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Annelise Masters, Jane Mertz Garcia, Edgar Chambers IV

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Line Spread Test: Moving Toward Clinical Implications

Annelise Masters[1], Jane Mertz Garcia[1], Edgar Chambers IV[2]

Communication Sciences & Disorders[1]; Human Nutrition[2]

Kansas State University, Manhattan

Author Note

Annelise Masters, Communication Sciences & Disorders, Kansas State University; Jane Mertz Garcia, Communication Sciences & Disorders, Kansas State University; Edgar Chambers IV, Human Nutrition, Kansas State University.

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Correspondence concerning this article should be addressed to Jane Mertz Garcia, PhD, Communication Sciences & Disorders, School of Family Studies & Human Services, 139 Campus Creek Complex, Manhattan, KS 66506-7500. E-mail: jgarcia@ksu.edu

Abstract

Purpose: Preparing modified liquids to a target level of consistency as specified by the speech-language pathologist is critical to service delivery. This study explored the value of line spread testing (distance a liquid flows) in comparison to viscometry readings for differentiating a variety of modified liquids prepared to nectar-thick vs. honey-like consistency.

Method: We tested combinations of four thickening products (three starch-based and one gum-based thickener) prepared with six serving temperature beverages that had various levels of fat, fiber, and added nutrients. A total of 32 product/liquid combinations measured within the target range of 80-800 centipoise (cP). Measurements were recorded from the Line Spread Test (after 60 seconds of spread) and a Brookfield RVDV-II+ viscometer.

Results: Nectar-thick and honey-like consistencies significantly differed in their degree of spread. Using our line spread apparatus, a value of 4.5 centimeters (cm) differentiated between nectar-thick and honey-like consistencies. There was an inverse correlation (-.75) between viscometer data and line spread test results across consistencies.

Conclusions: The Line Spread Test may be a cost effective method for assisting with staff training in the preparation of thickened liquids in different care environments by providing visual feedback about sample consistency.

Diet modifications that included thickened liquids remain an ongoing challenge in service delivery. Nearly half of surveyed speech-language pathologists (SLPs) report use of thickened liquids for 25 to 75% of their patients with dysphagia (Garcia, Chambers, & Molander, 2005). Both SLPs and dietitions indicate that a substantial percentage of their facilities serve modified liquids that require preparation, which is further complicated by the diverse group of care providers who participate in their service delivery (Garcia & Chambers, 2012; Garcia et al., 2005). Survey findings suggest use of a wide range of thickening products in clinical practice (Garcia et al., 2005) with food service contracts and cost considerations representing key factors that impact decisions about products (Garcia & Chambers, 2012).

Inaccuracies in preparing to target levels of thickness and ongoing concerns about caregiver knowledge and compliance with thickening recommendations highlight the importance of training practices (Colodny, 2001; Garcia, Chambers, Clark, Helverson, & Matta, 2010; Pelletier, 2004). Many caregivers report informal instruction (e.g., shown by another caregiver) and professionals acknowledge inconsistent use of formal training practices such as in-services (Garcia & Chambers, 2012; Garcia et al., 2005; Garcia et al., 2010). Patients who consume inappropriately modified liquids (especially over-thickened beverages) may heighten their risk of pneumonia because of difficulty in clearing aspirated material from the airway (Robbins et al., 2008).

Effective training strategies for making judgments about modified liquid consistency are important given that even experienced professionals have difficulty making decisions about thickness (Brown, Mills, Daubert, & Casper, 1998; Glassburn & Deem, 1998). Glassburn and Deem found discrepancies in how SLPs and dietitians evaluate thickness even though participants “were allowed to stir, spoon, and plop” samples (1998, p. 4). Although viscometers

and rheometers provide a current standard for measuring fluid thickness, they are costly and impractical for use in clinical settings for instructional purposes.

