Application of a manufacturer's guideline and an IDDSI-driven guideline to thickening of some non-water beverages: a rheological study.

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Abstract

Purposes: This study aimed to evaluate an existing liquid thickening guideline provided by a major manufacturer of thickener in Hong Kong and to provide directions for the implementation of the IDDSI framework.

Method: Fifteen participants who are naïve to liquid thickening were required to prepare thickened liquids samples from three drink bases (i.e. Milk-tea, Chinese tea and Herbal tea) at two target consistency levels (i.e. mildly and medium/moderately thick) based on two guidelines (i.e. the manufacturer's guideline and an IDDSI-driven guideline). Viscosities of the samples were measured rheologically to reflect liquid consistency.

Results: The Manufacturer's guideline resulted in distinguishable viscosities at the two consistency levels ($F(1, 35.464) = 113.764$, $p < 0.001$, $\eta_p^2 = 0.802$), as well as different viscosities in different drink bases ($F(1.267, 35.464 = 92.951$, $p < 0.001$, $\eta_p^2 = 0.769$). Comparison between the Manufacturer's and the IDDSI-driven guideline showed that the later resulted in more viscous liquid samples in all drink bases and at both consistency levels. The difference between the two guidelines was statistically significant ($F(1,28) = 35.137$, $p < 0.001$, $\eta_p^2 = 0.557$).

Conclusion: Following only the Manufacturer's guideline when thickening non-water beverages may lead to discrepancy between the resultant and prescribed consistencies. Thus, it should be considered inadequate to ensure swallowing safety. The effect of drink base should be emphasized to patients and caregivers, and pre-serving tests should be introduced. Despite similar classifications and terminologies used between the current local framework and the IDDSI framework, measures should be taken to avoid potential confusions and associated threats to swallowing safety.

Keywords:

1. Dysphagia
2. Deglutition disorders
3. IDDSI
4. Non-water local beverages
5. Viscosity
6. Liquid thickening guidelines

Introduction

Dysphagia is not an uncommon consequence after neurological impairment, such as stroke and dementia, oral surgery, laryngectomy and radiation therapy for head and neck cancer [1]. Around 8% of the world's population is affected by dysphagia [2]. In Hong Kong, studies indicated that the average prevalence of dysphagia in residential facilities and day care centers is around 50% [3, 4]. Swallowing thin liquids, as characterized by its fast flow rate, is found to be risky for patients with dysphagia [5]. Liquid being swallowed may enter the airway as foreign bodies and, in turn, lead to aspiration and pose a risk of pneumonia [6, 7]. Diet modification is a commonly adopted compensatory management approach for dysphagia. In the case of liquid, drinks are thickened to a certain level of consistency to achieve an optimal flow rate so as to provide sufficient time for airway closure before bolus reaches the airway opening [8, 9]. Defining the specific properties of consistency levels is of paramount importance in ensuring swallowing safety since it stipulates the optimal level of consistency to be prescribed and prepared for patients with dysphagia.

Liquid thickening in the management of dysphagia

Garcia, Chamber, Matta and Clark [10] conducted a survey with 145 speech-language pathologists and the result showed that 84.6% of the professionals considered thickening thin liquid an effective management technique for patients with dysphagia. A systematic review by Steele and colleagues [11] reported evidence showing the relationship between liquid thickening and the reduced likelihood of aspiration. One of the major challenges in liquid thickening, from clinicians', patients' and/or caregivers' perspectives and in both the national and international contexts, includes the lack of standardized classification and terminology in describing consistency levels [2].

Different countries might have developed their own national frameworks for liquid thickening. Objective and valid measures for consistency are, nevertheless, largely lacking, with the exception of the National Dysphagia Diet (NDD) framework [12]. Referencing data on shear viscosity were suggested by the NDD task force for each consistency level, based upon a fixed and assumed shear rate of $50s^{-1}$. However, the shear rate is more complex and may vary from $5s^{-1}$ to $1000s^{-1}$ during the actual swallowing processes and viscosity is dependent on the shear rate in non-Newtonian fluids like the thickened liquids [13]. Therefore, the actual viscosity of thickened liquid being swallowed may be different from the suggested viscosity in frameworks like the NDD.

To date, there is no standardized framework available for liquid thickening in Hong Kong. Diet modification mainly follows a set of local terminology and a seemingly standardized framework. This framework is being used across settings (e.g. hospitals, rehabilitation centers, elderly homes etc.) and is adopted by all locally-trained speech therapists. The Local framework consists of two separate classifications for food textures and liquid consistencies. For liquid thickening, patients with dysphagia are usually prescribed with an optimal consistency level upon swallowing assessments conducted by speech therapists. Without specific instructions provided, patients with dysphagia and/or caregivers would simply follow the guidelines provided by the thickener manufacturers, which were developed largely according to the Local framework. A local study investigating the knowledge and skills on dysphagia management of 243 heath workers and care-workers of 12 government-supported residential care homes in Hong Kong showed that a majority of participants demonstrated insufficient knowledge and skills, including the preparation of thickened liquids to their targeted level of consistency [14]. Lao [15] found that the accuracy of thickening liquids to targeted levels of consistency by 19 carers from three local nursing homes in Hong Kong was only 16% prior to training. Discrepancy between the consistency of thickened liquid and the prescribed consistency will undoubtedly threaten swallowing safety in patients with dysphagia.

Another source of discrepancy involves the enzymatic action of salivary amylase. Food or liquid boluses will be lubricated with saliva in the oral preparatory phase. As a part of the digestive process, the amylase in saliva will react with the starch in the boluses and result in glucose and water. Such enzymatic action will lead to reduced viscosity in thickened liquids, especially if starch-based thickening agents are used [16-18]. This may further threaten swallowing safety in dysphagic individuals.

