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Reliability of human senses for evaluating texture of food

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Abstract. The measurement of physical properties often depends on senses or feelings of practitioners. For example, dietitians adjust the viscosity of fluids for people with dysphagia to prevent aspiration at institutions for the elderly or hospitals. In such circumstances, a mistake could put lives of the patients in danger. To investigate accuracy of practitioners' sense, we asked 50 dietitians to select one sample fluid with the closest viscosity to potage soup, yogurt, or jam. The viscosities of the samples were adjusted with an Instant food thickener (IFT) product. Without references of real food, less than 50% of subjects selected the correct sample. The correct answer ratios were significantly higher in subjects with the 15~25 year experience of nutritional guidance than those with less than 5 years. Only around 20% of subjects selected the right viscosity sample when compared with the reference. These results suggest that senses of an experienced individual are not always reliable. And it must be necessary to introduce an appropriate assessment process such as the Line Spread Test (LST), although it still has certain limitation in applicability.

Keywords: thickener, viscosity, texture, sensory evaluation, dysphagia

1. Introduction

Dysphagia is a disorder of swallowing and is caused by neurologic or motor disabilities, head or neck cancer, head or spinal cord injury, or stroke (Curran, 1990). People suffering from dysphagia have a high risk for being affected with severe conditions and illness such as choking, aspiration, aspiration pneumonia, dehydration, malnutrition, and even death (O'Gara, 1990; Kuhlemeier, 2001). Recently, many kinds of powdered instant food thickeners (IFTs) have been developed and are commercially available for people with dysphagia. IFTs are used to adjust viscosity of fluids for people with dysphagia to prevent aspiration by making it of adequate consistency, which often falls into three categories; potage soup like, yogurt like, and jam like, in order, as viscosity increases. There are however no consistent definitions of what terminology we should use or matching of terms to describe viscosity and range of real viscosity. Therefore, each company, which produces IFT, set up own definition, and therefore in some cases, IFTs from two different companies would give totally different texture even when following product instructions to prepare the consistency which is described with the same term. On the other hand, in real situations at the cuisine of an institution for the elderly or a hospital, person who thickening the food virtually depend on their own feeling to adjust the viscosity of foods. Furthermore, it is not always the same person who decides how much viscosity should be used and actually adjusts the viscosity of food. Likewise, there are two uncertain factors, one is the uncertain definition for consistency and the other is the uncertain sensory capacity of person who adjusts viscosity. Our hypothesis is that the consistency adjustment with IFT is less likely to be appropriate most of the time. Therefore, we evaluated if these feelings are consistent between different individuals. First, we interviewed registered dietitians to figure out the real situations in preparing thicker foods by using IFT. Next, we examined individual thresholds for discrimination of the viscosity. Then, we conducted two set of experiments to test reliability of human feeling. We expected that these experiments were the first step to establish the adequate utilization of IFTs.

2. Materials and methods

2.1. Interview

Fifty registered dietitians were asked to be subjects for the interviewing. Contents of the interview were summarized in table 1. This interview was performed at the exhibition booth in 11th annual meeting of Japan society of metabolism and clinical nutrition.

Table 1. Summary of questions in the interview for 50 registered dietitians.

No.	Question
1	Select your work place (medical facility, welfare institution for the elderly, both in parallel)
2	Select a title of your occupation (registered dietitian, dietitian, other)
3	Select typical work contents (nutritional guidance, menu making, cooking), and fill in the number of years to perform each type of work
4	In your work place, whether patients whose foods are needed to be thickened are present or not.
5	Select type(s) of occupations for those who assign the level of thickness (OTA) List of occupations: doctors, nurses, registered dietitians, dietitians, speech therapists, welfare caretakers, chefs, the patient, family of the patient, physical therapists, dental hygienists, occupational therapists, and dentists.
6	Select type of occupations for those who prepare thickened foods (OTP) List of occupations: doctors, nurses, registered dietitians, dietitians, speech therapists, welfare caretakers, chefs, the patient, family of the patient, physical therapists, dental hygienists, occupational therapists, and dentists.
7	Select a communication method of the assignment regarding food thickness. List of methods: verbally, a document of descriptive assignment, a document where the amount of IFT was indicated, giving a sample, other methods
8	Frequency of thickening the foods (select one, the most applicable) List of frequencys: every day, sometimes, rarely, and never

2.2. Preparation of thickened fluids

"Toromi-meijin (Thickening-Master)" (Saraya Co. Ltd) was used as an IFT to prepare thickened fluids. Various amounts of Thickening-Master were dissolved in deionized water at 20ºC and stayed still for more than 1h. These fluids were changed for every three to five subject in order to exclude possibility of viscosity reduction after several trials.

