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Conflict of Interest

The authors declare that they have no
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Rheological Information of Pudding- Thick Liquids Prepared Using Commercial Food Thickeners Marketed in Korea for Dysphagic Patients According to the Manufacturers' Guidelines

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ABSTRACT

Food thickeners are commonly used to prepare thickened liquids for the management of dysphagia. The National Dysphagia Diet (NDD) thickness levels of thickened liquids prepared with commercial food thickeners are known to vary depending on the thickener type, recommended amount of thickener, thickener brand, and preparation instructions. Particularly, detailed preparation instructions must be provided by the manufacturers to achieve the correct thickness levels. However, the rheological information on product labels provided by manufacturers is typically not accurate. Here, various pudding-thick liquids were prepared by mixing commercial xanthan gum (XG)-based thickeners based on the manufacturers' guidelines, and their rheological properties were characterized. Several thickened liquids prepared with four different XG-based thickeners (A-D) marketed in Korea did not meet the pudding-like criterion ($> 1,750$ mPa·s) based on the NDD guidelines. Significant differences in rheological parameter values ($\eta_{a,50}$, n , and G') were also identified among the various thickened liquids. Only one thickener (thickener A) manufactured in Korea showed optimal results, which satisfied the pudding-thick viscosity range for various food liquids and also showed lower stickiness and enhanced bolus formation ability for easy and safe swallowing when compared to other thickeners (B, C, and D).

Keywords: Dysphagia; Swallowing; Viscosity; Rheology

INTRODUCTION

Dysphagia is defined as a sensation of food or beverage being stuck in the chest or esophagus, which is caused by aging, neuromuscular disorders, and cerebrovascular diseases. Patients with dysphagia often experience a feeling of food being stuck in their throat or chest after swallowing [1]. Generally, the neurological causes of dysphagia include stroke, traumatic brain damage, Parkinson's disease, multiple sclerosis, dementia, cerebral nerve paralysis, and muscle damage caused by inflammatory muscle disease [2]. Symptoms such as choking, voice changes after meals, feeling of food stuck in the throat, and refluxing of food

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through the nose can lead to malnutrition or dehydration, all of which are serious problems that dysphagic patients face on a daily basis [3]. Thickened liquids are a key component for the care of dysphagic individuals. However, since the advent of commercial thickeners, experts have repeatedly questioned the availability and amount of free water in thickened liquids. Patients with oropharyngeal dysphagia often recount experiences of delayed food bolus passage. Therefore, thickened liquids play an important role in the treatment of such patients.

Commercial xanthan gum (XG) or starch-based food thickeners are the most common products for the treatment of dysphagic patients. Liquids are typically thickened to decelerate their passage through the oropharynx during swallowing, thus allowing for better coordination. Once swallowed, thickened liquids become a cohesive bolus that can safely descend into the esophagus. To promote safe liquid intake in people with dysphagia, XG-based thickening agents have been recently promoted to thicken both food and beverages. Commercial XG-based thickeners have been used for the management of dysphagia to allow for an optimum swallowing response. Particularly, these products improve the rheological properties and bolus formation ability capacity of food and beverages and are therefore considered safe and highly efficient for the treatment of patients with dysphagia [3,4]. Additionally, due to their palatability and smooth texture, XG-based thickeners are generally preferred over starch-based thickeners, as the latter present some limitations in taste, viscosity, stability, and solubility [4,5]. Moreover, starch-based thickeners may increase the likelihood of aspiration, as they lose their viscosity upon contact with amylase in the human saliva, leading to potential safety problems for dysphagic patients [6].

Thickened liquids are classified into several different consistency levels. The National Dysphagia Diet (NDD) guideline has established these categories at a shear rate of 50 s^{-1} as follows: thin: 1–50 mPa·s; nectar-like: 51–350 mPa·s; honey-like: 351–1,750 mPa·s; and pudding-like: $> 1,750 \text{ mPa·s}$ [3,5]. Particularly, dysphagia-friendly diets generally have a pudding-like consistency. Consistencies are classified based on a range of viscosity values measured at 50 s^{-1} , which is the shear rate considered to be representative of the swallowing process [5,7]. However, concerns have been raised by clinicians regarding the consistency of commercially pre-thickened liquids, as manufacturers are not required to provide the precise viscosity measurements of their products. A wide range of viscosity values has been reported for commercially available thickened liquids for any given labeled thickness (e.g., honey-like or pudding-like) [8]. Thickened liquids made with different XG-based thickeners may also have different perceived thickness levels. Some reports found that each thickener brand produces significantly different viscosities for nectar- and honey-like thickened juices [9]. Further, thickened liquids made with different commercial food thickeners are known to exhibit disparate rheological properties, depending on the thickener brand, thickener type, manufacturing company, thickener concentration, medium for preparation, storage temperature, and time between preparation and consumption [3,4,9–11]. To treat dysphagia, determining the optimal viscosity liquids is critical because lower viscosity materials travel faster into the pharynx and are more likely to enter the pathway earlier than the protective mechanisms during the swallowing process [8,9]. In contrast, excessively high viscosities can result in malnutrition and dehydration in dysphagic patients. Therefore, determining the rheological properties of thickened liquids based on the manufactures' instructions is critical to establish more precise guidelines for the preparation of thickened liquids.

