

Zhong Lei (Orcid ID: 0000-0003-2585-9658)

Sensory discrimination of the viscosity of thickened liquids for dysphagia management

Lei Zhong¹, Enrico K. Hadde², Zeguang Zhou¹, Yao Xia¹, Jianshe Chen^{2*}

¹ School of Chemistry and Chemical Engineering, Guangxi Key Laboratory Cultivation Base for Polysaccharide Materials and Modifications, Guangxi University for Nationalities, Nanning, Guangxi, 530006, China

² School of Food Science and Biotechnology, Zhejiang Gongshang University, Hangzhou, Zhejiang, 310018, China

ABSTRACT

Thickened water and thickened milk are frequently used in dysphagia management. However, there is still lack of information regarding the correlation between their measured viscosity and sensory viscosity. In this work, the relationship was investigated by rheological measurements and a series of tactile sensory tests. Both magnitude estimation and triangle protocols were used for the evaluation. The rheological data indicated that both thickened water and thickened milk were shear thinning, but the shear viscosity of thickened milk was obviously higher than that of thickened water for the same amount of thickeners. For the participants considered, the perception of thickened water and thickened milk both obeyed the Stevens' power law according to the results of magnitude estimation. It was found in the triangle assessments that within the proposed nectar- and honey-thick viscosity ranges, participants were able to correctly discriminate a 0.83-fold and a 1.05-fold increase in shear viscosity for thickened water and thickened milk,

This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: [10.1111/joss.12464](https://doi.org/10.1111/joss.12464)

respectively. Results of both magnitude estimation and triangle tests suggested that human abilities in detecting the viscosity changes of thickened water and thickened milk by finger tactile sensory were similar within nectar- and honey- thick viscosity range in spite of their different compositions and rheological properties.

PRACTICAL APPLICATIONS

Thickened water and thickened milk are commonly used in the management of individuals with dysphagia to improve their quality of life. However, it is difficult to determine the optimal thickening degree in clinical practice because there is a lack of information of the perception of their rheological properties. To investigate the human sensory ability in detecting viscosity differences of thickened water and thickened milk is essential to improve our understanding of the perception of thickened liquids. Moreover, it provides significant information for manufacturing high quality thickened liquids products and for setting guidelines for effectively preparing and serving thickened liquids to individuals with dysphagia.

Key words: thickened liquids, sensory discrimination, rheology, dysphagia

1. INTRODUCTION

Dysphagia refers to the medical condition of having difficulty in swallowing. It can result from diseases such as stroke, Alzheimer's disease, Parkinson's disease and cancer, etc.(Clavé & Shaker, 2015). Dysphagia can significantly reduce the quality of life. Individuals experiencing dysphagia usually suffer from dehydration and malnutrition(Kaiser, Bandinelli, & Lunenfeld, 2010).

Furthermore, serious respiratory problems caused by dysphagia like aspiration pneumonia can even lead to death(Althaus, 2002; Atherton, Bellis-Smith, Cichero, & Suter, 2007; Kikawada, Iwamoto, & Takasaki, 2005). In recent years, dysphagia has emerged as an important health issue around the world(Cichero et al., 2017; Ney, Weiss, &Kind, 2009). It can affect individuals across all ages, especially the elderly population due to their weakened physical conditions and chronic illness.

A variety of ways have been developed to treat dysphagia, including postural adjustment, swallow maneuvers and diet modifications(Crary, Sura, Madhavan, & Carnaby-Mann, 2012). Among them, the provision of thickened liquids is considered as a cornerstone in dysphagia management. It becomes one of the most recommended treatments in hospitals and long-term care facilities(Atherton, Bellis-Smith, Cichero, & Suter, 2007; Chambers, Jenkins, & Garcia, 2017; Cichero & Lam, 2014; Mills, 2008). Since the boluses of thickened liquids have a longer transit time, it allows better oral and pharyngeal control during the swallowing, which can effectively help to avoid swallow complication (Mackley et al., 2013; Reimers-Neils, Logemann, & Larson, 1994).

Although thickened liquids are widely used in clinical practice, it is difficult to determine the optimal thickening degree for patients(Glassburn & Deem, 1998; Kim, Hwang, Song, & Lee, 2017). In the National Dysphagia Diet (NDD), a dysphagia guidelines established by the American Dietetic Association in 2002 (McCallum, 2003; National Dysphagia Diet Force, 2002), thickened liquids are categorized into three levels of modifications to thin liquids according to their shear

viscosity, as shown in Table 1. However, the NDD guidelines are based on consensus, the viscosity range of each level is quite large and whether these viscosity ranges have clinical benefit has not yet been clearly proved. The sensory of viscosity differences of thickened liquids is thought to be closely related to the oral processing and swallowing process. Therefore, in order to determine the optimal thickening degree for dysphagia management, it is significant to investigate the relationship between the instrumental measured viscosities and the perceived viscosities, and find out the human sensory abilities in detecting viscosity differences.