The Line Spread Test (LST) provides information about modified liquid consistency by visually representing flow distance across a flat surface (Mann & Wong, 1996). The implication for use with thickened liquids is that thinner liquids (e.g., modified to a nectar-thick consistency) flow a further distance in comparison to thicker liquids (e.g., honey-like consistency). LST findings suggest reproducible measurements and success in using line spread testing to broadly differentiate flow distance of some nectar and honey-like liquids (Adeleye & Rachal, 2007; Budke, Garcia, & Chambers, 2008; Nicosia & Robbins, 2007). A limitation of current literature is that line spread measurements have primarily focused on two starch-based thickening products mixed with liquids (often juices) typically measured at room vs. serving temperature. Less is known about the usefulness of the LST across a variety of thickening products and liquid types, even though these factors have been shown to impact measurements of viscosity (Adeleye & Rachal, 2007; Garcia, Chambers, Matta, & Clark, 2008; Garcia et al., 2010).

The LST may be a cost-effective tool to incorporate in the service delivery of thickened liquids to help care providers modify beverages to a target level of consistency (Budke et al., 2008; Mann & Wong, 1996; Nicosia & Robbins, 2007). This study focuses on LST and viscometer measurements for nectar- and honey-modified liquids given the frequency of their use in clinical practice (Castellanos, Butler, Gluch, & Burke, 2004; Garcia & Chambers, 2012; Garcia et al., 2005). In comparison to past research, this study includes more thickening products (both starch and gum-based) and a greater variety of liquids modified at their serving temperature. It addresses the following research questions:

1. Are Line Spread Test measurements sensitive to differences in thickness across an assortment of product/liquid combinations prepared to nectar and honey-like consistencies?
2. How comparable are line spread measurements to viscometer readings for a range of nectar and honey-modified liquids?
3. Is there a line spread measurement (amount of spread) that distinguishes target levels (nectar-thick and honey-like) with consistent accuracy?

Methods

Materials

The thickening products included three starch-based thickeners (Thick-It®, Thick & Easy®, Thicken Up®) and one polysaccharide gum-based thickener (Simply Thick®). The six beverages, water, whole milk, prune juice, cran-apple juice, coffee, and Ensure, reflected a wide variety of characteristics including liquids that had various levels of fat, fiber, acid, added nutrients, and temperature.

Sample Preparation Procedure

Product labels provided directions to prepare a 4 fl oz sample of each beverage; conversion of volumetric amounts into grams (averaged across three replicate measurements) assured that each sample reflected exactness in the amount of thickener and liquid. The thickening agent was slowly poured and mixed into the liquid with a Cimarec stirring device set to a constant speed for 25 seconds. Samples prepared with Simply Thick were vigorously shaken (following manufacturer guidelines) for the same time interval. Five minutes of setting time assured that products were allowed to thicken for a recommended time interval. Digital temperature readings taken at four minutes ranged from 5.2° C (Thicken Up, Nectar-thick Cran-apple) to 9.9° C (Simply Thick, Honey-like Water) for modified samples prepared with

refrigerated beverages and from 49.9° C (Simply Thick, Honey-like) to 60.2° C (Thicken Up, Honey-like) for a hot beverage (coffee). A total of 5 separate samples were prepared and measured for each product/beverage combination.

Measurement Procedures

The LST measures the distance a liquid flows over a flat surface (confirmed with a carpenter's level). The apparatus used consisted of a Plexiglas board marked with concentric circles spaced .5 cm apart at a distance of 2.5 to 7.5 cm, divided into 4 quadrants (90-degree intervals). The sample is held in a hollow tube (cylinder of 3.5 cm height and 5 cm diameter) positioned at the center of the concentric circles. Each thickened sample was poured into the cylinder placed in the middle of the line spread board after 5 minutes of setting time. Tubes were slightly overfilled and leveled with a metal spatula to ensure the same amount was placed in each tube. Once lifted, the sample spread for 60 seconds (Figure 1). The average measurement from each quadrant represented the amount of spread.

