Prev. Nutr. Food Sci. 2024;29(1):87-92
https://doi.org/10.3746/pnf.2024.29.1.87
ISSN 2287-8602

Note

Effect of Setting Time on Viscosity Stability of Xanthan Gum- and Starch-Based Thickened Beverages for Patients with Dysphagia: Comparison of IDDSI Syringe Flow Test and Line-Spread Test

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ABSTRACT: Because the viscosity of thickened beverages prepared with thickeners gradually changes before consumption, achieving their desired viscosity is important for managing dysphagia. This study aimed to investigate the viscosity changes of thickened beverages (water, orange juice, and milk) prepared with xanthan gum (XG)- and starch-based commercial thickeners over time using the syringe flow test (SFT) and line-spread test (LST). The LST values of beverages stabilized more quickly (≤1.5 h) than the SFT values (2.0∼3.5 h) at level 2 (mildly thick), whereas the opposite finding was observed at level 3 (moderately thick). After stabilization in a water system, SFT and LST yielded similar results. However, the SFT values of orange juice and milk thickened with XG-based thickener exceeded the reference values at level 2 and gradually increased at level 3. These results may be attributed to particulates interrupting fluid flow from the small tip of the syringe and the high friction force caused by the contact between the thickened sample and the syringe surface. The results suggest that the LST method is more reliable than the SFT method in clearly distinguishing between levels 2 and 3 of thickened beverages and demonstrate that the viscosity measurements of thickened beverages over time after preparation were strongly influenced by the measurement tools used for predicting the thickness level.

Keywords: food thickener, line-spread test, syringe flow test, thickened beverage

INTRODUCTION

Patients with dysphagia often experience discomfort and difficulty swallowing thin beverages including water, fruit juices, and milk, with some developing complications including aspiration pneumonia (Kim et al., 2014b; Thiyagalingam et al., 2021). Thus, food thickeners have been widely used to facilitate the swallowing process of these patients (Dewar and Joyce, 2006; Bolivar-Prados et al., 2022). Food thickeners typically rely on high-viscosity components, particularly xanthan gum (XG) and starches (Jo et al., 2018).

The National Dysphagia Diet (NDD) Task Force has standardized fluid diets for patients with dysphagia using apparent viscosity at a shear rate of 50 s^{-1} ($\eta_{a,50}$), which was determined using precision-controlled rheometers (Kim et al., 2014b; Bolivar-Prados et al., 2022; An et al., 2023). However, these instruments are unfamiliar to individual patients, caregivers, or clinics, which limits the practical application of NDD standards (Kim et al., 2014b). Therefore, the International Dysphagia Diet Standardization Initiative (IDDSI) was established to categorize fluid thickness into five levels (0∼4) using a syringe flow test (SFT): level 0 (thin), level 1 (slightly thick), level 2 (mildly thick), level 3 (moderately thick), and level 4 (extremely thick) (Cichero et al., 2017). Table 1 summarizes the reference values for SFT corresponding to thickness levels.

Before the introduction of the IDDSI SFT, the line-spread test (LST) was widely used to evaluate the consistency of thickened fluids because of its cost-effectiveness, simplicity, and ease of use (Mann and Wong, 1996; Kim et al., 2018). Several studies have also reported a strong exponential relationship between the LST values of thickened beverages and the rheological properties relevant to fluid viscosity (Nicosia and Robbins, 2007; Kim et al., 2014b; Kim et al., 2018). One common approach to compare the thickness of thickened fluids involves measuring the average flow distance in the quadrant directions of thickened fluid poured into a cylindrical container (Mann and Wong, 1996; Nicosia and Robbins, 2007; Barbon and Steele, 2018; Kim et al., 2018; Giura et al., 2021; Jeong et al., 2021).