To date, there are only a few studies about the viscosity perception of thickened liquids. Christensen used magnitude estimation (ME) techniques to investigate the perceived viscosities of aqueous solutions thickened with sodium carboxymethyl cellulose(Christensen, 1979). It was found that the relation between a perceived viscosity and a measured viscosity can be adequately described by the power law equation. The power law exponent was 0.34, 0.38 and 0.39, respectively. Smith et al. also used magnitude estimation to explore the oral perception of corn-syrup solutions, the measured viscosities ranged from 3-2409 mPa.s at 21°C, the power law exponent obtained was 0.33, which was close to the results of Christensen(Smith, Logemann, Burghardt, Carrell, & Zecker, 1997). More recently, Steele et al. used the triangle test paradigm to evaluate the capabilities of healthy adults in detecting the viscosity differences of thickened liquids(Steele, James, Hori, Polacco, & Yee, 2014). The viscosity ranged from 190mPa.s to 380mPa.s, which was much narrower than those in Smith's study. The results showed that participants were able to detect a 0.67-fold increase in apparent viscosity at 50s⁻¹. Lv et al

compared the human capability in perceiving the shear and extensional viscosity of thickened liquids(Lv, Chen, & Holmes, 2017). The sensory thresholds obtained for shear viscosity and extensional viscosity were 9.33% and 6.20%, respectively.

This work aims to investigate individual ability in discriminating viscosity difference of thickened water and thickened milk, two typical thickened liquids currently used in dysphagia management. Previous studies have focused on their different rheological properties due to the compositions(Hadde, Nicholson, Cichero, & Deblauwe, 2015). But it is still lack of information of human sensory of their rheological properties. Therefore, it is worthwhile to conduct a study from both rheology and sensory aspects. To conduct a more comprehensive test than previous works, both ME and triangle protocols were implemented for sensory assessment. Although our ultimate goal is to explore the mechanism of oral sensory, we use finger tactile tests as a first stage study. Finger tactile test is one of the non-oral methods to perceive the viscosity of liquids. Participants may perceive the viscosity according to the shear force, shear rate and flow resistance. The process of finger tactile test is similar to that of oral tactile tests. During the tests, participants use touch-pressure mechanoreceptors to detect the flow resistance and the flow rate, and use intramuscular receptors to detect the force to move the liquids. Christensen and Casper used finger tests to measure the perception of viscosity of thickened water and compared the results with oral tests, they found out the relation between instrumental and sensory measurement of thickened water obtained by these two different methods were similar, and the thickened water were perceived more viscous in oral tests than in finger tests(Christensen, & Casper, 1987). Recently,

Aktar et al. investigated the capacity of viscosity discrimination of golden syrup by applying both finger and oral tests, the results showed that the viscosity discrimination threshold obtained by finger tests was higher than oral tests (Aktar, Chen, Ettelaie, & Holmes, 2015). Although there are differences that exist in these two sensory methods, finger tests can still be used as a reference for oral tests. Especially since there is still lack of knowledge about the effects of saliva on the oral evaluation of viscosity of thickened liquids, applying finger tests can avoid the complications due to the involvement of saliva. More recently, Lv et al. used finger tests to compare the human capability in the perception of extensional and shear viscosity of water thickened by guar gum and sodium carboxyl methylcellulose (Lv, Chen, & Holmes, 2017). The objectives of this study are to answer the following questions:

- (1) What are the relation between the perceived viscosity and measured viscosity of thickened water and thickened milk by applying finger tactile tests using ME?
- (2) What are the human sensory abilities in detecting shear viscosity difference of thickened water and thickened milk by applying finger tactile tests using triangle test protocols?
- (3) Are there any big differences in viscosity discrimination between thickened water and thickened milk in finger tactile tests?

2. MATERIALS AND METHODS

2.1 Materials

The liquids used were drink water and commercial long-life whole milk (Yili, Yili Industrial Group Co., Hohhot, China) purchased from local supermarket. The commercial thickener was Instant ThickTM (Flavour Creations, Brisbane, Australia). This thickener is xanthan gum based-powder, it is one of the most commonly used products for dysphagia management in Australia. All samples were prepared by slowly adding the thickener powders into the water or milk and kept stirring it with a spoon until the thickeners were completely dissolved.

2.2 Rheological Characterisation

Ten samples of thickened water and ten samples of thickened milk both ranging from 1% - 10% thickener concentration were prepared. Prior to the rheological test, the samples were allowed to stand for at least 5 minutes for water samples and 30 minutes for milk samples to reach equilibrium viscosity. It is known that the viscosity of the fluid is increased over a period of time until it reached equilibrium viscosity (Garcia et al., 2005; Hadde et al., 2015). It was shown that milk thickened with xanthan gum based thickener required more time to reach equilibrium than thickened water due to an ionic interaction between calcium and xanthan gum (Hadde et al., 2015). All testing was conducted at a controlled temperature of 25°C.