The International Dysphagia Diet Standardization Initiative (IDDSI) framework

The IDDSI framework offers a set of new globally-standardized definitions for texture-modifications of food and liquids [11, 19]. It is noteworthy that the terminologies used to label liquid consistencies in the IDDSI framework are similar to those in the Hong Kong Local framework. Table 1 lists the consistency levels in the two frameworks.

Table 1

Terminologies used to label liquid consistencies in the IDDSI and Hong Kong Local frameworks

The IDDSI framework	The Hong Kong Local framework
Slightly thick (Level 1)	Slightly thick
Mildly thick (Level 2)	Mild thick
Moderately thick (Level 3)	Medium thick
Extremely thick (Level 4)	Extra thick

One of the strengths of the framework is the inclusion of objective testing methods for texture modified liquids and foods. In order to allow assessment on the consistency of thickened liquids at each level, IDDSI developed a pre-serving test which provides a physiologically related flow condition of liquids as a sensitive and reliable measure [19]. The IDDSI flow test is, nevertheless, not without limitations. For instance, the test was not validated rheologically using shear viscosity, considering the variety of shear rates in non-Newtonian liquids like the thickened ones [19]. Further, even if the flow test results are referenced to shear viscosities, some important rheological properties may still be overlooked (e.g. the extensional viscosity that is more sensitive to the effect of salivary amylase) [13]. Parties adopting the IDDSI flow test should be informed about these potential limitations.

Purpose of the study

The present study aimed to evaluate an existing Manufacturer's guideline, which is developed from the Local liquid thickening framework, and to provide directions for the implementation of the IDDSI framework. Specifically, the present study would like to address a) is the liquid thickening guideline provided to patients with dysphagia and/or their caregivers in Hong Kong adequate to ensure swallowing safety? (Specific aim #1); and b) are the viscosities of liquid thickened according to the Hong Kong Local framework and IDDSI framework comparable at the corresponding consistency levels? (Specific aim #2). Shear viscosity, measured objectively through rheology, was taken as the quantitative outcome measure that reflects liquid consistency in the present study.

Regarding Specific aim #1, a guideline provided by the manufacturer of a major thickener, which is made available to patients and/or caregivers in Hong Kong and globally, was adopted to thicken some frequently consumed local beverages. Similar to other commonly used thickeners, the guideline does not mention specifically about the possible variability in consistency when the thickener is added to different liquids and to liquid at different temperatures [22,23]. It is hypothesized that simply following the Manufacturer's guideline will result in significantly different consistencies in different non-water drink bases and thus compromise swallowing safety.

Regarding Specific aim #2, the Manufacturer's guideline was compared with a guideline developed based on the IDDSI framework by Lao [15]. Based on a preliminary study by Kwong and colleagues [22], the two guidelines gave rise to significantly different viscosities in three non-water drink bases (i.e. Milk-tea, Chinese tea and Herbal tea) at the mildly thick consistency level, as well as different viscosities in Milk-tea and Chinese tea at the moderately thick consistency level. However, since the preparation procedures and sample temperature for the two guidelines were not controlled, results might be attributed to factors other than the thickening guideline. The present study served to replicate the study by Kwong and colleagues

[22] with better control over the aforementioned factors and provide insights for future implementation of the IDDSI framework in the Hong Kong context.

Method

Participants

The present study was approved by the Human Subjects Ethics Sub-committee, the Hong Kong Polytechnic University (Ref. HSEARS20180301001). Fifteen participants (5 males and 10 females) aged from 22 to 58 took part in this study. They were all fulltime undergraduate or postgraduate students from the Hong Kong Polytechnic University who had no prior knowledge in dysphagia or experience in preparing texture-modified liquids. This was to ensure that all participants had 1) comparable knowledge in dysphagia and diet modification, and 2) knowledge resembled that of patients with dysphagia and/or caregivers who had received little or no training on liquid thickening.

Materials and equipment

Rheometer. A dynamic shear rheometer (Anton Paar MCR 702 TwinDrive™) was used for rheological analysis of the samples. A cone-and-plate fixture was employed to ensure accurate measurement of viscosity [24] (Cone dimension: diameter = 49.983mm, cone angle = 0.996mm, cone truncation = 103μm; parallel plate dimension: diameter = 52.000mm). A JULABO FP50 Refrigerated/Heating Circulator was used to maintain the temperature at 25°C during the experiment.

Thickener. The starch-based thickener, RESOURCE® THICKENUP®, manufactured by Nestle Health Science, was used for liquid thickening. This was selected for the present study as it is considered one of the most frequently used thickeners across settings in Hong Kong. The product was powdered and the active ingredient was modified food starch (maize). No other information about the type of starch modification and the viscosities of each consistency level were specified on the product labels and company website [25].

Drink bases. Three kinds of Hong Kong local beverage were selected as the drink bases for thickening in the present study. They are Milk-tea, Chinese tea and Herbal tea. Table 2 summarizes the details of the drink bases.

Table 2

Details of the drink bases under investigation

Drink	Brand	Main composition	Package / Preparation
Milk-tea (Hong Kong-styled milk tea)	Vitasoy™	Water, sugar, milk solid, evaporated milk, creamer, black tea, Ceylon tea, emulsifier (473), salt, flavouring, antioxidant (316)	Bottled, ready for consumption
Chinese tea (*Pu-erh*)	Luk Yu®	Pu-erh tea leaves	Infusions, prepared by adding 210mL of boiling water and constant stirring for 2 minutes
Herbal tea (Prunella vulgaris)	Hung Fook Tong®	Purified water, cane sugar, common selfheal fruit-spike, dates, grosvenor momordica fruit, liquorice root	Bottled, ready for consumption

Procedures

Preparation of thickened liquid. A previous study showed that differences in temperature might lead to differences in viscosities at a certain consistency level (i.e. honey-like consistency) [26]. In order to prevent inconsistencies in temperature of the liquids during the thickening process, the drink bases were stored in the electronic thermostat water bath at 25°C for at least 15 minutes before sample preparation. Two sets of preparation guidelines, the Manufacturer's guideline [25] and the IDDSI-driven guideline suggested by Lao [15] and used in Kwong and colleagues [22] were adopted. Each participant was required to thicken three drink bases to two consistency levels (i.e. mildly thick and moderately thick) by following the two guidelines. These two consistency levels were selected for investigation as they are the most frequently prescribed liquid thickening levels in dysphagic clinics in Hong Kong.