2.3. Threshold for the viscosity discrimination

Discrimination from three samples by the ascending method of limit was performed for 10 subjects. Briefly, viscosity of two fluids in three test samples were adjusted to be 4,000 mPa·s, and that of the rest varies from 4,100 to 5,000 mPa·s (10 series with 100 mPa·s interval). Subjects were allowed to mix three fluids with a spoon and then selected one sample which they thought had different viscosity.

2.4. Sensory evaluation of fluids with proper viscosity

Three reference terms representing different range of viscosity were used in the first sensory evaluation; "potage-like", "yogurt-like", "jam-like." Viscosities of Knorr cup potage (Ajinomoto), Meiji Burgaria yogurt (Meiji Dairies Co.,), and Aohata 55 strawberry jam with less sweetness (Aohata Co., Hiroshima, Japan) were 1,600 mPa·s at 20ºC, 5,000 mPa·s at 5ºC and 20,000 mPa·s at 20ºC, respectively, and we defined these viscosities as representing "potage-like", yogurt-like", and "jam-like", respectively. Four fluids with various viscosities for each of three references were prepared as in table 2, in which one has the same viscosity as the reference foods. The interval of viscosity was assigned higher than 1,000 mPa·s, which is high enough to distinguish each other according to the threshold for the viscosity discrimination determined by the experiment described in the previous section. In the first series of examination, fifty registered dietitians, who answered in the interview described in the previous section, were asked to evaluate these test fluids just by mixing with a spoon, and to select one fluid with the viscosity closest to the reference food with imagination for each of three references. In the second series of examination, ten subjects were allowed to compare a series of test fluids with the real reference food by mixing with a spoon, and to select one fluid whose viscosity was the closest to the reference for each of the three cases.

Table 2. Viscosities of test fluids

No.	Viscosity (mPa·s)		
	Potage-like	Yogurt-like	Jam-like
1	520±40	3070±120	4420±160
2	1600±280*	4120±220	7470±200
3	2810±230	5160±280*	13100±420
4	3610±170	7100±330	19650±920*

*indicate fluids with the closest viscosity as the reference

2.5. Statistical Analysis

Logistic regression analysis was performed to determine the threshold for the viscosity discrimination by the following conditions; correct rate at the certain viscosity was assigned as the objective variable and difference of viscosity was assigned as the explanatory variable. The threshold for the viscosity discrimination was defined as the correct rate equal to 50%. One-way analysis of variance (ANOVA) was performed to assess differences in each data group. The pos-hoc multivarant comparison was performed with the Bonferroni's test, with an overall statistical significance of 0.05.

3. Results and Discussions

3.1. Interview results

Within the 50 registered dietitians, 43 worked at the medical institutions and 3 subjects worked at the welfare institution. The rest were undefined, but the other than the medical institution, or the welfare institution. None worked at the institution including both the medical and the welfare in parallel. Interview results were shown in figure 1. There were multiple choices for which type of occupation should assign the degree of consistency (Occupation to assign: OTA), and who should prepare the thickened food according to the assignment (Occupation to prepare: OTP). The medical doctor was the most prevalent as OTA (20%), but never as OTP. On the other hand, chefs mostly worked as only OTP (figure 1A). Nurses and registered dietitians tended to act as both OTA and OTP, which reflect the high matching ratio between OTA and OTP (figure 1B). The matching ratios of OTA and OTP for nurses and registered dietitians were 59% and 63%, respectively. The matching ratios for dietitians, speech therapists, and welfare care-takers were 30~33%, and the overall matching ratio was 37% for all occupations. These results suggest that the matching ratio is usually not so high and that OTA and OTP were different in the most situations (>60%). Therefore, accuracy of information transmission would be crucial to minimize the number of unfavorable incidences such as mis-swallowing or choking.