Received 6 November 2023; Revised 5 December 2023; Accepted 14 December 2023; Published online 31 March 2024

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Table 1. Thickness level of thickened fluids (International Dysphagia Diet Standardization Initiative)

Thickness level	Description	Reference value (mL)
0	Thin	<1.0
1	Slightly thick	1.0~4.0
2	Mildly thick	4.0~8.0
3	Moderately thick	>8.0
4	Extremely thick	10.0

Table 2. Composition of beverages used in this study

Beverage type	Main ingredient	Nutrition (per 100 mL)
Water	Water	Carbohydrate (0.0 g) Protein (0.0 g) Fat (0.0 g)
Orange juice	Orange juice concentrate	Carbohydrate (9.0 g) Protein (0.6 g) Fat (0.0 g)
Whole milk	Raw milk	Carbohydrate (5.0 g) Protein (3.0 g) Fat (4.0 g)

By contrast, manufacturers of commercially available food thickeners provide guidelines to assist customers in preparing thickened beverages with their desired viscosity. However, these guidelines are overly simplistic and inaccurate. Moreover, several studies found that various factors, including setting time (Dewar and Joyce, 2006; Kim et al., 2014b; Kim and Yoo, 2015), beverage type (Kim et al., 2014a; Yoon and Yoo, 2017; Jeong et al., 2021; An et al., 2023), and thickener type (Dewar and Joyce, 2006; Kim et al., 2014a; Kim et al., 2018), are closely linked to the $\eta_{a,50}$ values of thickened beverages as determined using rheometers. These factors often result in failure to achieve the desired viscosity. In particular, customers are at risk of consuming thinner beverages than they anticipated in cases where it takes time to reach the desired viscosity of thickened beverages (Dewar and Joyce, 2006). Therefore, more comprehensive guidelines that consider the impact of setting time after preparation on the viscosity stability of thickened beverages are urgently needed. However, in terms of clinical practice, few studies have explored practical methods (e.g., SFT and LST) to assess the viscosity stability of various cold thickened beverages prepared with different thickener types over time and at different thickness levels. Therefore, the present study aimed to investigate the viscosity changes of various cold thickened beverages prepared with XG- and starch-based thickeners over time after preparation using SFT and LST. In addition, the study compared the performance of both methods to identify the most effective approach to assess thickness levels.

MATERIALS AND METHODS

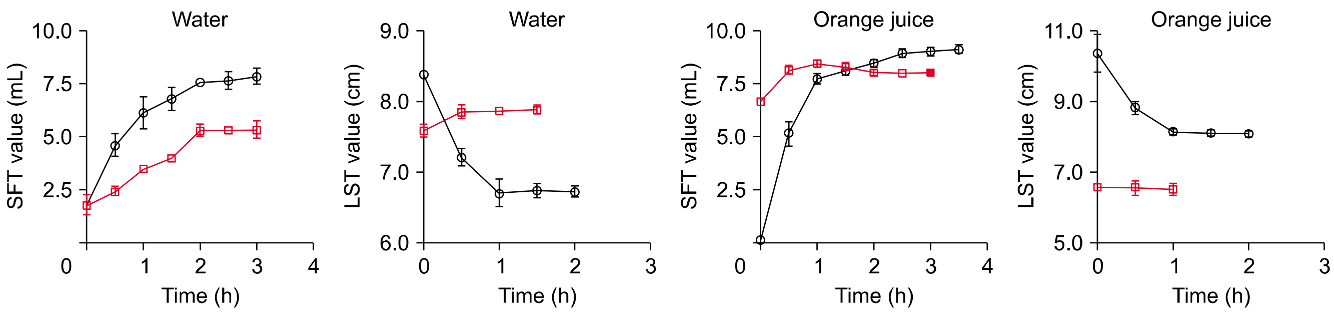
Materials and preparation of thickened beverage

Three commercially available cold beverages marketed in Korea [i.e., bottled water (Jeju Samdasoo), orange juice (The Coca-Cola Co.), and whole milk (Seoul Dairy Co.)] were purchased from a local market and used as the continuous phase to prepare thickened beverages. Table 2 summarizes the primary compositions and nutritional information of these products. Commercially available food thickeners, which were primarily composed of XG and starch, were obtained from Rheosfood Inc. and Hormel Health Labs Inc., respectively. Each continuous phase was thickened using a commercial XG-based thickener containing XG, guar gum, and dextrin (Rheosfood Inc.) and a commercial starch-based food thickener containing modified corn starch and dextrin (Hormel Health Labs Inc.). To prepare thickened beverages at thickness levels of 2 (mildly thick) and 3 (moderately thick), the thickeners were added at concentrations suggested by the manufacturer's guidelines. The mixtures were then prepared under constant stirring for 1 min using a magnetic stirrer. After the thickened beverages were prepared, some samples were immediately subjected to SFT and LST measurements, whereas the remainder was stored in a refrigerator (4°C) for subsequent measurements over time. The measurements were performed until the SFT and LST values of each sample were statistically constant three times in a row at 0.5-h intervals.