Insert Figure 1 about here

A Brookfield RVDV-II+ viscometer with a small sample adaptor (Brookfield Engineering, Middleboro, MA) provided measurement of viscosity for the same 4 oz sample after five minutes of setting time. Measurements that fell within a range of 80 to 800 cP at a shear rate of $55.8s^{-1}$ met instrument guidelines (torque) and also reflected modified liquids that clearly fell within the National Dysphagia Diet (NDD) guidelines for nectar-thick and honey-like modifications (NDDTF, 2002). Table 1 highlights the 48 modified beverages, including 24 prepared to a nectar-thick consistency and 24 prepared to honey-like thickness using product label information, that either "fit" the target range, or measured "above" 800 cP, or "below" 80

cP. A total of 32 product/beverage combinations measured within the target range of viscosity (80 to 800 cP) for this study.

Insert Table 1 about here

Statistical Analysis

Analyses were done using IBM SPSS System for Windows (Version 19, 2010). Line spread test measurements for nectar-thick and honey-like samples were compared using *t* tests. Pearson product-moment correlation coefficients were used to compare viscometer readings and LST measurements. Chi-square analysis tested a "border" LST measurement to examine expected and observed frequencies for nectar-thick and honey-like samples. An alpha level of less than .05 reflected a statistically significant difference.

Results

Table 2 includes mean values for the LST and viscometry for the 32 samples that measured within the accepted range using viscometry. The overall mean spread of 20 nectar-thick samples was 5.3 cm and 4.15 cm for the 12 honey-modified beverages. Line spread measurements significantly differed in comparing nectar-thick and honey-like beverages ($p <$ .05). Additionally, LST and physical measurements of viscosity showed an inverse correlation (r = -.752, $p <$. 01) for the 32 modified beverages, suggesting a relationship between viscometer data and line spread test results for nectar-thick and honey-like samples. This meant that modified beverages that were "thicker" typically had high measurements of viscosity but relatively less spread (low line spread values). Modified beverages that were "thinner" typically measured low in viscosity but spread further (higher LST values). A line spread measurement of 4.5 cm appeared to represent a boundary between nectar-thick and honey-like beverages as illustrated in Figure 2 for water and coffee. The Chi-square test verified that a spread of more

than 4.5 cm suggested a nectar-thick beverage and a spread 4.5 cm or less a honey-like beverage, X^2 (1, N = 32) = .533, $p > .05$).

Insert Table 2 & Figure 2 about here

Discussion

This study explored the use of line spread testing with an expanded variety of liquids and thickening products. Similar to previously reported results, line spread measurements distinguished modifications prepared to nectar-thick and honey-like consistency (Adeleye & Rachal, 2007; Budke et al., 2008; Nicosia & Robbins, 2007). The current study did not examine the flow distance of spoon-thick consistency (more viscous samples), in part, because spoon-thick samples do not spread and nectar- and honey-like consistencies represent the most frequently recommended modifications in clinical practice (Castellanos et al., 2004; Garcia & Chambers, 2012; Garcia et al., 2005).

The LST does not replace the use of rheometers/viscometers and related challenges in measuring modified liquids (Nicosia & Robbins, 2007). In fact, the flow distance of nectar-thick and honey-like consistencies appeared impacted by variables that also complicate measurements of viscosity.

Factors such as beverage temperature and time to thicken influence viscosity (Adeleye & Rachal, 2007; Garcia et al., 2008; Garcia et al., 2010) and also seemed to have an effect on flow distance. Although Budke et al. (2008) reported that most nectar-thick samples flowed more than 3.7 cm, the current study found that nectar-thick samples flowed further (4.5 cm or more). Both studies applied similar line spread instrumentation, but varied in methods for sample preparation (liquid temperature and length of thickening time), which may help explain differences in flow distance and interpretation regarding the border of nectar vs. honey-like consistency.