All rheological tests were performed on a Discovery HR-1 rheometer (TA Instruments Ltd., New Castle, U.S.). Cone and plate geometry was selected; diameter: 40 mm; angle: 2° 0' 29". A total of 0.6 ml of fluid sample was used for each test measurement. The rheometer was operated in

a strain-controlled mode where the shear rate was specified and the required torque (shear stress) was the value being measured.

Steady shear sweep tests were performed to measure the apparent shear viscosity of the fluids. The shear rate range chosen was $1 - 100 \text{ s}^{-1}$ as this corresponds to the typical values for shear rates during swallowing (Christensen, 1984; Sworn, 2009). The measurements were repeated in duplicate with different samples used and the mean of the two measures were calculated for the analysis.

2.3 Sensory evaluation

Both ME and triangle test were participated by the same participants (35 subjects, mean age=20, Female=20, Male=15). Each participant performed the ME and triangle tests in two separate sessions. 17 of them performed ME tests as the first session and triangle test as the second session, 18 of them performed in a reverse sequence. Each session was arranged at 3:00 pm -5:00 pm in two different days. All of the participants were students selected from Guangxi University for Nationalities. They are nonsmokers, of normal body weight and without any known skin diseases.

For all the participants, before they performed the session of ME or triangle tests, a brief introduction was made to help them to learn about the procedures. No extra introductions were given during the tests. When conducting the test, a small volume (about 0.1 mL) of thickened liquids were loaded onto the participant's index fingertip for sampling. Then the participant was instructed to sense the liquid by pressing and moving index finger and thumb in a circle, either

clockwise or anti-clockwise. The moving speed was about one circle per second. The participant was asked to appraise the thickness and gave the answer in 2-3 seconds. For all tests, participants were blindfolded by a mask to avoid the effects of appearance of thickened liquids. Their fingers were cleaned with room temperature water and dried with tissue paper for each sampling. All the stimuli of thickened liquids were prepared according to their shear viscosities at 50s^{-1} .

2.3.1 Magnitude estimation

ME tests were performed following the procedures similar to Lv's study(Lv, Chen, & Holmes, 2017). Samples were prepared and served at room temperature. Participants were assigned to make a pairwise comparison of samples, one of them was the reference which had the lowest viscosity. After the tactile sensory, participant was asked to give a number to the viscosity magnitude of the sample in proportion to the reference. The number should be positive, both whole numbers and decimals were allowed. Samples were randomized by three-digits number and served in a random order. Then a well-known relation called Stevens' power law can be established by correlating the viscosity measured by rheometer and the perceived viscosity(Stevens, 1957; Stevens, 1960). Here the Stevens' power law can be described as Eq. 1:

$$S(\mu)=k\mu^n \quad (1)$$

where μ is the measured viscosity, $S(\mu)$ is the perceived viscosity, k is a proportional constant, n is the power law index that can be calculated by fitting the equation with measured data. n can be the indication of human sensitivity to the stimuli. In general, $n<1$ indicates human have less

sensitivity than the corresponding instrumental measurement to the stimuli, $n>1$ indicates human have greater sensitivity than the corresponding instrumental measurement to the stimuli (Chen, 2014).

2.3.2 Triangle test

Triangle tests were carried out according to ISO 4120 (International Organization for Standardization, 2004). To ensure the test can confirm that statistically significant difference exists in tactile sensory of thickened liquids, 35 participants were chosen to satisfy $\alpha=0.01$, $\beta=0.05$ and $p_d=50\%$. Five viscosity levels (labeled as A, B, C, D and E) of the stimuli were prepared. Then these stimuli were arranged by sets. Each set contained three cups of samples, one of them was different, either thicker or thinner, from the other two samples in the set. The cup contained this different sample was random. The sample viscosity difference for each set was randomly assigned by nine pairwise of viscosity level combinations (A-B, A-C, A-D, A-E, B-C, B-D, B-E, C-D and D-E). During the test, participants were asked to assess all three samples in turn for each set following the procedures mentioned above in sensory evaluation section (section 2.3). After the sampling, they were asked to point out which sample had the different viscosity. If the participants felt too difficult to tell the difference, they were asked to make their choice with their best guess. The responses of the participants were collected, and in order to evaluate the sensitivity of viscosity for each participant, a mean apparent viscosity discrimination acuity (MAVDA) score was calculated following the procedures introduced in Steele's work (Steele,

James, Hori, Polacco, & Yee, 2014). For each participant, higher MAVDA scores means less sensitive to the viscosity changes.

2.3.3 Statistical analysis

To determine whether the participants in triangle tests were able to discriminate the thickness difference between thickened liquids samples, the number of correct responses were calculated and then analyzed by the “Minimum number of correct responses needed to conclude that a perceptible difference exists based on a triangle test” table in ISO 4120 (International Organization for Standardization, 2004).

Furthermore, an independent t-test was carried out to explore whether females and males showed significantly different performance in their viscosity discrimination tests according to the MAVDA scores. The analysis was conducted by using Microsoft Office Excel.