IDDSI SFT and LST

SFT was conducted in accordance with the IDDSI testing methods (IDDSI, 2019). Ten milliliters of the thickened beverage solution were used to fill a Luer-Lok tip syringe (10 mL, Becton Dickinson Medical Pte., Ltd.), while the nozzle was sealed with a finger. The nozzle was then opened for 10 s to allow the solution to flow out. Thereafter, it was resealed with a finger. The amount of solution that remained in the syringe was measured and considered as the SFT value.

LST was performed in accordance with a previously reported method (Kim et al., 2018). In brief, a cylinder (height 3.5 cm, diameter 5.0 cm) was placed in the center of a plastic plate marked with concentric circles at 1.0-cm intervals. The cylinder was filled with the thickened solution and left to stabilize for 5 min at room temperature. After stabilization, the cylinder was lifted, and the thickened solution was allowed to flow horizontally onto the plate for 1 min. The flow distances of the thickened beverage at the four cardinal points were recorded, and their average value was considered as the LST value. The SFT and LST values were measured three times at each time point at room temperature and 0.5-h intervals. The meas-



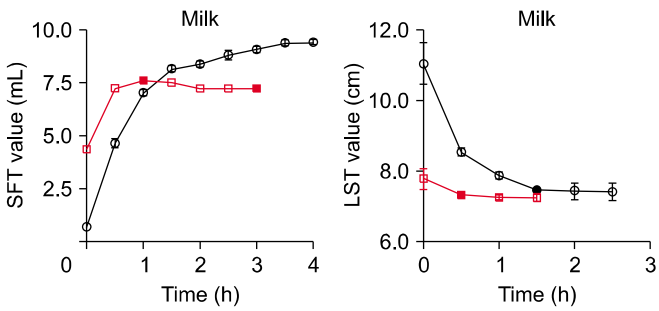


Fig. 1. Time-dependent changes in International Dysphagia Diet Standardization Initiative syringe flow test (SFT) and line-spread test (LST) values of beverages thickened with xanthan gum-based thickener (○) and starch-based thickener (□) at thickness level of 2.

urements were continued until a statistically constant value was obtained three times in a row. With regard to SFT, the measurement was terminated when the value reached the maximum value of 10 mL because the viscosity of the thickened sample was beyond the measurable range (0~10 mL).

Statistical analysis

One-way analysis of variance followed by Duncan's multiple range test for *post hoc* analysis at a significance level of $P<0.05$ was used to identify significant differences between the SFT and LST values of thickened beverages with different thickeners over time. Statistical analyses were conducted using SAS version 9.2 (SAS Institute).

RESULTS

The changes in SFT and LST values of thickened water (TW), thickened orange juice (TOJ), and thickened milk (TM) using XG- and starch-based thickeners, stabilized over time at a thickness level of 2, are shown in Fig. 1. The SFT values of TW gradually increased within the first 2.0 h after preparation. Specifically, the SFT values of samples thickened with the XG-based thickener reached level 2 (4.0~8.0 mL) within 0.5 h, whereas those of samples thickened with the starch-based thickener achieved the same level within 2.0 h. After 2.0 h, all SFT values were stabilized, with the XG-based thickener (7.7 mL) having a greater stabilized value than the starch-based thickener (5.3 mL). By contrast, the LST values of TW with the XG-based thickener gradually decreased during the initial 0~1.0 h and stabilized after 1.0 h. Conversely, the LST value of TW with the starch-based thickener slightly increased during 0~0.5 h and after 0.5 h. TW with the XG-based thickener had a lower stabilized LST value (6.7 cm) than that with the starch-based thickener (7.8 cm). This finding indicated that the viscosity of TW with the XG-based thickener, as estimated by LST, was greater than that with the starch-based thickener at level 2. In the orange juice system at level 2, the SFT value of TOJ with the XG-based thickener was lower than the reference value for level 2 (4.0~8.0 mL) immediately after preparation (0 h). However, the SFT value gradually increased over time and stabilized at 2.5 h (Fig. 1). By contrast, the SFT values of TOJ with the starch-based thickener increased at 0~1.0 h, slightly decreased at 1.0~2.0 h, and remained statistically constant after 2.0 h. These results indicated that the viscosity of TOJ with the starch-based thickener, as evaluated by SFT, stabilized faster (2.0 h) than that with the XG-based thickener (2.5 h; Table 3). Similar results were observed with LST. The LST values of TOJ with the XG-based thickener decreased at 0~1.0 h and stabilized after 1.0 h (Fig. 1). In comparison, no changes in LST values of TOJ with starch-based