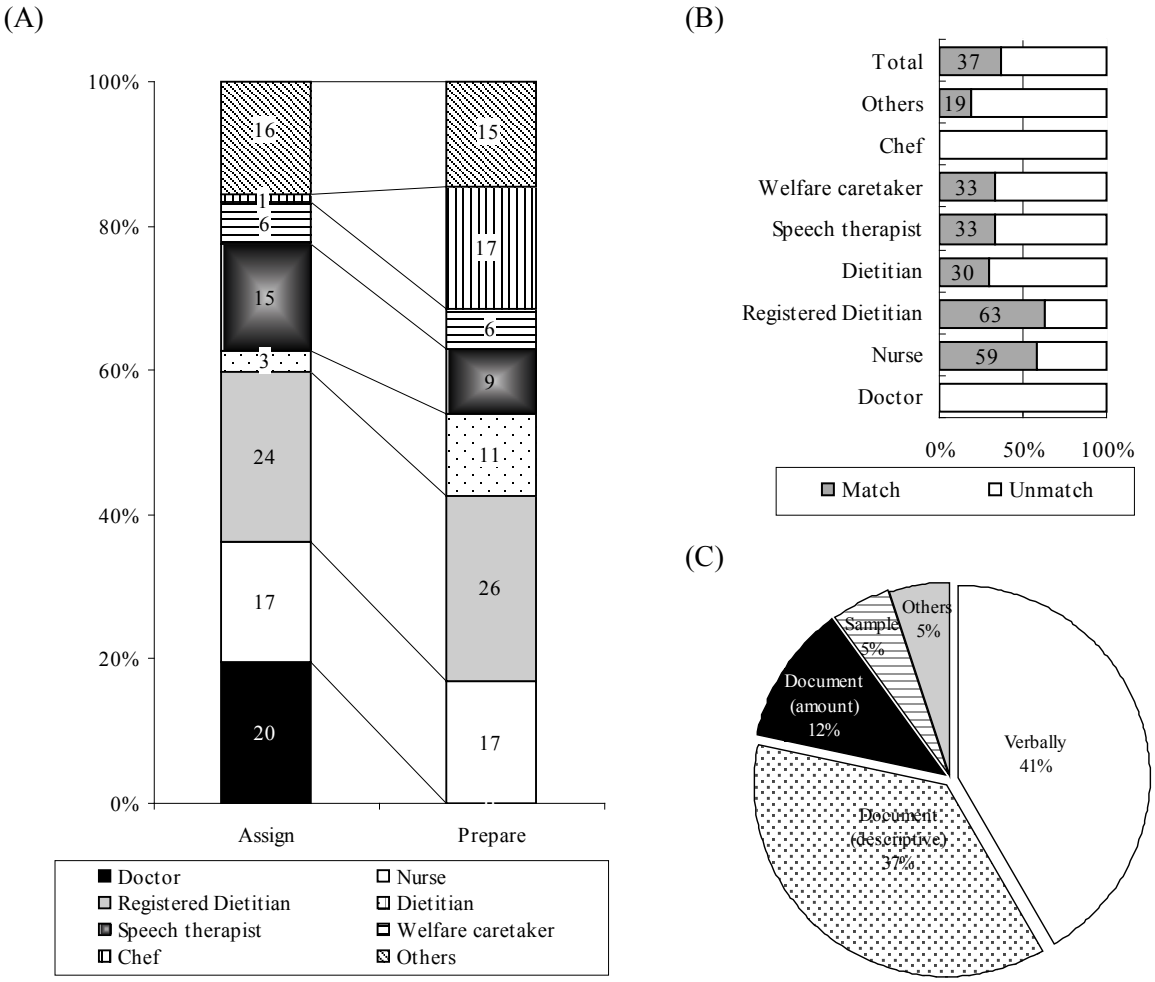

Figure 1. Interview results from the 50 registered dietitians. Histogram of the ratio of OTA and OTP for consistency preparations (A). The matching ratio between OTA and OTP for each occupation (B). The methods for transmitting information of what consistency should be prepared (C).

The ratio of methods for transmitting information of what consistency should be prepared was shown in figure 1C. Forty-one percent was transmitted verbally, 37% was transmitted by a document of descriptive assignment, 12% was transmitted by a document where the amount of IFT was indicated, 5% was transmitted by giving a sample, and the rest was other methods. The case of showing a sample with appropriate thickness was only 5%. Therefore, people who prepare thickened foods must use their imagination in most cases at cuisines, suggesting that the appropriateness of viscosity is likely to be dependent on the human senses, which we assessed in the following sections.