When preparing for each sample according to the Manufacture's guideline, each participant would first measure 300mL of liquid as suggested using a 500-mL beaker. Then, the liquid was transferred into a 350-mL container. The amount of thickener was measured by the measuring spoon provided in the package. Thickener was slowly added to the liquid. The number of scoops suggested by the manufacturer was added according to the target consistency level. The mixture was stirred gently with a glass rod at a constant speed for at least 20s or until the thickener was completely dissolved. The second author (T.T., a Master of Speech Therapy student who had received training on dysphagia management and diet modification) then judged and made sure all thickener was completely dissolved.

Preparation procedures were modified for samples prepared using the IDDSI-driven guideline developed by Lao [15]. Participants were required to measure 200mL, instead of 300mL, of liquid. A different measuring spoon that holds 4.5g of thickener was used, whereas the original measuring spoon only holds 1.35g of thickener. Table 3 shows the comparison on the dosage of thickener added to liquid for the two guidelines.

Table 3

Dosage of thickener added to liquid at different consistency levels according to the two guidelines

Thickening guidelines	Mildly thick	Medium / Moderately thick
Manufacturer's guideline	13.5g of thickener into 300mL of liquid (4.5g/100mL)	18g of thickener into 300mL of liquid (6g/100mL)
IDDSI-driven guideline	9.45g of thickener into 200mL of liquid (4.735g/100mL)	12.15g of thickener into 200mL of liquid (6.075g/100mL)

Measurement of viscosity using rheology. The thickened liquid samples were allowed to set for approximately one minute before being transferred to the stationary container with a dropper. The moving plate attached to the rheometer's motor was then lowered to exert pressure on the sample. The plate was set to move at a constant speed (shear rate) while the force needed (shear stress) to move at that speed was measured. The viscosity was given by obtaining the ratio of shear stress to shear rate. As the viscosity of the liquid samples varied with the change in flow rate and temperature, all samples were measured under a fixed shear rate of 50 s^{-1} and constant temperature of 25°C (room temperature). This setting resembles standard commonly used in previous studies for viscosity measurement based on the NDD framework [27]. The dynamic shear rheometer was preset to run the viscosity analysis for three times on each sample. The three viscosity readings were averaged and taken as the viscosity of the corresponding sample for later data analyses.

Statistical analyses. All statistical analyses were carried out using the IBM SPSS Statistics 25 software. Independent variables included the two guidelines, namely the Manufacturer's guideline and the IDDSI-driven guideline; the three drink bases, namely Milk-tea, Chinese tea and Herbal tea; and the two consistency levels, namely mildly thick and moderately thick. The dependent variable was the viscosity of thickened liquid measured with rheology. To address Specific aim #1, data on samples prepared based on the manufacturer's guideline were analyzed by a two-way mixed ANOVA (3 Drink bases x 2 Consistency levels). Drink base was regarded as the within subject independent variable. For Specific aim #2, data were analyzed by a three-way mixed ANOVA (2 Guidelines x 3 Drink bases x 2 Consistency levels) to study the interactions among the three independent variables. Within subject independent variables included Guideline and Drink base. Alpha level was set at 0.05 for both ANOVAs. Pairwise comparisons were conducted using paired-sample *t*-tests with Bonferroni adjustment if significant interaction and/or main effects were found.

Results

The Manufacturer's guideline (Specific aim #1)

From the Mauchly's tests of sphericity, the variable Drink base ($\chi^2(2) = 23.361$, $p < 0.001$) showed statistical significance and Greenhouse-Geisser correction was adopted for the mixed ANOVA. Table 4 summarizes the descriptive statistics of the viscosity data of samples prepared using the two guidelines from the three drink bases at the two consistency levels.

Table 4

Means and standard deviations of the viscosity data

	Viscosity in millipascal seconds (mPa·s)							
	Mildly thick consistency		Medium / Moderately thick consistency		Both consistency levels		All samples using the same guideline	
Guideline and Drink base	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Manufacturer's guideline								
Milk-tea	359.007	130.827	1103.978	326.212	731.492	450.738	419.624	363.961
Chinese tea	116.891	34.062	396.571	135.764	256.731	172.302	--	--
Herbal tea	158.044	71.314	383.256	121.185	270.650	150.540	--	--
Manufacturer's guideline sub-total	211.314	137.391	627.935	400.388	--	--	--	--
IDDSI-driven guideline								
Milk-tea	550.080	194.197	1258.356	333.794	904.218	449.146	556.689	399.089
Chinese tea	197.233	63.658	494.176	145.707	345.704	187.108	--	--
Herbal tea	259.011	99.768	581.280	249.777	420.146	248.563	--	--
IDDSI-driven guideline sub-total	335.442	201.655	777.937	425.881	--	--	--	--
All samples within the same consistency level	273.378	182.569	702.936	417.865	--	--	--	--

Note. SD = standard deviation.