3 RESULTS AND DISCUSSION

3.1 Shear rheological behaviors

Figure 1 and Figure 2 show the shear viscosity profile of thickened water and thickened milk respectively. It can be seen that all the fluids tested exhibited a shear-thinning behaviour.

Additionally, the shear viscosity of both fluids increased as the concentration of the thickener is increased.

For the same concentration of thickener, it can be seen that the shear viscosity of thickened milk is generally higher than thickened water. This suggests that the rheological behaviour of thickened fluid is highly dependent on the dispersing media. Individuals preparing thickened milk should be aware that less thickener than that recommended for water is required to achieve correct consistency. This result supports Hadde's work (Hadde et al., 2015) which showed that the shear viscosity was highly dependent on the dispersing media.

In order to conduct the sensory test within the similar viscosity range, different concentrations were chosen for thickened water and thickened milk when preparing the sensory samples. Concentrations of 3.00%, 4.00%, 5.00%, 6.00% and 7.00% were selected for thickened water and concentrations of 1.45%, 1.65%, 2.04%, 2.16% and 2.33% were selected for thickened milk.

3.2 Magnitude estimation

Both tests were conducted within nectar-thick and honey-thick ranges of National Dysphagia Diet(NDD). It is possible that human discrimination of viscosity changes can be varied for different viscosity range. Nectar-thick and honey-thick are often recommended as the effective thickness in dysphagia diets. Therefore, our sensory tests were also performed within this viscosity range to match with the viscosity in clinical practices.

. For thickened water, the viscosities were 299mPas, 370mPas, 507mPas, 547mPas, 605mPas, respectively. For thickened milk, the viscosities were 181mPas, 234mPas, 340mPas, 399mPas, 480mPas, respectively. All these viscosities were obtained at the shear rate of 50s^{-1} as suggested

by NDD.

The results were shown in Fig.3 and Fig.4. It can be seen that data from both thickened water and thickened milk fit well with the Stevens' power law. The power law index n was 0.63 for thickened water and 0.46 for thickened milk, respectively. Both of them were lower than 1. It indicates human tactile sensory was less sensitive than rheometer to viscosity changes within nectar-thick and honey-thick range. It is worth noting that the values of power index n were higher than the results obtained by Christensen's and Smith's oral sensory tests(Christensen, 1979; Smith et al., 1997), the reason might be that in tactile test, thickened liquids were directly put on the finger tip without mixing with saliva which might reduce the viscosity of the mixtures. Moreover, the n value of thickened milk was lower than n of thickened water in the tests. It has been reported that ME values were lower at lower viscosity ranges (Christensen, 1979). The viscosity range of thickened milk is slightly lower than thickened water in our measurements, therefore, ME values of thickened milk and thickened water obtained should be close. This suggests that the human tactile sensory discrimination ability for viscosity changes of thickened water and thickened milk are similar, even though they have different compositions and rheological properties.

3.3 Triangle test

3.3.1 Triangle test for thickened water

Thickened water were labeled as A, B, C, D and E, their viscosities were 299mPas, 370mPas, 507mPas, 547mPas, 605mPas, respectively. Table 2 and Figure 5 show the relationship between

the frequency of correct response and the magnitude of shear viscosity difference. It can be observed that generally larger viscosity differences led to greater accuracy in the discrimination. When the magnitude of shear viscosity difference was 1.83-fold, 26 participants correctly identified the odd sample, the percentage of correct responses was 74.29%. According to the “Minimum number of correct responses needed to conclude that a perceptible difference exists based on a triangle test” table in ISO 4120, 19 correct responses is sufficient to conclude that the two thickness levels of thickened water are perceptibly different. Therefore, for thickened water, it is evident that the difference of tactile perception is apparent when there is a 0.83-fold increase in the shear viscosity. It is important to mention that the value obtained might be valid only within the specific viscosity range we used. This magnitude value is quite close to the result previously reported by Steele et al of oral discrimination tests((Steele, James, Hori, Polacco, & Yee, 2014), which was 1.67-fold.

Table 3 summarized the mean score and standard deviation of females and males. According to the result of t-test, $p=0.19$, indicating there is no significant difference found in the ability of viscosity discrimination of thickened water between females and males, which is also in good agreement with previous studies((Steele, James, Hori, Polacco, & Yee, 2014).

3.3.2 Triangle test for thickened milk

Thickened milk were labeled as A, B, C, D and E, their viscosities were 181mPas, 234mPas, 340mPas, 399mPas, 480mPas, respectively. As shown in Table 4 and Figure 6, the relation of

correct responses and shear viscosity difference for thickened milk is similar to that for thickened water. And when the magnitude value was 2.05, the correct responses was 20, the percentage of correct responses was 57.14%. As mentioned in section 3.3.1, 19 correct responses can sufficiently confirm that the perceptible difference exists in two thickness levels of thickened milk. Therefore, it is evident that when increasing a 1.05 fold in shear viscosity, the thickened milk was perceptibly different in tactile tests. This magnitude value was close to the value obtained in thickened water test, considering it was performed in a slightly different viscosity range. It was thought that the fat content in milk reduced its friction coefficient, which might confuse the participants and make them much harder to detect the viscosity changes of thickened milk. However, the result suggests that the participants' discrimination was only associate with the viscosity changes, regardless of the different frictional properties.