3.2. Threshold for the viscosity discrimination

The correct ratio to discriminate the viscosity difference out of three samples is shown in table 3. Logistic analysis revealed that discrimination threshold, which is defined here as the viscosity range at the correct ratio reaching 50%, was 740.85 mPa·s. This result suggests that the viscosity difference of 1,000 mPa·s is well over the discrimination threshold and is supposed to be discriminative when subjects were allowed to compare samples by mixing with a spoon.

Table 3. Correct ratio to discriminate the viscosity difference

Difference of viscosity (mPa・s)	Correct ratio
100	0
200	0
300	0
400	0
500	0.1
600	0.4
700	0.5
800	0.7
900	0.8
1000	0.7

3.3. Sensory evaluation of fluids with proper viscosity

When subjects were asked to match the viscosity of thickened fluids and the image of reference foods, the correct ratios were 40, 48, and 20% for potage, yogurt, and jam, respectively (figure 2).

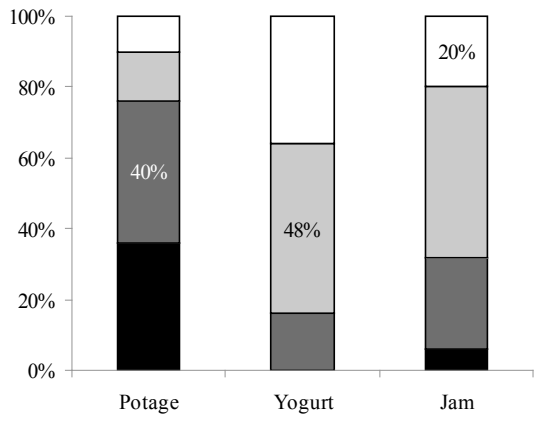

Figure 2. Viscosity matching between mixing of test fluids and the image of reference foods.

Subjects (n=50) were asked to select one out of four thickened fluids of which the viscosity was the same as either that of potage, yogurt, or jam. Reference foods were not given and the individual image of the reference foods was the only clue for the subjects. The viscosity of each area refers to table 2; the black area is No.1, the dark gray area is No.2, the bright gray area is No.3, and the white area is No.4. The correct answer is No.2, No.3, and No.4 for the potage test, yogurt test, and jam test, respectively, where the correct percentage is written in the corresponding area.

It is interesting that the correct ratio for jam was much lower than that for other two references. The interval of viscosities were largest (3,000~6000 mPa·s) in the test samples for the jam, letting us expect that jam-like texture might be the easiest test. The results, however, came out totally opposite to our expectation. We can bring up two possible reasons: one is that the higher the viscosity, the more difficult to sense viscosity correctly, the other is that image of the jam-like viscosity is not constant among subjects. Nevertheless, the overall correct ratio is well below 50%, suggesting that the current situation at cuisine may not be appropriate because people who adjust the thickness is likely to be told the assignment regarding thickness of food without any real reference and would have to depend on their image to adjust the thickness, which is similar to this test situation.

One may argue that the work experience may improve the situation. We thus re-analyzed the results in figure 2 to put in the aspect of the work experience, which is informed from the interviewing results (figure 3).

