, (composite of XG and dextrin), thickener C, (composite of XG, carboxymethyl cellulose, GG, and dextrin), and thickener D (composite of XG and dextrin). All food thickeners were obtained from their manufacturers (Rheosfood Inc, Sankyo Co, Tsuruya Chemical Industries, and Natural F & P, Inc, respectively). Six cold dispersing media were bottled water (JPDC), orange juice (OJ) (Coca Cola Beverage Co), apple juice (AJ) (Woonjin Foods Co, Ltd), grape juice (GJ) (Coca Cola Beverage Co), sport drink (SD) (Donga-otsuka, Co, Ltd), and whole milk (Seoul Milk, Co, Ltd), which were stored at refrigerator temperature. Each dispersing medium was thickened with each of the four thickeners and analyzed in triplicate. The thickened samples were prepared by mixing the food thickeners at a 3% concentration with the cold beverages at room temperature with moderate stirring for 1 minute and mild agitation provided by a magnetic stirrer. The amount of thickener used was based on the manufacturer's recommendations for producing a pudding-like fluid. The thickened sample was immediately transferred to the rheometer plate at the serving temperature of 8°C to measure the rheological properties.

### Rheological Measurements

Steady flow and dynamic viscoelastic properties were obtained with a controlled stress Carri-Med CSL$^2$ 100 rheometer (TA Instruments), using a parallel plate system (4-cm diameter) at a gap of 500 $\mu$m. Steady flow data were obtained over a shear rate range of 0.1–100 $s^{-1}$ at 8°C. The range of shear rates were chosen to represent the range of flow conditions encountered in clinical practice from gentle manipulation in a cup (<0.1 $s^{-1}$) to the muscular, healthy swallow, estimated at rates of up to 100 $s^{-1}$.[10] Data (shear stress and shear rate) were fitted to the well-known power law model (equation 1) to describe the flow properties of the samples.

$$\sigma = K\dot{\gamma}^n \quad (1)$$

where $\sigma$ is the shear stress (Pa), $\dot{\gamma}$ is the shear rate ($s^{-1}$), K is the consistency index (Pa.s$^n$), and n is the flow behavior index (dimensionless). Apparent viscosity ($\eta_{a,50}$) at 50 $s^{-1}$, a reference shear rate for swallowing, was calculated using the magnitudes of K and n. Furthermore, the effect of storage time on K values of cold thickened beverages stored at 5°C was studied to evaluate the maintenance of their rheological properties over time during refrigerated storage at 5°C for 0, 1, 2, 3, and 4 hours.

Dynamic rheological data were obtained from frequency sweeps over the range of 0.63–62.8 rad $s^{-1}$ at 2% strain using a small-amplitude oscillatory rheological measurement. A 2% strain value was in the linear viscoelastic region. Frequency sweep tests were also performed at 8°C. TA Rheometer Data Analysis software (version VI. 76) was used to obtain the experimental data and to calculate the storage (or elastic) modulus (G′) and loss (or viscous) modulus (G″). All thickened samples were allowed to rest at 8°C for 5 minutes to relax the samples before the rheological measurements were taken. The rheological measurements were done in triplicate.

### Statistical Analysis

All results are expressed as the mean±standard deviation. An analysis of variance was done using the Statistical Analysis System software version 9.1 (2004, SAS Institute). Differences in means were determined using Duncan's multiple-range test. A *P* value less than 0.05 was considered significant.

## RESULTS AND DISCUSSION

### Flow Properties

The shear stress ($\sigma$) vs shear rate ($\dot{\gamma}$) data for all thickened beverages with various food thickeners at 8°C were well-fitted to the simple power law (equation 1) with high determination coefficients ($R^2$=0.90 to 0.99), as shown in Table 1. All thickened samples with different thickeners had high shear-thinning behaviors with low n values (0.11 to 0.50), which could possibly be due to the presence of xanthan in the food thickeners.[13,15] The n values (0.11 to 0.16) of thickened water samples were lower compared with those (0.17 to 0.50) of thickened beverages. This indicates that the xanthan gum–based food thickeners had low n values and their n values of thickened beverages could be increased by the dispersing medium. Adding a thickener to beverages can reduce their organoleptic sliminess due to the xanthan gum with a high degree of shear thinning (low n value), as noted by Szczesniak and Farkas,[16] who found that gums with a high n value lead to a slimy feel in the mouth.

In general, significant differences were found for the steady flow rheological parameter ($\eta_{a,50}$ and K) values of the thickened samples with different food thickeners ($P$<0.05) (Table 1). In particular, K and $\eta_{a,50}$ values of the thickened beverages with thickener A were significantly higher compared with those of the other thickeners ($P$<0.05). In addition, the thickened SD were higher $\eta_{a,50}$ and K values compared to other thickened beverages. The order of effectiveness in increasing the $\eta_{a,50}$ and K values of thickened beverages with thickener B and C was as follows: SD>AJ>GJ>OJ>milk. However, the $\eta_{a,50}$ and K values for thickener A increased in the presence of dispersing media in the following order: SD>AJ>GJ>OJ>milk for $\eta_{a,50}$, and SD>AJ>GJ>OJ>milk for K. In addition, the $\eta_{a,50}$ and K values for thickener D increased in the following order: SD>GJ>AJ>milk>OJ. These results showed that the rheological parameter values of thickened SD were higher