Of additional importance is the type of beverage and its content. For example, honey-like Ensure prepared with two starch-based products (following manufacturer guidelines) yielded viscosity measurements within the range of nectar-like consistency. In these instances, line spread flow distance also confirmed nectar-like consistency (spread of approximately 6 cm). The components in Ensure (e.g., minerals, vitamins, sugars) appeared to interfere with the bonding process of starch thickening agents, which resulted in less viscous modifications than suggested by product label information.

Although there continues to be a heavy reliance on the use of thickened liquids that require some type of preparation, many facilities only offer informal training or one-on-one instruction by co-workers versus in-services or structured programs with competency testing (Garcia & Chambers, 2012). An important objective is to improve the preparation of modified liquids and the LST may be beneficial for instructional purposes. Current line spread testing showed that many nectar-thick samples measured 4.5 cm or higher, signifying a thinner beverage that has more gravitational flow. In comparison, LST measurements for honey-like samples typically fell below 4.5 (indicating a thicker beverage with not as much flow). The distinction in flow seemed more apparent for certain beverages, such as water and coffee, as illustrated in Figure 2.

The implication is that showing flow distance of some modified liquids may be useful to caregiver education in terms of providing visual feedback about samples prepared to a target level of consistency when mixed with a variety of thickening products. Future studies should explore use of the LST as part of caregiver education/training in order to determine its potential benefits. The LST appears to be a quick, objective, and visual method that might help staff achieve more accurate and consistent beverage preparation.

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Table 1

Viscosity Measurements that Fit within 80-800 cP or Measured Above 800 cP or Below 80 cP

Product	Beverage					
	Cran-apple	Coffee	Ensure	Milk (whole)	Prune	Water
Simply Thick						
Nectar	Fit	Fit	Fit	Fit	Fit	Fit
Honey	Fit	Fit	Fit	Fit	Fit	Fit
Thick & Easy						
Nectar	Fit	Fit	Below	Below	Fit	Fit
Honey	Above	Above	Fit	Below	Above	Above
Thick-It						
Nectar	Fit	Fit	Below	Fit	Fit	Fit
Honey	Above	Above	Above	Above	Above	Above
Thicken Up						
Nectar	Fit	Fit	Fit	Below	Fit	Fit
Honey	Fit	Fit	Fit	Below	Fit	Fit

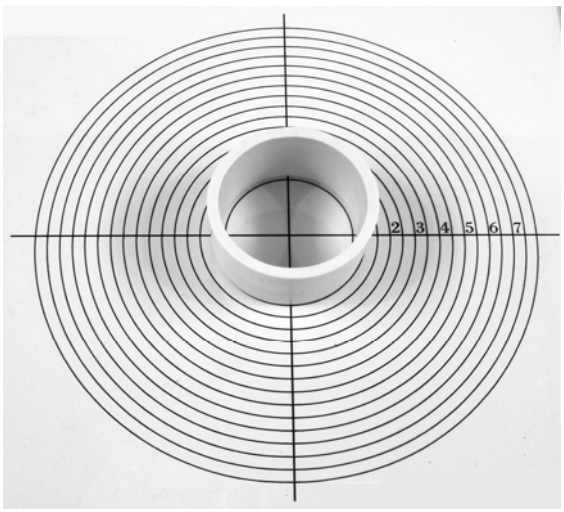
Table 2

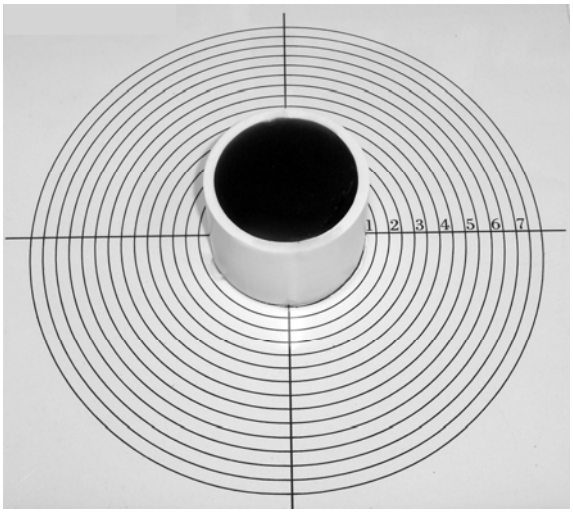
32 Samples' Mean Values for the LST and Viscometer