Interaction between Drink base and Consistency level. Table 5 summarizes the results of the two-way mixed ANOVA. Significant interaction effect was found between the two independent variables ($F(1.267, 35.464) = 25.978$, $p < 0.001$) with a large effect size (partial Eta squared = 0.481) (see Figure 1 for interaction plot). Simple effects were examined by conducting nine paired-sample t-tests with Bonferroni adjustment (see Table 6). At both mildly thick and medium thick consistency levels, milk-tea samples were significantly more viscous than samples prepared from the other drink bases ($p < 0.001$). Although the difference in viscosity was notable between Chinese tea (M = 116.891mPa·s, SD = 34.062) and Herbal tea (M = 158.044mPa·s, SD = 71.314) at the mildly thick consistency level, the difference was only considered significant at 0.05 level but not the corrected 0.0056 (i.e. 0.05/9) level (Table 5). The medium thick samples were consistently more viscous than the mildly thick samples for all drink bases ($p < 0.001$). Effect sizes for all the pairwise comparisons were large (Cohen's $d \geq 0.889$), except for the Chinese tea-Herbal tea comparison at the medium thick level (Cohen' $d = 0.145$, small effect size).

Table 5

Results of the two-way mixed ANOVA on the viscosity of sample based on the Manufacturer's guideline

Source	*df*	*F*	*p*	Partial Eta squared
Interaction				
Drink base x Level[#]	1.267	25.978	<0.001*	0.481
Main effects				
Drink base[#]	1.267	92.951	<0.001*	0.769
Level	1	113.764	<0.001*	0.802

Note. [#]Greenhouse-Geisser correction implemented. *significant at 0.05 level.

Level = Consistency level.

Table 6

Results of post-hoc pairwise comparisons on viscosity of samples prepared using the manufacturer's guideline from the different drink bases at different consistency levels

Comparison	*t*	*p*	Cohen's *d*
At mildly thick consistency level			
Milk-tea vs Chinese tea	7.837	<0.001*	2.962
Milk-tea vs Herbal tea	5.928	<0.001*	2.241
Chinese tea vs Herbal tea	-2.353	0.034	0.889
At medium thick consistency level			
Milk-tea vs Chinese tea	7.984	<0.001*	3.018
Milk-tea vs Herbal tea	8.385	<0.001*	3.169
Chinese tea vs Herbal tea	0.385	0.706	0.145
Milk-tea Mildly thick vs Medium thick	-9.156	< 0.001*	3.461
Chinese tea Mildly thick vs Medium thick	-7.841	< 0.001*	2.964
Herbal tea Mildly thick vs Medium thick	-7.172	<0.001*	2.711

Note. *significant at 0.0056 (0.05/9) level.

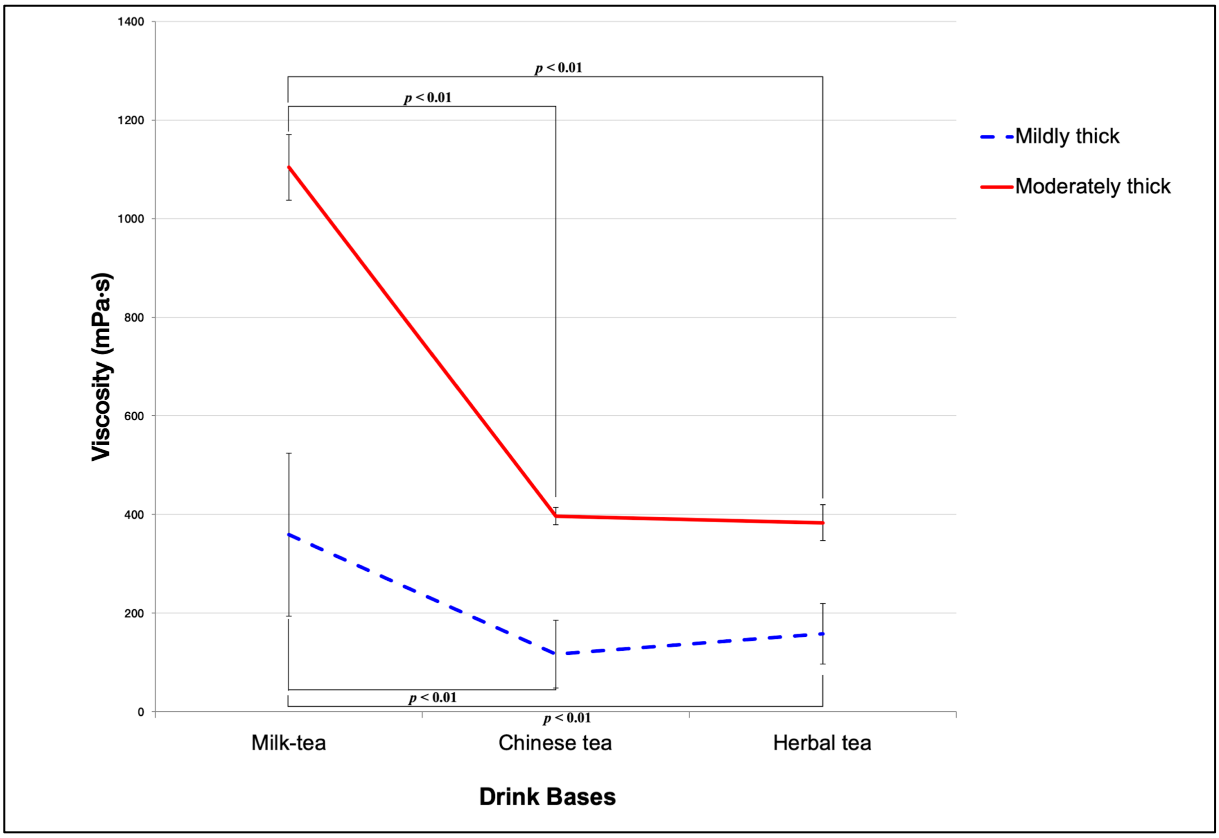

Figure 1. Mean viscosity of samples prepared using the manufacturer's guideline showing interaction between Drink base and Consistency level. Error bars represent 95% confidence interval.

