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ORIGINAL ARTICLE

Flow test by the International Dysphagia Diet Standardization Initiative reveals distinct viscosity parameters of three thickening agents

José Vergara[1] · Heloisa Sant'Ana Teixeira[2] · Cinthia Madeira de Souza[3] · Janaina Artem Ataide[4] · Felipe de Souza Ferraz[5] · Priscila Gava Mazzola[4] · Lucia Figueiredo Mourão[2]

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Abstract The International Dysphagia Diet Standardization Initiative (IDDSI) flow test is useful for the global standardization of food consistencies of dysphagia patients. In clinical practice, different compositions of food thickeners are commonly used, directly influencing viscosity parameters and swallowing physiology. We aimed to compare the IDDSI thickness levels, remaining volume in the syringe (RVS), and viscosity parameters of three different food thickeners. As a secondary objective, we compared the cost of preparing 100 mL of thickened drinks using the studied thickeners. Thickeners A (xanthan gum), B (corn starch, tara gum, xanthan gum, and guar gum), and C (corn starch) were prepared in increasing concentrations from 1 to 7 g/100 mL and were assayed in quintuplicate using the IDDSI flow test. Thickeners A, B, and C presented statistically different results for the IDDSI levels, RVS, and viscosity parameters at all concentrations. Thickener A reached higher levels in the IDDSI framework, RVS, and viscosity parameters compared with thickeners B and C. A large range of RVS was observed at different concentrations for thickener B compared with C. Regarding viscosity, thickeners B and C, with corn starch in their composition, showed exponential behavior as concentrations increased, while thickener A presented a linear trend. The thickener composition was significantly influenced by IDDSI classification, RVS, and viscosity parameters. The study shows that xanthan gum thickeners present less variability in IDDSI, RVS, and viscosity compared with starch-based thickeners.

Keywords Deglutition disorders · Viscosity · Thickened liquid · Thickening agent

Abbreviations

IDDSI	International dysphagia diet standardization initiative
RVS	Remaining volume in the syringe
XG	Xanthan gum
ST	Starch

✉ José Vergara
josevergaraherazo12@gmail.com

[1] Department of Surgery, University of Campinas, R. Tessália Vieira de Camargo, 126, Campinas, SP 13083-887, Brazil

[2] Speech-Language Pathology and Audiology Sciences, University of Campinas, R. Tessalia Vieira de Camargo, 126, Campinas, SP 13083-887, Brazil

[3] School of Medical Sciences, University of Campinas, Av. Tessalia Vieira de Camargo, 126, Campinas, SP 13083-887, Brazil

[4] Faculty of Pharmaceutical Sciences, University of Campinas, R. Cândido Portinari, 200, Campinas, SP 13083-871, Brazil

[5] Systems Analyst, Laudelino Gaspar, 48, Indaiatuba, Brazil

Introduction

Dysphagia rehabilitation entails compensation (Lazarus et al. 2002; Logemann 1999). Postural maneuvers, changes in viscosity, texture, volume, and delivery are examples of such strategies. Using thickeners to alter viscosity is a common clinical practice (Ortega et al. 2017), although it should be employed only under circumstances where no other treatment option is available (Logemann 1998).

Although some studies have reported that thickener use may increase stasis in pharyngeal recesses (Newman et al. 2016; Steele et al. 2015) and alter the texture and taste of liquids (Lotong et al. 2003; Ong et al. 2018; Stokes et al. 2013), this strategy has proven effective in improving swallowing safety in patients with dysphagia by reducing the risk of liquid penetration into the airway (Clavé et al. 2006; Hind et al. 2012; Molfenter and Steele 2013; Newman et al. 2016). Several studies have shown the urgent need for standard terminologies for dysphagia patients, reporting that the current terminologies are imprecise and confusing, hindering clinical practice and causing inaccuracies among patients, caretakers and professionals globally (Cichero 2013; Cichero et al. 2017; Steele et al. 2015). To address these issues, the International Dysphagia Diet Standardization Initiative (IDDSI) launched a new framework for the categorization of foods and drinks for dysphagia patients. A key element of this initiative was the development of a new test to measure the flow of a liquid using a syringe. In this framework, there are five levels—from zero to four—to measure the thickness of any drink based on the remaining volume in the syringe (RVS) after a gravity flow test with a 10 mL syringe (Cichero et al. 2017).