Table 5 shows that females and males also performed similarly in the thickened milk sensory tests, and the result of t-test $p=0.22$ confirmed that no significant difference was found in the ability of viscosity discrimination of thickened milk between females and males.

Compared the results obtained by ME and triangle tests in this study, it is found that although the memory demands and cognitive process of ME and triangle tests might not be equivalent in this study, the results obtained by them both suggest that human have similar sensory discrimination of viscosity differences for thickened water and thickened milk. This result provides a good base for oral sensory studies. In the future work, to explore the oral sensory mechanism of thickened liquids, oral evaluation tests will be conducted by the same participants

following similar procedures, the effects of saliva on the rheological properties and the roles of milk components like fat and protein in the sensory discrimination will be investigated.

3.4 Limitations of current study

To interpret the findings of this study, it is necessary to acknowledge some limitations. First, the viscosity of thickened water and thickened milk were not perfectly matched. Originally the sensory test of thickened water and thickened milk were designed to conduct at the same viscosity range, but only a small change in the amount of thickener led to much bigger changes in the viscosities, and the viscosity was not as stable as we expected under different conditions and different periods, we ended up doing the sensory tests at two slightly different viscosity ranges. Moreover, Instant ThickTM was the only one thickener product applied in our tests and it is gum-based. It is possible that other products, especially starch-based thickeners, will lead to different results. To obtain a more comprehensive understanding, further studies with various thickeners and beverages should be conducted. Furthermore, it is lack of control of shear movements during the sensory tests. Both thickened water and thickened milk are non-Newtonian fluids, their shear viscosities are highly dependent on the shear rate. The shear rate of rheometric measurements was set at 50s^{-1} , but the actual shear rate of participants' finger movements during the tests was impossible to determine. Although all the participants were instructed to move their fingers in the same way, variations among individuals were still unavoidable. Therefore, it is important to measure the intra-rater reliability in the future studies.

4 CONCLUSIONS

Despite of the limitations, our study provides valuable information about the rheological and sensory properties of thickened water and thickened milk used in dysphagia management. Both thickened water and thickened milk were non-Newtonian liquids. By adding same amounts of thickeners, shear viscosity of thickened milk was higher than that of thickened water at the same shear rate. The tactile sensory of viscosity of both thickened water and thickened milk obeys the Stevens' law with close n values, which were 0.63 and 0.46, respectively. Our data of both ME and triangle tests suggest that the viscosity changes of thickened water and thickened milk that can be detected by healthy adults were close, and females and males have similar discrimination abilities. The magnitude of shear viscosity difference for thickened water and thickened milk that can be detected by tactile sensory were a 0.83-fold and 1.05-fold, respectively, according to triangle test protocols.

In addition, our findings also support several conclusions given by previous studies. One is that the power law index n of Stevens' law was 0.63 for thickened water and 0.46 for thickened milk, confirming that healthy adults are not as good as instrument in detecting the viscosity differences of these two types of thickened liquids within nectar- and honey-thick range. The other is that current viscosity ranges in NDD for categorizing the thickened levels might be too broad, according to our triangle test results, individual can sense more than three detectable viscosity

increments in the nectar- and honey-thick range span 50-1750mPas , narrowing down the margin might be necessary for better clinical use.

Acknowledgement

This research was supported by Guangxi Natural Science Foundation (No. 2015GXNSFAA139044), Research Funds for Universities in Guangxi (No. KY2015ZD40), and Xiangsihu Young Scholars Innovative Research Team of Guangxi University for Nationalities (2016). Thickeners for this study were provided by Flavour Creations Incorporated.

References:

- Aktar, T., Chen, J., Ettelaie, R., & Holmes, M. (2015). Evaluation of the sensory correlation between touch sensitivity and the capacity to discriminate viscosity. *Journal of Sensory Studies*, *30*, 98–107.
- Althaus, C. B. (2002). Dealing with dysphagia. *Food and Industries*, *15*(3), 58.
- Atherton, M., Bellis-Smith, N., Cichero, J. A. Y., & Suter, M. (2007). Texture-modified foods and thickened fluids as used for individuals with dysphagia: Australian standardised labels and definitions. *Nutrition and Dietetics*, *64*(SUPPL. 2), S53–S76.
- Chambers IV, E., Jenkins, A., & Garcia, J. M. (2017). Sensory texture analysis of thickened liquids during ingestion. *Journal of Texture Studies*, *48*(6), 518–529.
- Chen J. (2014). Food oral processing: Some important underpinning principles of eating and sensory perception. *Food Structure*, *1*(2), 91–105.
- Christensen, C. M. (1979). Oral perception of solution viscosity. *Journal of Texture Studies*, *10*(2), 153–164.