Table 3. Time required to stabilize the viscosity of thickened beverages with xanthan gum (XG) and starch-based thickeners at International Dysphagia Diet Standardization Initiative thickness levels of 2 and 3 using the syringe flow test (SFT) and line-spread test (LST)

Beverage type	Thickener type	Time (h) at level 2		Time (h) at level 3	
		SFT	LST	SFT	LST
Water	XG	2.0	1.0	0.5	1.0
	Starch	2.0	0.5	0.5	0.5
Orange juice	XG	2.5	1.0	n.d.	1.0
	Starch	2.0	0.0	0.5	0.0
Milk	XG	3.5	1.5	n.d.	1.5
	Starch	2.0	0.5	0.5	0.5

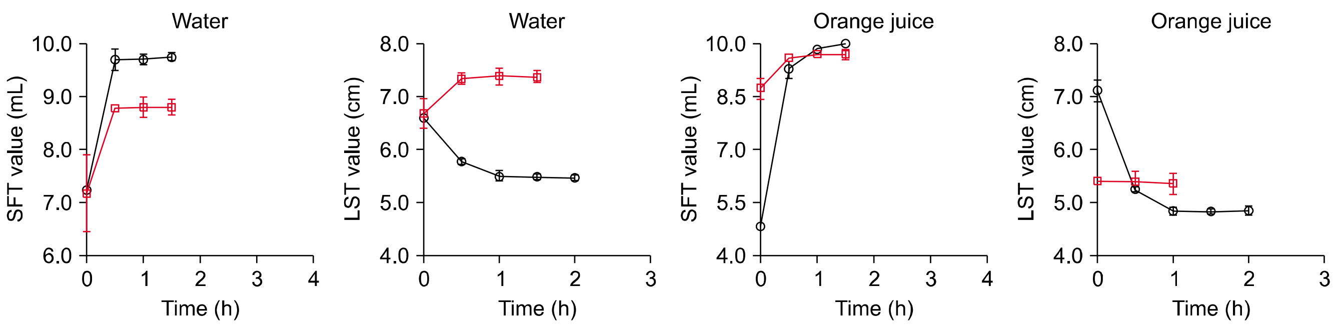
n.d., not determined.

thickener were observed at 0∼1.0 h. This finding indicated that the viscosity of TOJ with the starch-based thickener stabilized much faster than that with the XG-based thickener. In the milk system at level 2, the SFT values of TM showed similar trends to those of TOJ (Fig. 1). The only difference was that the SFT value of TM with the XG-based thickener stabilized slower (3.5 h) than that of TOJ with the XG-based thickener (2.5 h; Table 3). The LST values of TM with the XG-based thickener gradually decreased over time and stabilized after 1.5 h (Fig. 1). However, the LST values of TM with the starch-based thickener decreased at 0∼0.5 h and stabilized after 0.5 h. These results indicated that the starch-based thickener rapidly stabilized the viscosity of TM compared with the XG-based thickener.