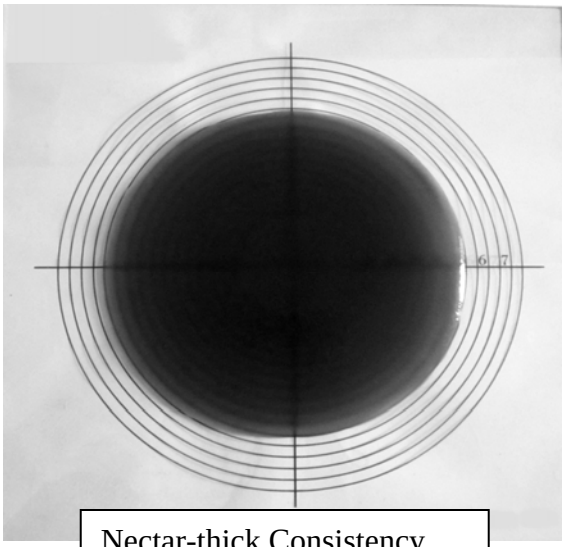
Consistency	Product	Beverage	LST *cm*	Viscosity *cP*
Nectar				
	Thick-It	Water	5.43	159.98
		Milk (whole)	6.02	138.66
		Cran-apple	4.15	217.30
		Prune	5.58	353.68
		Coffee	5.71	354.66
	Thick & Easy	Water	5.71	136.66
		Cran-apple	4.38	207.66
		Prune	5.10	332.02
		Coffee	7.19	143.34
	Thicken Up	Water	4.51	307.02
		Cran-apple	5.07	122.66
		Prune	5.76	207.32
		Ensure	6.56	103.16
		Coffee	5.37	348.34
	Simply Thick	Water	5.09	126.64
		Milk (whole)	4.09	310.32
		Cran-apple	5.30	169.52
		Prune	4.80	232.34
		Ensure	4.42	383.50
		Coffee	6.02	147.66
Honey				
	Thick & Easy	Ensure	6.39	119.48
	Thicken Up	Water	3.59	543.84
		Cran-apple	3.21	390.18
		Prune	3.93	665.84
		Ensure	6.23	154.84
		Coffee	4.33	604.00
	Simply Thick	Water	3.91	299.48
		Milk (whole)	2.99	585.50
		Cran-apple	4.06	434.80
		Prune	3.74	519.16
		Ensure	3.22	730.00
		Coffee	4.25	357.84

Figure 1

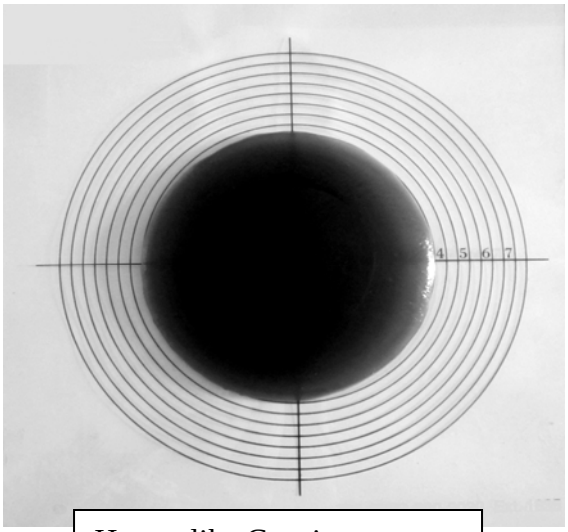
Line Spread Test Illustration for Thickened Coffee







Nectar-thick Consistency



Honey-like Consistency

Figure 2

Spread in Centimeters for Coffee and Water Prepared to Nectar-Thick and Honey-Like Consistency across Products