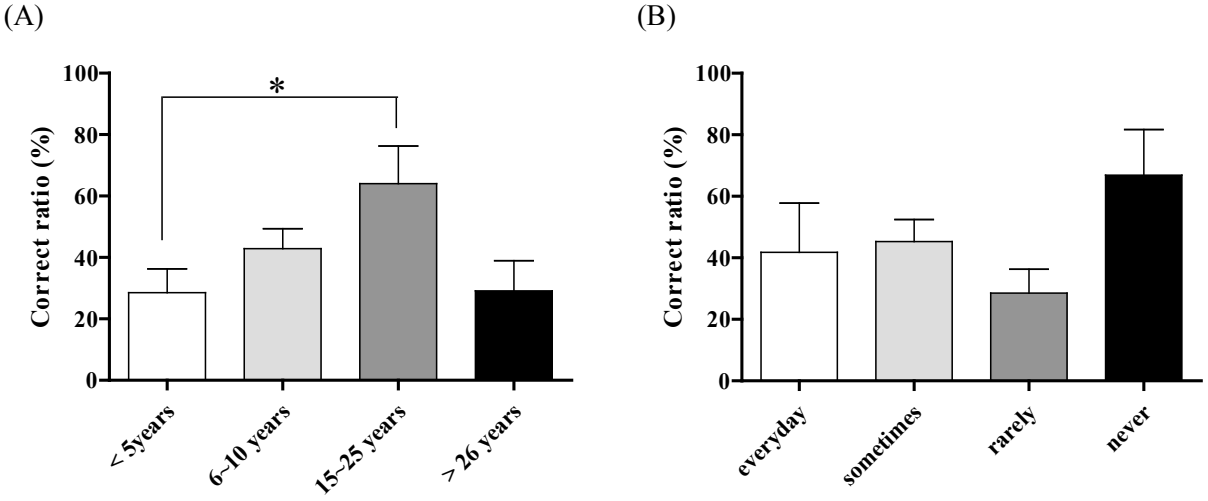

Figure 3. Relationship between experience of working on the thickness adjustment and correct ratio.

(A) Relationship between years of experience for the nutritional guidance and the correct ratio. Subjects were categorized into 4 groups; experience with 5 years or less (n=14), 6 to 10 years (n=14), 15 to 25 years (n=13), longer than 26 years (n=8). (B) Relationship between experience of working on thickness adjustment and the correct ratio. Working frequency for the thickness adjustment; "every day" (n=4), "sometimes" (n=25), "rarely" (n=14), and "never" (n=6).

First, we categorized all subjects into 4 groups according to the experience of the nutritional guidance, and compare the average correct ratio among 4 groups (figure 3A). There were significant differences between groups in ANOVA, and post-hoc multivarant comparison indicated that the correct ratio of subjects with experience with 15~25 years was significantly higher than that with experience with less than 5 years. Therefore, gaining the experience of nutritional guidance appeared to improve the sense of having the right image for reference foods and to enhance the capacity of discriminating viscosities, but the subject group with the longest experience (above 25 years) appears to lose sensitivity. Second, we categorized all subjects into 4 groups according to the experience of using IFTs, and compared the average correct ratio among 4 groups (figure 4B). The average correct ratio was highest in group "never", and "sometimes", "everyday", and "rarely", in descending order. There were, however, no significant differences between groups. Half of the registered dietitians who work on preparing thickened fluids everyday were not able to find the right answer in all three of the tests. In contrast, registered dietitians who never work on this kind of procedure got the better score. To put these results together, the work experience may improve having the right image of reference foods, and having the right image appeared to be an important factor to get the right answer in this

examination. Frequency of dealing with thickening process should enhance sensitivity to discriminate different viscosities, but this ability does not help enhance the correct ratio in this examination. Glassburn et al has previously reported that the experienced speech-language pathologists could prepare Nector-like viscosity (9.3~514 mPa·s at 30ºC) and Honey-like viscosity (118~6213 mPa·s at 30ºC) using Thick-It, which is a starch-base IFT, reproducible within intra-subject, but largely variable within inter-subject (Glassburn, 1998). Thus, the image of the viscosity of certain standard thick foods might become more rigid while gaining this kind of work experience, which however is not necessarily enhancing the accuracy of sensing the viscosity. Steel et al (Steele, 2003) reported that 50 speech-language pathologists could not figure the right order of viscosity when asked to rank 10 drinks by imaging from their raw material information. It was especially difficult to get the right ranking between nector-like viscosity drink and honey-like viscosity drink whose viscosities were close to each other. These studies indicate that people who have knowledge of adjusting viscosity do not have the standardized image of representative foods. Therefore, it may be necessary and helpful to introduce some reference samples to compare the viscosity while adjusting the thickness.

We thus let 10 subjects compare the samples with real reference foods by mixing both to find the sample with the same viscosity. Interestingly, the correct ratios were 20, 20, and 20% for potage, yogurt, and jam, respectively (figure 4). This is quite intriguing because one's imagination gave the higher correct ratio than comparing with reference food, indicating that giving a reference food as a hint appeared to perplex human sense to select precise viscosity. It is however not totally surprising when we consider that viscosity is not the unique factor for us to sense physical properties. Anyhow, these results suggest that simply giving a reference food may not help improve the accuracy of thickened fluid preparations.