- Christensen, C. M. (1984). Food Texture Perception. *Advances in Food Research*, 29, 159–199.
- Christensen, C. M., & Casper, L. M. (1987). Oral and nonoral perception of solution viscosity. *Journal of Food Science*, 52, 445–447.
- Cichero, J. A. Y., Lam, P., Steele, C. M., Hanson, B., Chen, J., Dantas, R. O., ... Stanschus, S. (2017). Development of International Terminology and Definitions for Texture-Modified Foods and Thickened Fluids Used in Dysphagia Management: The IDDSI Framework. *Dysphagia*, 32(2), 293–314.
- Cichero, J. A. Y., & Lam, P. (2014). Thickened liquids for children and adults with oropharyngeal dysphagia: The complexity of rheological considerations. *Journal of Gastroenterology and Hepatology Research*, 3(5), 1073–1079.
- Clavé, P., & Shaker, R. (2015). Dysphagia: current reality and scope of the problem. *Nature Reviews. Gastroenterology & Hepatology*, 12(5), 259–270.
- Crary, M., Sura, L., Madhavan, A., & Carnaby-Mann, G. (2012). Dysphagia in the elderly: management and nutritional considerations. *Clinical Interventions in Aging*, 7, 287–298.
- Garcia, J. M., et al. (2005). Viscosity Measurements of Nectar- and Honey-thick Liquids: Product, Liquid, and Time Comparisons. *Dysphagia* 20(2), 325-335.
- Glassburn, D. L., & Deem, J. F. (1998). Thickener viscosity in dysphagia management: Variability among speech-language pathologists. *Dysphagia*, 13(4), 218–222.
- Hadde, E. K., Nicholson, T. M., Cichero, J. A. Y., & Deblauwe, C. (2015). Rheological characterisation of thickened milk components (protein, lactose and minerals). *Journal of Food Engineering*, 166, 263–267.
- International Organization for Standardization. (2004). Sensory analysis: Methodology: Triangle test. ISO 4120(2004). Geneva, Switzerland: ISO.
- Kaiser, M., Bandinelli, S., & Lunenfeld, B. (2010). Frailty and the role of nutrition in older people. A review of the current literature. *Acta Bio-Medica : Atenei Parmensis*, 81 Suppl 1, 37–45.
- Kikawada, M., Iwamoto, T., & Takasaki, M. (2005). Aspiration and infection in the elderly:

- Epidemiology, diagnosis and management. *Drugs and Aging*, 22(2), 115–130.
- Kim, H., Hwang, H. I., Song, K. W., & Lee, J. (2017). Sensory and rheological characteristics of thickened liquids differing concentrations of a xanthan gum-based thickener. *Journal of Texture Studies*, 48(6), 571–585.
- Lv, Z., Chen, J., & Holmes, M. (2017). Human capability in the perception of extensional and shear viscosity. *Journal of Texture Studies*, 48(5), 463–469.
- Mackley, M. R., Tock, C., Anthony, R., Butler, S. a., Chapman, G., & Vadillo, D. C. (2013). The rheology and processing behavior of starch and gum-based dysphagia thickeners. *Journal of Rheology*, 57(6), 1533–1553.
- McCallum, S. L. (2003). The National Dysphagia Diet: Implementation at a regional rehabilitation center and hospital system. *Journal of the American Dietetic Association*, 103(3), 381–384.
- Mills, R. H. (2008). Dysphagia management: Using Thickened liquids. *The ASHA Leader*, 13, 12–13.
- National Dysphagia Diet Task Force. National Dysphagia Diet: Standardization For Optimal Care. Chicago, IL: American Dietetic Association; 2002.
- Ney, D., Weiss, J., Kind, A., Robbins, J. (2009). Senescent Swallowing: Impact, Strategies, and Interventions. *Nutr Clin Pract*, 24(3), 395–413.
- Reimers-Neils, L., Logemann, J., & Larson, C. (1994). Viscosity effects on EMG activity in normal swallow. *Dysphagia*, 9(2), 101–106.
- Smith, C. H., Logemann, J. A., Burghardt, W. R., Carrell, T. D., & Zecker, S. G. (1997). Oral sensory discrimination of fluid viscosity. *Dysphagia*, 12(2), 68–73.
- Steele, C. M., James, D. F., Hori, S., Polacco, R. C., & Yee, C. (2014). Oral perceptual discrimination of viscosity differences for non-newtonian liquids in the nectar- and honey-thick ranges. *Dysphagia*, 29, 355–364.
- Stevens, S. S. (1957). On the psychophysical law. *Psychological Review*, 64(3), 153–181.
- Stevens, S. S. (1960). The Psychophysics of Sensory Function. *American Scientist*, 48, 226–253.
- Sworn, G. (2009). Xanthan gum. In Handbook of Hydrocolloids (G.O. Phillips and P.A. Williams eds),

pp. 186–203, CRC Press LLC, Boca Raton.