Historically, a variety of starches (STs) and gums have been used to thicken liquids (Cichero 2013). There are several brands of food thickeners based on xanthan gum (XG) and ST. XG is a polysaccharide gum derived from *Xanthomonas campestris* through a fermentation process (Law et al. 2015). There are different forms of ST, but they are defined as polysaccharides composed of a long polymeric chain of glucose units. Different effects on the oral and pharyngeal phases have been documented for both thickeners (Newman et al. 2016; Ong et al. 2018; Vilardell et al. 2015). However, few studies examined the behavior of different thickeners using the IDDSI framework without the participation of human subjects (Barbon and Steele 2018; Kim et al. 2018). Recently, a report showed that commercially available XG-based and ST-based thickeners exhibit distinct behaviors in IDDSI flow tests regarding their apparent viscosity (Kim et al. 2018). Other researchers compared similar thickeners using the IDDSI framework, but found no significant differences between them (Barbon and Steele 2018). Inconsistent sampling methods and instruments have limited the ability of these studies to assess the variability of thickener agents using the flow test proposed by IDDSI. Therefore, there is a call for new research to evaluate the performance of different thickening agents in flow tests.

This study compared the IDDSI flow test results by analyzing the framework level, RVS, viscosity parameters, and cost analysis in water samples with progressively higher concentrations of three commercially available thickeners based on XG and/or ST.

Materials and methods

Selected thickeners

Three commercially available food thickeners in Brazil were randomly selected for this study. Table 1 presents the composition and manufacturer preparation instructions.

Sample preparation

Samples were prepared using colored mineral water at a controlled temperature (20–25 °C). For each test, 100 mL of mineral water was used, and one drop of Mix® food coloring (Mix®, São Paulo, Brazil) was added to improve visibility and enable greater accuracy of the record of RVS and the IDDSI level. Each test mixture was prepared by weighing each component, resulting in a progressive thickener concentration starting at 1% weight/volume (w/v) until level four on the IDDSI scale was reached. Each sample was prepared according to the manufacturer's instructions (Table 1) and tested in quintuplicate.

Flow test: IDDSI level and RVS

The flow test was performed according to IDDSI instructions (IDDSI - International Dysphagia Diet Standardization Initiative 2020). Ten milliliter of thickened water was added to a 10 mL syringe (BD®, barrel length from 0 to 10 mL line = 61.5 mm). To avoid leakage, the syringe nozzle was blocked using a finger. The nozzle was left open for 10 s and then blocked again, and the RVS was recorded. IDDSI levels were then attributed: level zero for volumes between 0,0 and 0,9 mL; level one, between 1,0 and 3,9 mL; level two, between 4,0 and 7,9 mL; level three, between 8,0 and 9,9 mL; and level four, 10,0 mL.

Viscosity parameters

Apparent viscosity was evaluated using a rotational viscometer (Brookfield, Mod LV-T, São Paulo, Brazil). The spindle was chosen to keep a dial reading between 10 and 90, following the equipment guidelines. The settings were fixed at 1.5 rpm for 30 s at 25 ± 2 °C.

Cost estimation

The cost of the three thickeners on American e-commerce websites was compared in US dollar terms. Since the packs differ in terms of weight content, the cost per gram and per 100 g (Table 1) was calculated based on thickener prices on nine different e-commerce websites. These costs were used to estimate the cost of preparing 100 mL of drink at

Table 1 Composition of evaluated thickeners and manufacturer preparation instructions

Thickener	Ingredients	Preparation method	Cost/100 g (US$)*
A	Maltodextrin, xanthan gum and potassium chloride	Pour the liquid onto the powder and mix for 20 to 30 s	10.65 ± 3.63
B	Corn starch, tara gum, xanthan gum and guar gum	Add the thickener to the food and mix using a fork. Let it rest for a few minutes	5.47 ± 1.88
C	Corn starch and maltodextrin	Mix the liquid and the thickener, shaking for 30 s to 1 min	15.00 ± 4.00

*Average cost per 100 g calculated based on thickeners price in nine different American e-commerce

each IDDSI level, based on the thickener quantity found in this study.