Main effects of Drink base and Consistency level. Significant main effect of Drink base was found (F(1.267, 35.464) = 92.951, p < 0.001), with a large effect size (partial Eta squared = 0.769) (Table 5). Post-hoc pairwise comparisons showed that Milk-tea samples (M = 731.492mPa·s, SD = 450.738) were significantly more viscous than samples prepared from the other two drink bases (p < 0.001). (see Table 7). Significant main effect of Consistency level was found with a large effect size (F(1, 35.464) = 113.762, p < 0.001, partial Eta squared = 0.802). The viscosities of medium thick samples (M = 627.935mPa·s, SD = 400.388) were higher than the mildly thick samples (M = 211.314mPa·s, SD = 137.391) (see Table 4).

Table 7

Results of post-hoc pairwise comparisons among different drink bases thickened based on the Manufacturer's guideline

Comparison	Mean difference	p
Milk-tea vs Chinese tea	474.761	<0.001*
Milk-tea vs Herbal tea	460.842	<0.001*
Chinese tea vs Herbal tea	13.919	1.000

Note. *significant at 0.016 (0.05/3) level.

Both the Manufacturer's and IDDSI-driven guideline (Specific aim #2)

From the Mauchly's tests of sphericity, both Drink base ($\chi^2(2) = 22.174$, $p < 0.001$) and interaction between Guideline and Drink base ($\chi^2(2) = 18.746$, $p < 0.001$) showed statistical significance. Greenhouse-Geisser correction was adopted for the mixed ANOVA.

Interactions among Guideline, Drink base and Consistency level. The only significant interaction was found between the independent variables Drink base and Consistency level ($F = 24.301(1.282, 35.895)$, $p < 0.001$) (Table 8 and Figure 2 for interaction plot). Effect sizes of the three-way and two-way interactions were considered small (partial Eta squared ≤ 0.055), except for the interaction between Drink base and Consistency level (partial eta squared = 0.465, large effect size). Simple effects were examined by conducting multiple pairwise comparisons among the three drink bases within the same consistency level and the results are summarized in Table 9. Effect sizes of the pairwise comparisons were considered large (Cohen's $d \geq 1.882$), except for the Chinese tea-Herbal tea comparisons at the mildly thick consistency level (Cohen's $d = 0.761$, medium effect size) and at the moderately thick consistency level (Cohen's $d = 0.320$, small effect size).

Table 8

Results of the three-way mixed ANOVA on the viscosity measure

Source	*df*	*F*	*p*	Partial Eta squared
Three-way interaction				
Guideline x Drink base x Level#	1.333	0.986	0.351	0.034
Two-way interactions				
Guideline x Drink base#	1.333	1.628	0.213	0.055
Guideline x Level#	1.000	0.313	0.580	0.011
Drink base x Level#	1.282	24.301	<0.001*	0.465
Main effects				
Guideline#	1.000	35.137	<0.001*	0.557
Drink base#	1.282	120.353	<0.001*	0.811
Level	1.000	128.644	<0.001*	0.821

Note. #Greenhouse-Geisser correction implemented. *significant at 0.05 level.

Level = Consistency level.