Author Manuscript

TABLE 1 Thickening levels definition according to National Dysphagia Diet for Texture Modified

Foods and Fluids		
Country	Level	Definition
USA	Thin	Apparent viscosity 1-50mPa.s at 50s ⁻¹
	Nectar-thick	Apparent viscosity 51-350mPa.s at 50s ⁻¹
	Honey-thick	Apparent viscosity 351-1750mPa.s at 50s ⁻¹
	Spoon-thick	Apparent viscosity >1750mPa.s at 50s ⁻¹

TABLE 2 List of correct responses in discriminating thickened water samples at different magnitudes of shear viscosity difference

Stimulus pair	Magnitude of shear viscosity difference at 50/s	Percentage of correct responses (by pair)
C-D	1.08	25.71%
D-E	1.11	22.86%
A-B	1.24	34.29%
B-C	1.37	37.14%
B-D	1.48	45.71%
B-E	1.64	40.00%
A-C	1.70	48.57%
A-D	1.83	74.29%
A-E	2.02	68.57%



TABLE 3 Statistics of triangle tests of 35 participants for thickened water with concentration ranging from 3 to 7%

Group	Mean	Standard deviation
Female	1.62	0.13
Male	1.56	0.22
Total	1.59	0.17

TABLE 4 List of correct responses in discriminating thickened milk samples at different magnitudes of shear viscosity difference

Stimulus pair	Magnitude of shear viscosity difference at 50/s	Percentage of correct responses (by pair)
C-D	1.17	17.14%
D-E	1.20	28.57%
A-B	1.29	40.00%
B-C	1.45	37.14%

B-D	1.70	45.71%
A-C	1.89	42.86%
B-E	2.05	57.14%
A-D	2.20	62.86%
A-E	2.65	71.43%

TABLE 5 Statistics of triangle tests of 35 participants for thickened milk with concentration