Statistical analysis

All results are presented as mean ± standard deviation. Statistical analysis was performed with the Kruskal Wallis test for the concentrations 1 g/100 mL–5 g/100 mL, and the Mann Whitney test for the concentrations 6 g/100 mL and 7 g/100 mL, with a global significance level of 5%.

Results

In the flow test, the concentrations to reach IDDSI level four were different for each product. Thickener A reached level four at a concentration of 5 g/100 mL, while B and C required 7 g/100 mL to attain the same level in the IDDSI framework. Figure 1 presents the variability of the IDDSI levels at different concentrations for all the studied thickeners. Figure 2 demonstrates the cost of preparing 100 mL of thickened drink in each IDDSI level, for the studied

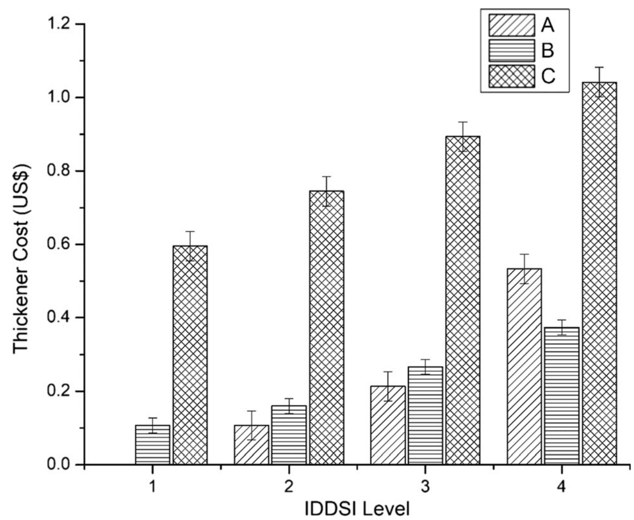

Fig. 2 Cost estimation to prepare 100 mL of a thickened drink reaching each IDDSI level for studied thickeners in US dollars. *Cost of preparing 100 mL of a thickened drink.