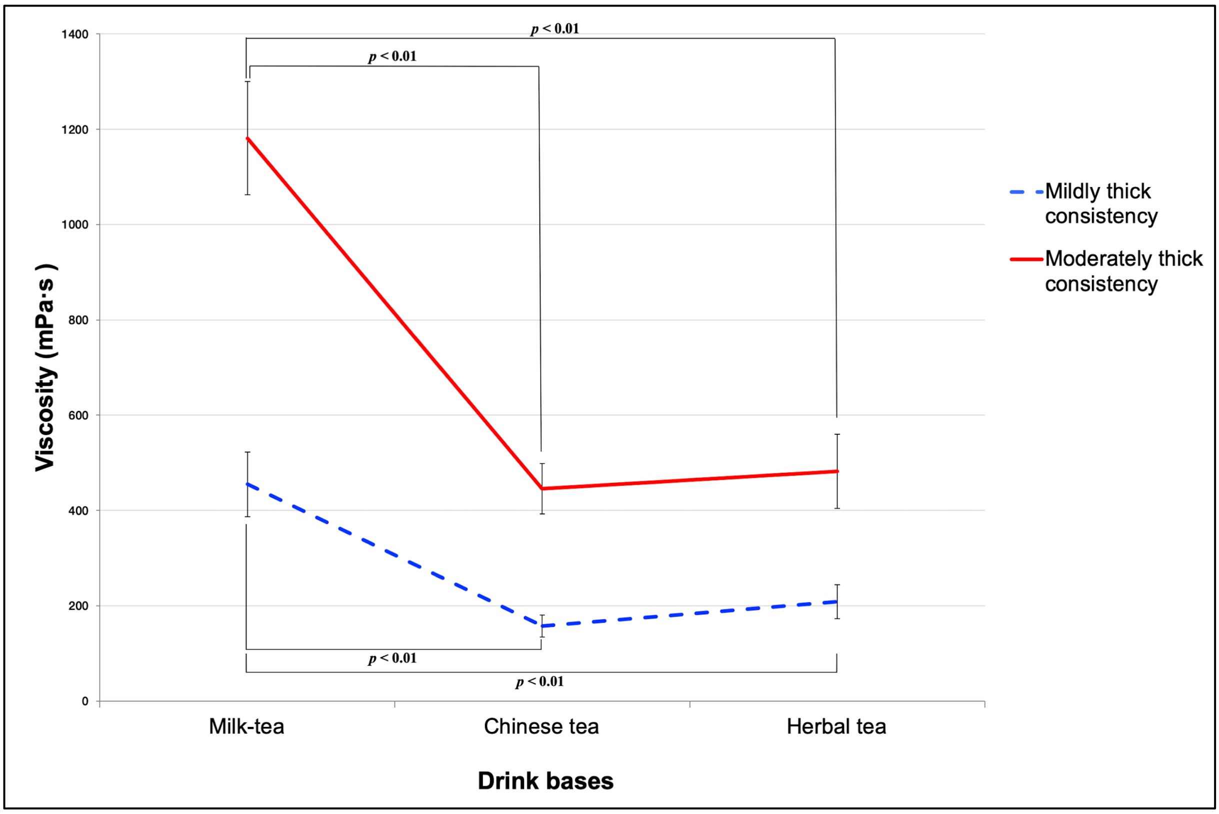

Figure 2. Mean viscosity of samples prepared from different drink bases showing interaction between Drink base and Consistency level. Error bars represent 95% confidence interval.

Table 9

Results of post-hoc pairwise comparisons on viscosity of samples prepared using both guidelines from different drink bases at different consistency levels

Comparison	*t*	*p*	Cohen's *d*
At mildly thick consistency level			
Milk-tea vs Chinese tea	10.025	<0.001*	2.633
Milk-tea vs Herbal tea	7.165	<0.001*	1.882
Chinese tea vs Herbal tea	-2.899	0.007*	0.761
At moderately thick consistency level			
Milk-tea vs Chinese tea	12.186	<0.001*	3.206
Milk-tea vs Herbal tea	10.224	<0.001*	2.685
Chinese tea vs Herbal tea	-1.218	0.233	0.320

Note. *significant at 0.0083 (0.05/6) level.

Within the same consistency level, Milk-tea samples were significantly more viscous than the other two drink bases ($p < 0.001$). A similar pattern was also found at the moderately/medium thick consistency ($p < 0.001$). The viscosities of the Chinese tea and Herbal tea samples were also significantly different at the mildly thick consistency level (t(29) = -2.899, $p = 0.007$), but not at the moderately/medium thick consistency level ($t(29) = -1.218$, $p = 0.233$).

Main effect of Guideline. The main effect of guideline was significant ($F(1, 28) = 35.137$, $p < 0.001$), with a large effect size (partial Eta squared = 0.557). The viscosity of samples prepared using the Manufacturer's guideline (M = 419.624mPa·s, SD = 363.961) was significantly lower than that prepared using the IDDSI-driven guideline (M = 556.689mPa·s, SD = 399.090) (see

Table 4). Figure 3 illustrates the viscosities of samples prepared based on the two guidelines. It was found that the viscosities of samples prepared using the IDDSI-driven guideline were consistently higher than those prepared using the manufacturer's guideline across different drink bases and consistency levels.

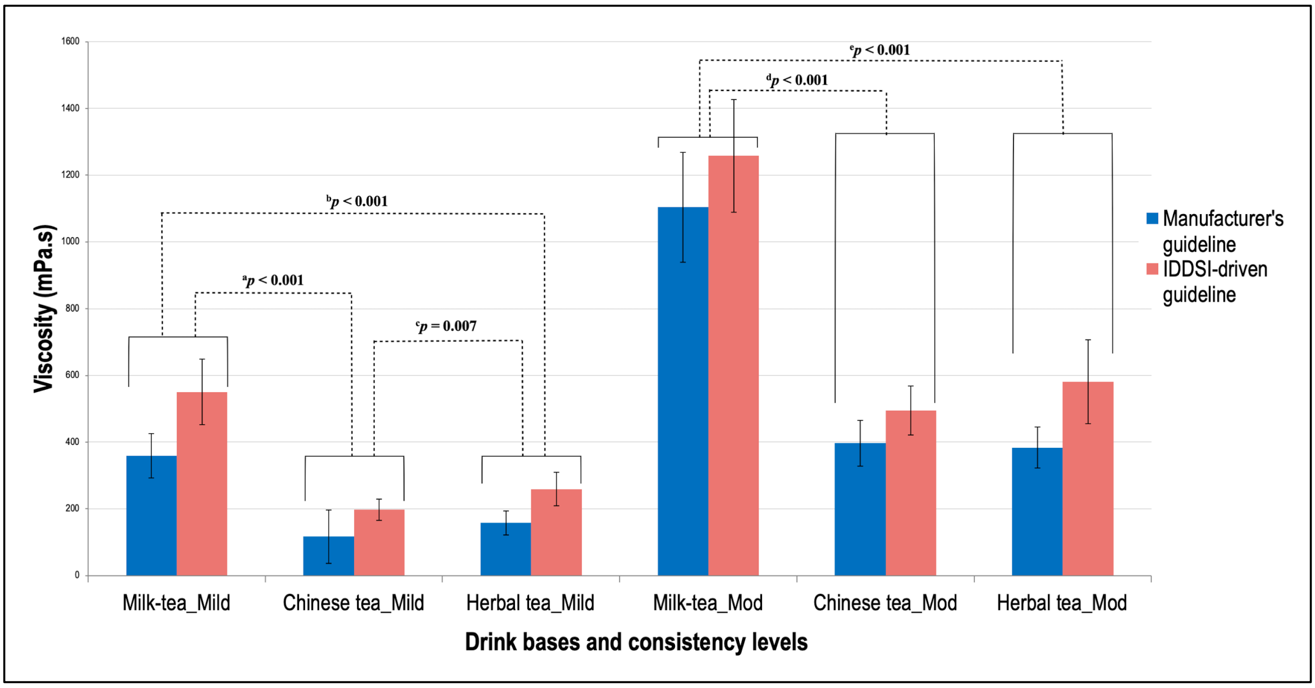

Figure 3. Mean viscosity of samples prepared using the two guidelines from different drink bases and at different consistency levels. Error bars represent 95% confidence interval.