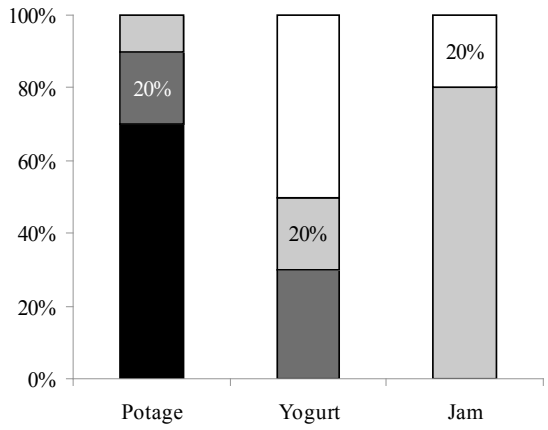

Figure 4. Viscosity matching between mixing test fluids and mixing real reference foods.

Subjects (n=10) were asked to select one out of four thickened fluids of which the viscosity was the same as potage, yogurt, or jam. The viscosity for each area of the bar refer to table 2; the black area is No.1, the dark gray area is No.2, the bright gray area is No.3, and the white area is No.4. The correct answer is No.2, No.3, and No.4 for the potage test, yogurt test, and jam test, respectively, where the correct percentage was shown in the corresponding area.

The viscosity intervals of all experimental settings were well over 1000 mPa·s, and these are higher than the threshold of viscosity discrimination, 740 mPa·s, which was determined in this report. These results implicate that when subjects were mixing the thickened fluids, they may not sense the viscosity exclusively. We therefore measured hardness and adhesive energy of all thickened samples that we used in this study (table 4).

Table 4. Hardness and adhesive energy of all thickened fluids and reference foods

No.	Potage		Yogurt		Jam	
	hardness ($\times 100 N/m^2$)	adhesive energy (J/m^3)	Hardness ($\times 100 N/m^2$)	adhesive energy (J/m^3)	hardness ($\times 100 N/m^2$)	adhesive energy (J/m^3)
1	1.70±0.02	6.99±4.89	2.68±0.09	19.57±6.55	3.16±0.32	35.02±0.34
2	1.97±0.06	13.64±5.02	2.91±0.08	35.85±9.48	3.84±0.25	71.15±3.63
3	2.31±0.04	20.35±2.98	3.14±0.07	44.51±4.18	5.27±0.33	115.79±7.49
4	2.59±0.07	29.99±7.20	4.08±0.30	81.96±15.94	7.51±0.90	192.35±16.16
reference	1.69±0.08	1.94±0.86	3.41±0.34	74.14±9.14	18.42±5.07	405.45±43.95

The percentages of subjects, who selected the sample with the hardness closest to the reference, were 66, 20, and 20 % for potage, yogurt, and jam, respectively. In addition, the percentages of subjects, who selected the sample with the adhesive energy closest to the reference, were 66, 50, and 20% for potage, yogurt and jam, respectively. Therefore, it is possible that subjects, when mixing the samples, may comprehensively sense textural factors of given materials including viscosity, hardness, and adhesiveness, which thus cause detrimental results as shown in figure 4. It should be noted that the correct ratio for the potage-like and the yogurt-like viscosity sets were higher when comparing test samples without reference foods rather than comparing them with reference foods. In the case of the jam-like viscosity set, the correct ratio was always around 20%. IFT solution is in the form of sol, and jam is a more gel-like texture. Cohesiveness of sol is generally much higher than that of gel. Thus, one possible reason why the correct ratios for the jam-like viscosity set was the lowest may be that the subjects were sensing cohesiveness more while sensing other textual factors to a less extent.

4. Conclusions

In practical situations as in hospitals, the food thickness to be prepared by IFTs is usually ordered verbally from one occupation to another. Our experiment suggests that foods' thickness is made inappropriate under such conditions, which may endanger the patients' lives. Some objective methods to measure and communicate foods' physical properties are needed, but hospitals and institutions for the elderly do not usually use any instrument such as viscometer or rheometer because these instruments are expensive and require some space. The Line Spread Test (LST) is suggested as a simple and inexpensive tool for measuring the rheological properties of thick food. An experiment using various foods and different commercial IFTs shows that using the LST standard for food thickness is practical and useful for standardizing diets for dysphagia (Nakamura, 2012). On the other hand, however, the experiment also suggested that there are limitations in applicability, and some foods are not accurately measured with LST. Human five senses may still be more accurate when they are integrated to measure physical properties of food than linear measurement system. We have to further explore the measurement methods of human senses.

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