Relationship between Apparent Viscosity and Line-Spread Test Measurement of Thickened Fruit Juices Prepared with a Xanthan Gum-based Thickener

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ABSTRACT: The flow behaviors of three thickened fruit juices (orange, apple, and grape juice) prepared with a commercial instant xanthan gum (XG)-based thickener that is marketed in Korea were investigated at different thickener concentrations (1.0%, 1.5%, 2.0%, 2.5%, 3.0%, and 3.5%) and setting times (5 and 30 min) using a rheometer and a line-spread measurement method. The flow distance values measured by the line-spread test (LST) were compared with the apparent viscosity ($\eta_{a,50}$) values measured with a sophisticated computer-controlled rheometer. The $\eta_{a,50}$ values of the juices increased as thickener concentration increased, whereas their flow distances decreased. The $\eta_{a,50}$ values at the 30-min setting time were much higher than those at the 5-min setting time, indicating that the setting time before serving or consuming thickened juices can affect viscosity values. Plots comparing $\eta_{a,50}$ values to LST flow distances revealed strong exponential relationships between the two measures ($R^2=0.989$ and $R^2=0.987$ for the 5- and 30-min setting times, respectively). These results indicate that the LST can be a suitable instrument for evaluating the viscosity of thickened fruit juices prepared with different XG-based thickener concentrations and setting times for the dysphagia diet.

Keywords: thickener, viscosity, thickened juice, dysphagia, line-spread test

INTRODUCTION

Dysphagia is generally defined as a difficulty or inability to swallow thin fluid foods such as water, juice, tea, and coffee, which may lead to aspiration pneumonia and other respiratory problems. Diet modification is a compensatory technique needed for the clinical management of dysphagic patients (1,2). Therefore, thin fluids are commonly thickened with commercial food thickeners to reduce the risk of aspiration and optimize the swallowing ability of patients with dysphagia. The effective treatment of dysphagia requires that fluid foods are consistently prepared with the correct viscosity. Inaccuracies in preparing fluid foods to target thickness levels can increase the risk of aspiration (3). Therefore, the use of sophisticated computer-controlled rheometers is necessary to provide a more accurate measurement of the viscosity of thickened fluids. However, these rheometers are costly and impractical for instructional purpose in most clinical settings.

In general, thickened fluids are classified into several different “consistency” classes established by the National Dysphagia Diet Task Force: thin (1 ~ 50 mPa·s), nectar-thick (51 ~ 350 mPa·s), honey-thick (351 ~ 1,750 mPa·s) and pudding-thick (>1,750 mPa·s). These values are determined by the viscosity of a product at a shear rate of 50 s⁻¹, which is thought to represent the shear rate in oral cavity during swallowing (4-7). Recently, several researchers have studied the use of the line-spread test (LST) for estimating the viscosity of thickened fluids (2,4,8-10) because the LST is an inexpensive, simple and visual clinical tool (9). However, there is little information available regarding the ability of the LST to differentiate the flow distance of the consistency levels (nectar-, honey- and pudding-like) of thickened fruit juices prepared with a xanthan gum (XG)-based food thickener marketed in Korea. In particular, there are no studies exploring the relationship between the apparent viscosity ($\eta_a$) values obtained using a sophisticated rheometer and the flow distance (cm) values measured by the LST for thickened fruit juices at different setting times. In general, it is of considerable practical importance to in-
vestigate the effect of setting time on juice viscosity because some thickened fluids are prepared in bulk and served at a much later time (more than 30 min after preparation) rather than being served or consumed immediately after mixing with thickeners (11). Therefore, in order to manage dysphagia properly, it is vital to know the viscosity of thickened juices that have been prepared under different conditions before serving these juices to patients with dysphagia.

This study evaluated the ability of the LST to measure correct viscosity of thickened juices prepared with a commercial XG-based food thickener for the management of dysphagia. Thus, the objective of this study was to investigate the relationship between the apparent viscosity measured by a rheometer and the line-spread distance measured by the LST for XG-based thickened juices prepared with different setting times.