ranging from 1.45 to 2.33%

Group	Mean	Standard deviation
Female	1.89	0.21
Male	1.95	0.22
Total	1.91	0.21



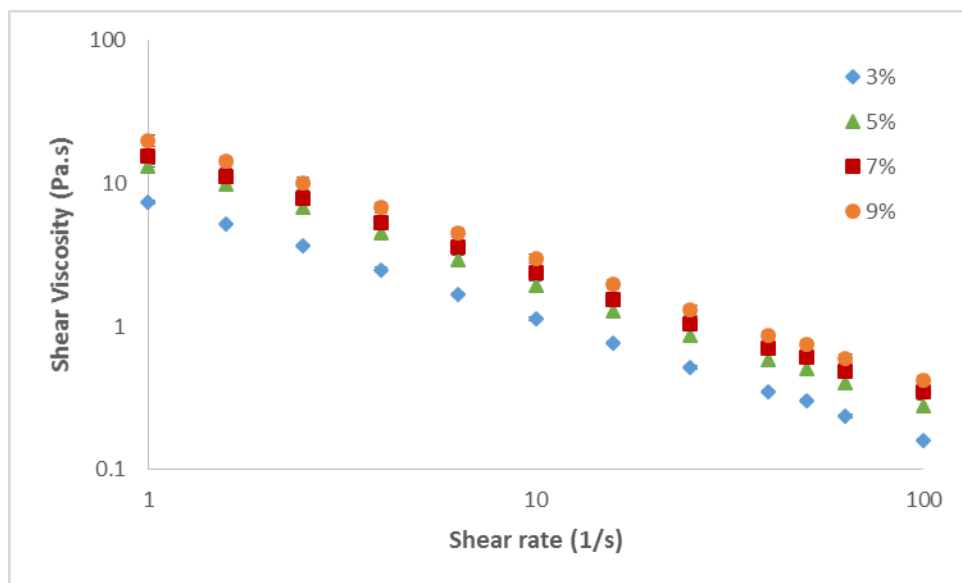


Figure 1.tif

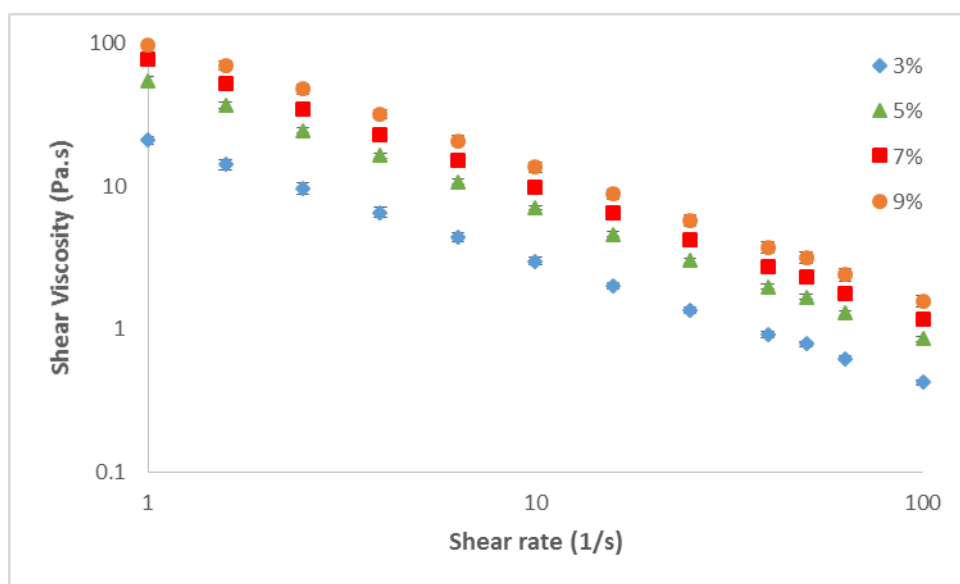


Figure 2.tif

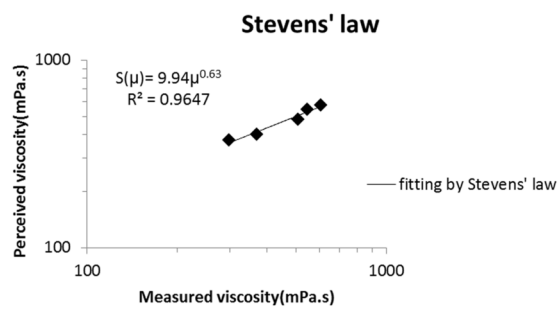


Figure 3.tif

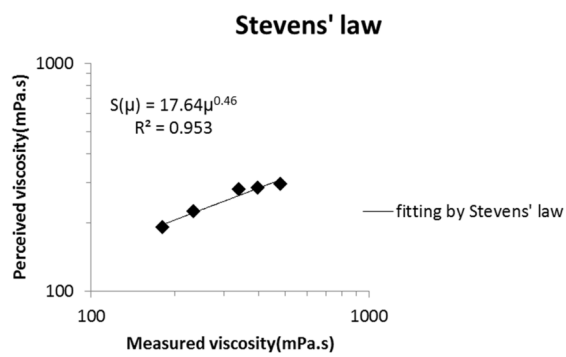


Figure 4.tif

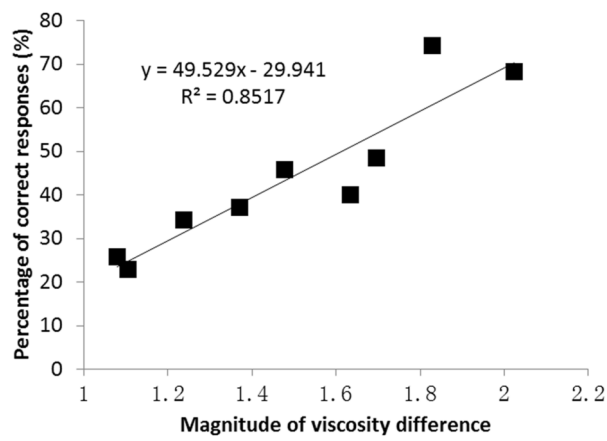


Figure 5.tif

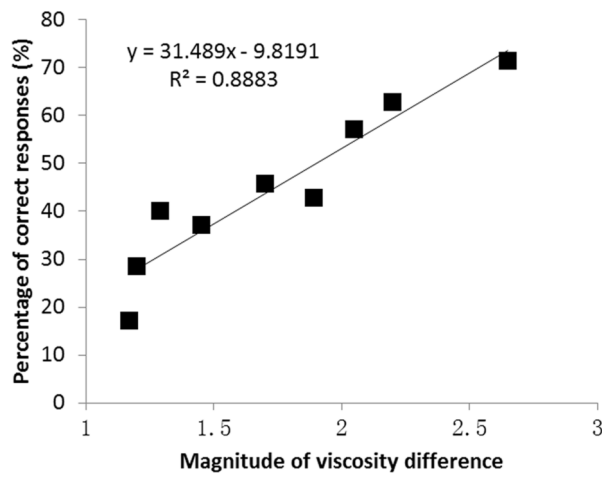


Figure 6.tif



Minerva Access is the Institutional Repository of The University of Melbourne

Author/s:

Zhong, L; Hadde, EK; Zhou, Z; Xia, Y; Chen, J

Title:

Sensory discrimination of the viscosity of thickened liquids for dysphagia management

Date:

2018-12-01

Citation:

Zhong, L., Hadde, E. K., Zhou, Z., Xia, Y. & Chen, J. (2018). Sensory discrimination of the viscosity of thickened liquids for dysphagia management. JOURNAL OF SENSORY STUDIES, 33 (6), <https://doi.org/10.1111/joss.12464>.

Persistent Link:

<http://hdl.handle.net/11343/261069>

File Description:

Accepted version