Note. Comparisons between [a]Milk-tea and Chinese tea at mildly thick consistency level, [b]Milk-tea and Herbal tea at mildly-thick consistency level, [c]Chinese tea and Herbal tea at mildly-thick consistency level, [d]Milk-tea and Chinese tea at moderately thick consistency level, and [e]Milk-tea and Herbal tea at mildly-thick consistency level.

Main effect of Drink base. Significant main effect was found in the independent variable Drink base (F(1.282, 35.895) = 120.353, $p < 0.001$), with a large effect size (partial Eta squared = 0.811) (Table 9). When compared within the same consistency level, samples prepared from Milk-tea were consistently more viscous than samples prepared from the other two drink bases, regardless of the guideline being used (Table 9 and Figure 3). The differences between Milk-tea and Chinese tea, and Milk-tea and Herbal tea increased as the target consistency level increases (i.e. from Mildly thick to Moderately/medium thick). Results of Post hoc pairwise comparisons are summarized in Table 10. It was found that the viscosities of samples prepared from the three drink bases were significantly different from one another ($p \leq 0.014$). The mean viscosity of the Milk-tea samples was notably higher than the other two drink bases, even at the same consistency level and when prepared using the same guideline. For example, when using Manufacturer's guideline at the medium thick level, the mean viscosity of Milk-tea samples was 1258.356mPa·s (SD = 333.794), whereas that of Chinese tea samples and Herbal tea samples were 494.176mPa·s (SD = 145.707) and 581.280 mPa·s (SD = 249.777) respectively. Comparisons between Milk-tea and the other two drink bases showed large effect sizes (Cohen's $d \geq 2.582$) and that between Chinese tea and Herbal tea showed a medium effect size (Cohen's $d = 0.666$).

Table 10

Results of post-hoc pairwise comparisons among the three drink bases.

Comparison between drink bases	t	p	Cohen's d
Milk-tea vs Chinese tea	11.599	< 0.001*	3.046
Milk-tea vs Herbal tea	9.831	< 0.001*	2.582
Chinese tea vs Herbal tea	-2.534	0.014*	0.666

Note. *significant at 0.0167 (0.05/3) level.

Main effect of Consistency level. Viscosity of thickened liquid samples prepared at moderately/medium thick consistency level were significantly higher than that prepared at the mildly thick consistency level with a large effect size ($F(1, 28) = 128.644$, $p < 0.001$, partial

Eta squired = 0.821) (Table 8). It is noteworthy that despite targeted at the mildly thick consistency, the Milk-tea samples (M = 550.080mPa·s, SD = 194.197) prepared using the IDDSI-driven guideline were more viscous than the Chinese tea samples (M = 494.176mPa·s, SD = 145.707) and comparable to the Herbal tea samples (M = 581.280mPa·s, SD = 249.777) targeted at the moderately thick consistency based on the same preparation guideline. (see Table 4 and Figure 3).

Discussion

Liquid thickening based on the Manufacturer's guideline (Specific aim #1)

The Manufacturer's guideline resulted in significantly different viscosities between the mildly thick and medium thick consistency levels. In consideration of individual drink bases, all the medium thick samples were significantly more viscous than the mildly thick samples for all three drink bases. This was also confirmed by the significant main effect of Consistency level in the two-way ANOVA, and the large effect sizes of the above comparisons suggested strong relationships between the targeted consistency levels and viscosities of the thickened liquid samples. The Manufacturer's guideline and the framework upon which it was based would result in distinguishable consistencies, and thus may be adopted to make recommendations to patients with dysphagia who require different levels of liquid thickening. Nevertheless, to ensure that the existing Manufacturer's guideline would result in liquid consistency that is comparable to the intended consistency prescribed, viscosity of the samples thickened from the three drink bases should be compared with that of samples thickened from water, the drink base that is being used for thickening guideline developments and swallowing assessments.

Another finding that is relevant to the Manufacturer's guideline lies in the significant interaction effect between Drink base and Consistency level, and the main effect of Drink base. The extent of across-consistency level difference was considerably greater in Milk-tea samples (744.971mPa·s), when compared to Chinese tea (279.680mPa·s) and Herbal tea (225.212mPa·s) samples. Milk-tea samples were significantly more viscous than the samples prepared from the other two drink bases, with large effect sizes. The between-drink base difference was exacerbated as the target consistency level increased from mildly thick to medium thick in terms of both mean viscosities and effect sizes. Although the differences between Chinese tea and Herbal tea did not reach statistical significance, one should note the large effect size in the Chinese tea-Herbal tea comparison at the mildly thick consistency level (Cohen's d = 0.889, Table 10). These findings suggest that Drink base plays a part in the viscosity of the resultant samples. This echoes with findings from previous studies conducted on different beverages (e.g. [22, 23, 28]).

Milk-tea used in the present study contains a number of ingredients (see Table 2). There are a number of dairy compositions including milk, evaporated milk and creamer. It had been reported that fat, protein and lactose content in milk would react with the thickener and give rise to an increased viscosity. Thus a longer time to establish equilibrium viscosity is required [29, 30]. Furthermore, solids content of drink bases would also increase viscosity after thickening [31]. These may account for the significantly higher viscosity of thickened milk-tea and should be taken into consideration when patients with dysphagia are to consume thickened milk-tea and other non-water beverages.