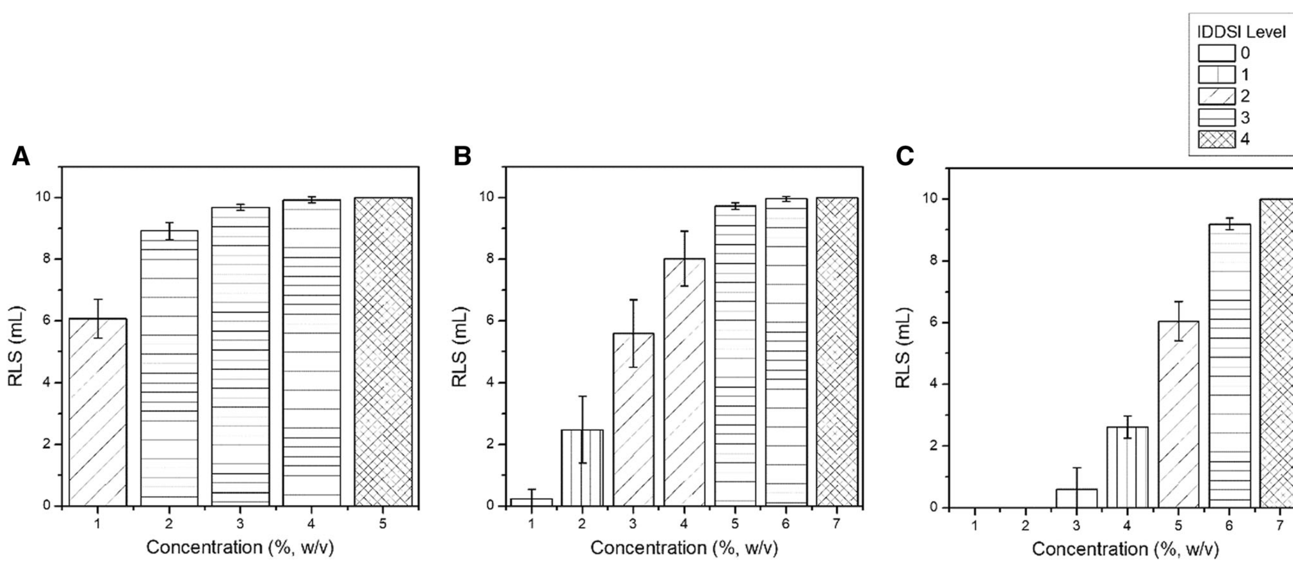

Fig. 1 Flow test of all concentrations of thickener A (**A**), B (**B**) and C (**C**). Bars represent average volume of remaining liquid in syringe (RLS) in mL, and error bars represent standard deviation of quintuplicate. Bars are pattern-filled according to IDSSI level

thickeners, in US dollars.

Thickeners A, B, and C presented statistically different IDDSI levels and RVS at all investigated concentrations, as shown in Table 2. Thickener A had higher IDDSI levels than thickeners B and C (Fig. 1). Thickener A did not reach level one at the initial concentration (1 g/100 mL). Furthermore, thickeners A and B attained higher RVS values compared with thickener C, following the A > B > C trend, except at a concentration of 7 g/100 mL.

Table 2 shows the statistically different viscosity parameters for all the agents. Thickener A presented the highest viscosity compared with thickeners B and C. The last two did not behave consistently with respect to the viscosity levels. Additionally, thickeners B and C presented an exponential rise in viscosity as concentrations increased; this pattern was not repeated with thickener A, which showed a linear trend (Fig. 3).

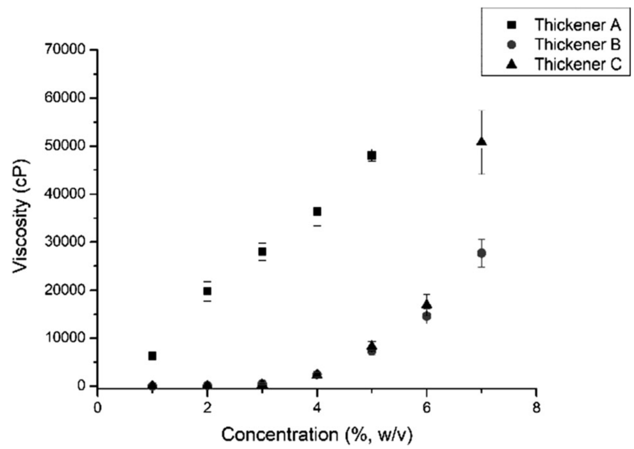

Fig. 3 Comparison of viscosity in all concentrations for thickeners A, B and C. Each value is represented as an average with the standard deviation (error bars) of quintuplicate

Discussion

Polysaccharides are biopolymers found in many organisms and are responsible for many different functions. They have been used as thickeners owing to their ability to increase the viscosity of a liquid, as they form gels when in solution (Toneli et al. 2005). Food thickeners are mainly composed of ST and its derivatives (Salles et al. 2019), gum-based polysaccharides, or a mixture of these. Previous studies have shown that thickener composition influences the rheological behavior of liquids, among other factors, such as temperature, time to thicken, and even liquid type (Garcia et al. 2005, 2008; Park et al. 2014; Salles et al. 2019; Toneli et al. 2005).

This study presented evidence that, at every concentration, an XG-based thickener (A) reaches higher viscosity levels compared with ST-based (C) or mixed (B) thickeners. A pattern of A > B > C was established regarding IDDSI levels and RVS measurements, except at a concentration of 7 g/100 mL, in which B and C reached similar levels. This similarity is likely because both thickeners reached saturation at this concentration level.

With regard to thickener composition, it has been documented that agents based on gums, such as tara gum, guar gum, and XG, are able to alter the consistency of liquids in lower amounts than ST-based thickeners. Other researchers found the need for a much higher mass of ST-based thickeners than XG-based thickeners to reach the same IDDSI level in the flow test (Barbon 2018; Barbon and Steele 2018).