MATERIALS AND METHODS

Materials and sample preparation

A commercially available instant food thickener (Visco-up, Rheosfood Inc., Seoul, Korea) was used in this study. Visco-up is an XG-based thickener product that consists of XG, guar gum, and dextrin. Three commercial fruit juices were used as the dispersing medium [orange juice (Coca Cola Beverage Co., Yangsan, Korea), apple juice (Woongjin Foods Co., Ltd., Gongju, Korea), and grape juice (Coca Cola Beverage Co.)]. The thickened juices were prepared by mixing each of the fruit juices containing 1.0%, 1.5%, 2.0%, 2.5%, 3.0%, and 3.5% (w/w) XG, guar gum, and dextrin. Three commercial fruit juices (Coca Cola Beverage Co.) was used in this study. A commercially available instant food thickener (Visco-up, Rheosfood Inc., Seoul, Korea) was used in this study.

RESULTS AND DISCUSSION

Table 1 shows the apparent viscosity ($\eta_{a,50}$) measurements of thickened fruit juices prepared with different concentrations (1.0%, 1.5%, 2.0%, 2.5%, 3.0%, and 3.5%) of an XG-based thickener and different setting times (5 and 30 min). In general, significant differences in the $\eta_{a,50}$ values were found for the thickened fruit juices prepared with different thickener concentrations ($P<0.05$), suggesting that thickener concentration played a large role in determining the viscosity of the thickened juices. The $\eta_{a,50}$ values of the thickened beverages significantly increased with increasing thickener concentration, indicating that small differences in the amount of food thickener produced significant changes in viscosity. The increase in $\eta_{a,50}$ values with thickener concentration may be due to the fact that XG has a high molecular weight, as noted by Seo and Yoo (3).

At the 30-min setting time, the $\eta_{a,50}$ values of the thickened juices were significantly higher than those at the 5-min setting time ($P<0.05$), indicating that the vis-
The LST values at the 5- and 30-min setting times were in the range of 7.01~8.78 cm, 4.54~7.00 cm, and less than 4.54 cm, respectively. These findings suggest that a flow distance measurement method can be used to differentiate between the nectar-like, honey-like and pudding-like consistencies of thickened juices that have been prepared with different concentrations of an XG-based thickener (1.0~3.5%) and with different setting times (5 and 30 min).

Fig. 1 shows the relationship between the \( \eta_{a,50} \) values measured with a rheometer and the flow distance values measured by the LST. As the flow distance measured by the LST decreased, the \( \eta_{a,50} \) value measured with the rheometer increased, indicating that flow distances are inversely related to \( \eta_{a,50} \) values. Plots of the \( \eta_{a,50} \) values (y-axis) versus the LST measurement (x-axis) at 5- and 30-min setting times revealed a good exponential relationship between the two measurements (\( R^2=0.989 \) for 5-min setting time; \( R^2=0.987 \) for 30-min setting time). This exponential relationship means that, at higher thickener concentrations, LST values decreased slowly with increasing thickener concentration. Therefore, the LST may be limited in its ability to determine the viscosity values of thickened juices prepared with higher thickener concentrations. The exponential relationships between the \( \eta_{a,50} \) (y) and flow distance (x) values were well described by \( y=52663e^{-0.712x} \) at the 5-min setting time.
and \( y = 43869e^{-0.7205x} \) at the 30-min setting time. These relationships \( (R^2=0.987 \sim 0.989) \) were much stronger than those \( (R^2=0.86 \sim 0.90) \) reported in previous studies of other fluids thickened with starch-based thickeners (2,9). However, this study only investigated the relationship between the \( \eta_{a,50} \) and flow distance values for one thickener brand (Visco-up); the relationship between the \( \eta_{a,50} \) and flow distance values for other commercially available thickener products may be very different.

These results suggest that the LST provides a means to predict the rheometer-measured viscosity of fruit juices thickened with an XG-based thickener and is useful in the broad categorization of thickened fruit juices into therapeutically significant groupings, as suggested by Nicosia and Robbins (2). Therefore, it can be concluded that the LST is a reliable and simple method for evaluating the correct and desirable viscosity for the dysphagia diet, and that the LST may be a valuable clinical tool for caregivers and patients who need to prepare thickened fluids to a target level of consistency.

**AUTHOR DISCLOSURE STATEMENT**

The authors declare no conflict of interest.

**REFERENCES**