At thickness level 3, the SFT values of TW with each thickener dramatically increased and reached the range of level 3 (>8.0 mL) within 0.5 h (Fig. 2). After this initial period, stable values were observed, with the XG-based thickener having a higher stabilized SFT value (9.7 mL) compared with the starch-based thickener (8.8 mL). However, the changes in LST values with each thickener showed the opposite trend. The LST values of the XG-based thickener decreased during the initial 0∼1.0 h and stabilized after 1.0 h. Conversely, the LST value of the starch-based thickener significantly increased during the initial 0∼0.5 h and stabilized after 0.5 h. Consequently, TW with the XG-based thickener exhibited a lower stabilized LST value (5.5 cm) compared with that with the starch-based thickener (7.4 cm). In the orange juice system, the SFT values of TOJ with each thickener notably increased during the initial 0∼0.5 h. While the SFT values of TOJ with the starch-based thickener stabilized after 0.5 h, the values of TOJ with the XG-based thickener continued to increase and reached 10 mL at 1.5 h (beyond the measurable range for SFT). This finding indicated that the viscosity of TOJ with the XG-based thickener exceeded the measurable range of SFT, making it impossible to determine the time when the SFT value of TOJ with the XG-based thickener stabilized (Table 3). By contrast, LST was able to clearly distinguish the time required to stabilize the viscosity of TOJ with each thickener at level 3. The LST values of TOJ with the XG-based thickener decreased during the initial 0∼1.0 h and stabilized after 1.0 h. By contrast, no changes in the LST values of TOJ with the starch-based thickener were observed during 0∼1.0 h. This finding indicated that the viscosity of TOJ with the starch-based thickener stabilized faster than that with the XG-based thickener. In the milk system, the changes in the SFT and LST values of TM with each thickener followed a similar trend to those observed in TOJ. However, the LST values of TM with each thickener required a longer time to stabilize compared with those of TOJ.

DISCUSSION

Patients with dysphagia often consume thickened beverages prepared with commercial thickeners, and the period of consumption after preparation can vary from person to person. However, the viscosity of these thickened beverages can change gradually before consumption, posing serious consequences for patients if the viscosity is lower than expected when ingested. In addition, the viscosity of thickened beverages after preparation may be affected by the complex interactions between different components of beverages (e.g., carbohydrates, proteins, and



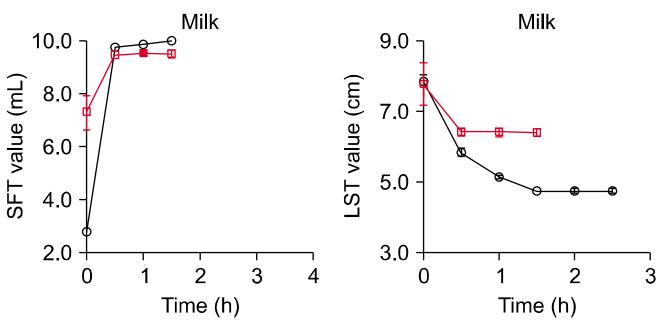


Fig. 2. Time-dependent changes in the International Dysphagia Diet Standardization Initiative syringe flow test (SFT) and line-spread test (LST) of beverages thickened with xanthan gum-based thickener (◯) and starch-based thickener (□) at thickness level of 3.

lipids) and thickeners (Hadde et al., 2015). Therefore, viscosity changes over the setting time after preparation need to be monitored until viscosity stabilizes. In this study, the SFT and LST values of thickened beverages with the XG-based thickener at levels 2 and 3 tended to increase and decrease over time after preparation, respectively. Moreover, these values stabilized at different time periods (Fig. 1 and 2). These findings indicate that the time required to stabilize the viscosity of thickened beverages with the XG-based thickener varied depending on the type of beverage. Similarly, previous studies have demonstrated that the $\eta_{a,50}$ values of thickened fruit juices (Kim et al., 2014b; Kim and Yoo, 2015), protein-based beverages (whole milk, skimmed milk, and soy milk) (Kim and Yoo, 2015; Kim and Yoo, 2018), and infant formula (Yoon and Yoo, 2017) gradually changed after preparation and eventually stabilized at different time periods. By contrast, the LST values of TW with the starch-based thickener at levels 2 and 3 slightly increased during the first 0.5 h after preparation and stabilized after 0.5 h, indicating that the viscosity of TW with the starch-based thickener decreased before stabilization. This finding is consistent with the findings of O'Leary et al. (2011). They found that the apparent viscosity of TW with a modified starch-based thickener slightly decreased for up to 3.0 h after preparation. In addition, Dewar and Joyce (2006) revealed that the $\eta_{a,50}$ value of TW with starch-based thickeners decreased 2.0 h after preparation. In the present study, the SFT and LST values of each beverage thickened with the starch-based thickener at level 2 and those of TOJ with the starch-based thickener at level 3 stabilized at different time periods (Table 3). This finding demonstrates that the tendency of viscosity changes of thickened beverages varies depending on the measurement tool, beverage type, thickener type, and thickness level.