As observed in previous studies (Alves et al. 2017; Barbon 2018; Barbon and Steele 2018), thickener A (XG-based) did not reach level one on the IDDSI framework at a concentration of 1 g/100 mL (the lowest concentration in the test), instead reaching level two or three (Fig. 1). This suggested that the thickener mixing instructions must consider volumes higher than 100 mL of water/liquid for level one preparations. This is a better practice than suggesting a lower mass of thickener because it may be difficult to obtain less than 1 g in clinical practice, as the measuring spoon offered with the product usually holds 1–2 g. These recommendations do not apply to commercial thickeners based on ST (thickener C) or mixed (thickener B), which reached every level from one to four in the tested concentrations.

Table 2 Comparison of the parameters of the three studied thickener

Concentration	RLS*	*p* value**	Viscosity	*p* value	Level	*p* value
1 g/100 mL	A > B > C	0.005	A > B = C	0.001	A > B = C	0.001
2 g/100 mL	A > B > C	0.002	A > B = C	0.008	A > B > C	0.002
3 g/100 mL	A > B > C	0.002	A > B > C	0.007	A > B > C	0.001
4 g/100 mL	A > B > C	0.002	A > B > C	0.008	A > B > C	0.002
5 g/100 mL	A > B > C	0.001	A > C > B	0.005	A > B > C	0.001
6 g/100 mL	B > C	0.016	C > B	0.222	B > C	0.032
7 g/100 mL	C = B	1.000	C > B	0.008	C = B	1.000

**RLS* Remain liquid in the syringe

Thickener B (a mix of XG, tara gum, guar gum, and corn ST) testing resulted in distinct RVS values at a concentration of 4 g/100 mL (Fig. 1). This high variability implied a risk of negative outcomes in clinical practice since inaccuracies in liquid preparation may lead to safety and efficiency limitations regarding food ingestion, as well as inconsistencies in manufacturer instructions. Clinically, dysphagia patients and professionals such as speech and language pathologists, clinicians, nutritionists, nurses, and caregivers must be aware that adding a certain amount of thickener B to a liquid may result in different IDDSI levels. This information is paramount to the precise preparation of a thickened liquid. There have been few studies on thickeners composed of a mix of gums and ST, and extant research did not provide information about their efficacy in swallowing physiology or their behavior in the IDDSI flow test (Killeen et al. 2015; Salles et al. 2019; Silva et al. 2017; Vallons et al. 2014). Therefore, research is required to evaluate the IDDSI framework for this type of thickener, both on its own and its application for patients with dysphagia.

Thickener C (ST-based) also presented different RVS values for a single concentration. At 3 g/100 mL, the IDDSI levels ranged from zero to one. However, thickener A did not register any level of variability. It is not yet possible to assert that small differences in RVS values have any clinical significance regarding safe swallowing and penetration/aspiration (Barbon 2018; Barbon and Steele 2018). The IDDSI framework is a new methodology, and there is still a lack of studies assessing the clinical relevance of each level in patients with dysphagia. Although some recent publications evaluated swallowing of different consistencies in healthy subjects based on the IDDSI framework, these consistencies do not exceed 1 mL in the flow test (Steele et al. 2019; Valenzano et al. 2020). However, this methodology prevents the assessment of clinical effects stemming from RVS variability within a single level, as observed in this study. Therefore, we recommend that professionals use thickened liquids with RVS values that fall close to the center of each level range (Barbon and Steele 2018), until further evidence allows a better understanding of the clinical significance of these disparities (Steele et al. 2015).

Thickener A attained higher viscosity levels than thickeners B and C. As the concentration increased, the viscosity as well as the volume of fluid flowing through the syringe decreased. The viscosity parameters increased linearly for higher concentrations of thickener A and exponentially for thickeners B and C (Fig. 3). Even though there were differences in the viscosity parameters of thickeners B and C, they were not significant enough to influence the IDDSI levels and RVS, despite the B > C trend holding for every concentration. These small changes in viscosity may not be related to flow test results in corn ST-based thickeners, in accordance with existing literature, suggesting that the flow test might not be sensitive enough to measure viscosity changes of liquids thickened with ST-based products (Kim et al. 2018). Moreover, a recent study with several types of thickeners could not establish any correlation between viscosity and IDDSI/NDD (National Dysphagia Diet) classifications (Kim et al. 2018).