In the present study, samples were thickened according to the guideline and instructions provided by the manufacturer to patients and/or caregivers. From the information that is available to the patients and/or caregivers, the thickener is applicable to both "hot or cold liquid", and no emphasis has been made on the potential effect of drink base in the guideline provided [25]. Patients and/or caregiver who are unaware of this effect may prepare thickened liquid samples that deviate from the prescribed consistencies, despite having added the instructed amount of thickener. It is well established that liquid that are thicker or thinner than the intended consistency may give rise to major swallowing safety issues. For instance, liquid with increased viscosity may require extra strength in tongue propulsion and/or pharyngeal squeeze. Residue may result in dysphagic patients with reduced muscle strength and aspiration/penetration risks may be increased [6, 7]. Therefore, the present guideline provided by the manufacturer may pose potential threats to swallowing safety.

Comparisons between the Manufacturer's guideline and IDDSI-driven guideline (Specific aim #2)

Samples prepared using the IDDSI-driven guideline were consistently more viscous than those prepared using the Manufacturer's guideline in different drink bases and at different consistency levels. This was not beyond expectation as the amount of thickener added is slightly greater for both consistency levels being investigated. The difference between the two guidelines is substantiated by the significant main effect of Guideline in the three-way ANOVA and its large effect size. Despite that the two frameworks share very similar terminologies, especially in Chinese, viscosity of liquid samples could be significantly different if different guidelines are based upon. This is highly relevant to swallowing safety in the dysphagic population, and thus, if transition to the IDDSI framework in the Hong Kong context are to be implemented, adequate education and training have to be provided to all stakeholders involved in dysphagia management.

The interaction between Drink base and Consistency level was significant and the two independent variables exhibited a similar pattern as in the Manufacturer's guideline-only analyses. When collectively looking at the samples prepared from both guidelines (i.e. the main effect of Consistency level), the viscosity was significantly higher at the moderately/medium thick consistency level than it was at the mildly thick consistency level. This implies that the two guidelines were capable of bringing about distinguishable across-level viscosities in thickened liquids. Nevertheless, the samples have to be compared with the viscosities prepared from water before the above observations could be confirmed.

Similar to the Manufacturer's guideline, significant main effect of Drink base with a large effect size was found when the IDDSI-guideline was also taken into account. The three drink bases resulted in viscosities that are significantly different from each other, with an at least medium effect size (Table 10). At mildly thick consistency level, samples prepared from the three drink bases were significantly different from each other with medium to large effect sizes. The only comparable viscosity was found between Chinese tea and Herbal tea at the moderately/medium thick consistency level (see Table 9). Variations in composition across drink bases should explain for the above differences.

An interesting finding was obtained from the samples prepared using the IDDSI-driven guideline. The viscosities of the Milk-tea samples were unexpectedly high, such that the mildly thickened Milk-tea samples were more viscous than the moderately thickened Chinese tea and comparable to the moderately thickened Herbal tea samples, despite more thickener had been added to the later. Such overlapping of viscosities would, apparently, negatively impact swallowing safety.

The IDDSI-driven guideline was developed on the basis of the IDDSI framework and testified against it [15]. However, even with this recently developed liquid thickening guideline and experimentally controlled procedures and conditions, significant differences in viscosity still exist across drink bases. This suggests that transitioning to another framework and guideline may not be sufficient to enhance swallowing safety, especially when thickening liquids other than water. This is in line with an earlier study on applying the IDDSI-driven guideline to the non-water beverages [22]. The importance of pre-serving testing; for instance, the IDDSI flow test; should be emphasized in the education for clinician, patients and/or caregivers [20, 19].

Limitations of the present study

In the present study, viscosities of thickened liquids were not compared with water, the drink base from which the two guidelines were developed [25, 15]. Clinically, recommendations and prescriptions on liquid thickening by speech therapists are usually made on the basis of water. Directly comparing viscosities of the thickened liquids with that of thickened water would shed lights on the deviance of the resultant consistencies, with regard to the prescribed consistency. This would help researchers, clinicians, patients and/or caregivers evaluate the applicability of different guidelines in a more comprehensive manner. Secondly, when preparing samples for rheological testing, the mixing time and the time allowed for the thickened sample to set were not precisely controlled. These factors would, nevertheless, affect the resultant viscosity of the thickened liquid especially when starch-based thickener is adopted [10]. To eliminate the possibility of viscosity discrepancy due to difference in sample preparation, it is suggested to standardize the duration and method of mixing, as well as the duration between the samples are mixed and the undergoing of rheological measurements. Furthermore, the effect of saliva was not investigated in the present study. There are evidence showing amylase in human saliva would significantly reduce viscosity of thickened liquids, especially if starch-based thickeners are used [16-18]. The present study may be replicated by incorporating amylase, through incubation of human saliva, as one of the independent variables. The enzymatic effect may reduce the discrepancies in viscosity of the starch-thickened liquids.

Conclusion

The existing guideline provided by the manufacturer of one of the commonly used thickener products is considered inadequate in ensuring swallowing safety. The effect of drink base should always be emphasized to patients and caregivers when thickening non-water beverages. Referencing rheological values (e.g. viscosity in mPa·s) for different consistencies and the amount of thickener required for different beverages to achieve the corresponding consistencies may be provided by manufacturers. The elimination of the drink base effect is not expected even if an IDDSI-driven thickening guideline is adopted. Pre-serving tests should, therefore, always be available and encouraged to confirm if the consistency of the thickened liquid matches with the prescribed and desired consistency. Besides, the guidelines developed from the Hong Kong Local framework and IDDSI framework gave rise to different viscosities in different drink bases, especially the non-water ones. To avoid potential confusions when implementing the IDDSI framework in the Hong Kong context, all parties involved in dysphagia management should be well aware of the discrepancies in resultant consistency. Measures should also be taken to avoid such confusions and the associated threats imposed on swallowing safety.

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