In the water system, the SFT and LST methods showed similar trends, indicating that TW with the XG-based thickener exhibited higher viscosity than that with the starch-based thickener. However, in the orange juice and milk systems, the results obtained from both methods were not consistent (Fig. 1 and 2). These inconsistent findings may be attributed to the presence of particulates generated in beverages thickened with thickeners (Weston and Clarke, 2020). LST measures the horizontal flow distance of fluids in at least four directions after releasing a cylinder with a large diameter and appears to be less influenced by the presence of particulates. In this study, no significant differences were observed in the time required to stabilize LST values at levels 2 and 3 for each beverage (Table 3). On the other hand, the syringe tip with a small diameter used in SFT could be partially or entirely obstructed by particulates formed by the complex interaction between different components of thickeners and beverages (Table 2), potentially impeding the flow of thickened beverages in the syringe (Hadde et al., 2015; Weston and Clarke, 2020). Additionally, the high friction resulting from the direct contact between the syringe surface and the thickened beverage might hinder the outflow of the thickened beverage contained in the syringe (An et al., 2023). These effects of particulates and friction might explain why the SFT value stabilized faster than the LST value at level 3, despite the opposite result observed at level 2 (Table 3). This may also explain why TOJ and TM with the XG-based thickener at level 2 showed higher SFT values (>8.0 mL) than the reference value (4.0∼8.0 mL) for thickness level 2 at 1.5 h after preparation (Fig. 1) and why the SFT values at level 3 were out of the measurable range (0∼10 mL) at 1.5 h (Fig. 2). These results suggest that SFT has limitations when used to estimate the viscosity of various thickened beverages containing different compositions that can form particulates with thickeners and create high friction between the syringe surface and the thickened beverage. These findings are also consistent with the results reported by Kim et al. (2018), who found limitations in using SFT to estimate the viscosity of beverages at thickness level 3 because of the absence of fluid flow. Compared with SFT, no significant differences were observed in the time required to stabilize LST values for each beverage with each thickener at levels 2 and 3 (Table 3). However, the LST values of thickened beverages with the starch-based thickener stabilized faster than those with the XG-based thickener (Table 3) because of starch retrogradation during storage in a refrigerator (4°C) between LST measurements (Zarim et al., 2021). Similar to the results reported in previous studies (Nicosia and Robbins, 2007; Kim et al., 2014b; Kim et al., 2018; Mertz Garcia et al., 2018), the stabilized LST values of thickened beverages with XG- and starch-based thickeners were clearly differentiated between levels 2 (>6.5 cm) and 3 (<6.5 cm) in this study (Fig. 1 and 2). Remarkably, TW with the starch-based thickener exhibited a greater LST value (7.4 cm) at level 3, but this value was still lower than that (7.9 cm) at level 2. These results demonstrate that LST is a useful practical method for distinguishing the viscosity of fluids regardless of their thickness level, although the values will still depend on the type of beverage and thickener used.

Taken together, the results revealed that the tendencies of viscosity changes of thickened beverages were influenced by the measurement tool, beverage type, and type and concentration of thickener used. These findings provide valuable insights into the performance of the SFT and LST methods for determining the viscosity of thickened beverages. Moreover, they may contribute to the improvement of guidelines for preparing thickened beverages with different types of food thickeners and for measuring the thickness levels of thickened beverages using a clinical practical measurement tool for managing dysphagia.

ACKNOWLEDGEMENTS

The authors would like to thank Rheosfood Inc. for providing technical assistance and the free XG-based food thickener (Visco-up®) sample.

FUNDING

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (No. 2022R1A2C1005180).

AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Concept and design: JB, BY. Analysis and interpretation: JB, SEK, DW. Data collection: SEK, DW. Writing the article: JB, BY. Critical revision of the article: BY. Final approval of the article: all authors. Statistical analysis: SEK, DW. Obtained funding: BY. Overall responsibility: BY.

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