Our results suggested that XG-based thickeners, followed by ST-based thickeners, could be preferentially recommended for patients with dysphagia, instead of mixed thickeners, due to lower variability between flow test levels, RVS values, and their linear viscosity trend as concentrations increased. However, among XG- and ST-based products, professionals should also consider other clinical aspects when recommending a thickening agent. For instance, studies with human subjects revealed that ST-based agents may be less efficient in decreasing the frequency of penetration/aspiration events (Newman et al. 2016) while increasing pharyngeal residue after swallowing (Vilardell et al. 2015). In addition, they may be less soluble in some liquids and may alter their taste and opacity, resulting in a less pleasant drinking experience (Ong et al. 2018) compared with XG-based thickeners. ST-based agents also begin to be hydrolyzed by salivary amylase, which significantly reduces the viscosity of the liquid in the mouth (Hanson et al. 2012a, b; Lee et al. 2016; Vallons et al. 2014, 2015). Furthermore, thickened liquids should always be prescribed with caution (Logemann 1998), since patients who need thickening agents are more prone to developing complications such as dehydration (Cichero 2013) (Flynn et al. 2018). Psychosocial issues have also been associated with thickener use, affecting the quality of life of these patients (Ekberg et al. 2002).

As previously reported (Schmidt and de Oliveira 2015), commercial thickeners can be costly, with the cost depending on the brand and composition. Despite not being the cheapest in terms of cost/100 g, a lower amount of thickener A is needed to reach IDDSI levels, which makes it commercially viable at levels two and three. Thus, multidisciplinary teams and caregivers should not only consider the cost per unit, but also the cost per level while choosing a thickener.

This study had some limitations. First, the study assessed a single brand of thickener for each composition. A higher number of products and compositions should be experimentally evaluated to further clarify some of the issues raised by our results, preferentially following IDDSI flow test guidelines. Second, this study used food coloring to improve the visibility of the liquid; however, we do not know what effect, if any, the food coloring had on the action of thickeners with water, which could influence the results regarding the level of IDDSI and RVS. Future studies should consider using samples of water and food thickeners, without adding other substances. Comparisons between patients with dysphagia and healthy subjects should also be performed to better understand the impact of thickeners' use on swallowing physiology. Professionals should always stay abreast of the available scientific evidence before offering any guidance to patients and caregivers, considering the safe ingestion of liquids as well as the composition and cost–benefit ratio of thickening agents.

Conclusion

This study revealed that the thickener composition significantly influences IDDSI levels, RVS, and viscosity. The evaluated XG-based thickener appeared to provide more accurate and/or safe preparations for patients and caregivers to use, and medical professionals to prescribe. ST-based and mixed thickeners proved to be less than ideal recommendations when accounting for clinically safer food products because their viscosity behavior fluctuated at different concentrations, which may compromise the safety and efficiency of swallowing in patients with dysphagia.

Author's contributions JVH, main author of the manuscript, conceptualization, and design, conducting the analysis and critical interpretation of the literature, writing original draft, editing and final review. HSAT, investigation, methodology, analysis, and interpretation of the literature, editing and final review of the manuscript; CM de S, investigation, conducting the methodology, supervision (supporting), analysis, and interpretation of the literature, editing and final review of the manuscript; JAA, investigation, methodology, analysis, editing and final review of the manuscript; F de SF, analysis, editing and final review of the manuscript; PGM, methodology, analysis, editing and final review of the manuscript; LFM, senior author, conceptualization, and design, conducting the analysis and critical interpretation of the literature, writing and final revision.

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Declarations

Conflict of interest The authors declare that they do not have any conflict of interest.

Ethical statement This study did not involve any human or animal testing. This research did not require submission to analysis by the Ethics Committee because there were no interventions performed with humans nor any data collected from them. This research was conducted in accordance to the World Medical Association Declaration of Helsinki.

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