This study sought to investigate the rheological properties of thickened liquids based on the manufacturers' guidelines, as the preparation methods of thickened liquids and the thickener

composition may vary depending on the thickener brand. The main objectives of this study were to investigate the rheological differences between thickened liquids prepared with commercially available thickeners marketed in Korea based on the manufacturers' guidelines for making pudding-like liquids. The results presented herein will aid in the selection of commercial food thickeners based on their viscosity by determining whether thickened liquids fall within the actual pudding-like range. Furthermore, the results will be useful for the development of preparation guidelines for thickened liquids to achieve the correct NDD levels for the treatment of dysphagic patients.

MATERIALS AND METHODS

Materials

A total of 5 dispersing media marketed in Korea were chosen: bottled water (BW) (Jeju Special Self-Governing Development Co., Jeju, Korea), orange juice (OJ) (Coca-Cola Beverage Co., Yangsan, Korea), whole milk (WM) (Seoul Milk, Co., Ltd., Seoul, Korea), black soy milk (BSM) (Dr. Chung's Food Co., Ltd., Cheongju, Korea), and instant sea mustard soup (SMS) (Ottogi Co., Ltd., Anyang, Korea). The main ingredients and nutritional information of the liquid foods are shown in **Table 1**. Hot SMS was prepared based on the manufacturer's instructions, as described by Kim et al. [12]. Four commercially available food thickeners (thickeners A, B, C, and D) for the management of dysphagia were selected because they are the most well-known products in Korea. Only thickener A is manufactured in Korea whereas the other thickeners are manufactured in Japan. The manufacturers' guidelines for the preparation of thickened liquids and thickener composition are shown in **Table 2**.

Preparation of pudding-like liquids

All thickened liquids were prepared by mixing the thickener with the corresponding medium based on the manufacturers' guidelines to achieve a pudding-like consistency for each corresponding medium (**Table 1**). The prepared samples were gently stirred for 60 seconds with a magnetic stirrer and visually inspected to identify impurities. Cold thickened liquids (BW, OJ, WM, and BSM) were stabilized in the refrigerator at 4°C for 60 minutes, whereas

Table 1. Composition of liquid products used in this study

| Liquid type | Main ingredient | Nutrition (per 100 mL) |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| BW | Mineral water | Calcium, potassium, sodium, magnesium |
| OJ | Concentrated orange juice, fructose, calcium gluconate, calcium lactate, citric acid, natural flavoring substances | Protein (0.6 g), carbohydrate (11.7 g), sodium, calcium, vitamins A, C, and E |
| WM | Whole milk | Protein (3.0 g), fat (4.0 g), carbohydrate (4.5 g), calcium, sodium |
| BSM | Crude soy milk, black bean extract, scorched rice powder, black bean paste, black rice concentrate, nutritional supplements | Protein (3.2 g), fat (2.6 g), carbohydrate (7.9 g), calcium, phosphorous, iron, zinc, vitamins B ₁ , B ₆ , C, and D |
| SMS | Dried seaweed, dextrin, starch, refined salt, garlic, seasoned tuna powder, seaweed soup seasoning powder, clam extract, cow brisket broth paste, tuna soy sauce, mixed soy sauce, beef concentration extract, sesame oil | Protein (0.4 g), fats (0.5 g), carbohydrate (2.0 g), sodium |

BW, bottled water; OJ, orange juice; WM, whole milk; BSM, black soy milk; SMS, sea mustard soup.

Table 2. Thickener composition and recommended content of thickener added to liquids to achieve a pudding-like thickness level according to the manufacturers' guidelines

| Thickener type | Thickener composition | Thickener required to achieve a pudding-like thickness |
|----------------|----------------------------------------------------------------------|---------------------------------------------------------|
| A | Xanthan gum, guar gum, and dextrin | 3.0 g of thickener into 100 mL of liquid (3.0 g/100 mL) |
| B | Xanthan gum, locust bean gum, sodium carboxymethylcellulose, dextrin | 3.0 g of thickener into 100 mL of liquid (3.0 g/100 mL) |
| C | Xanthan gum and dextrin | 2.5 g of thickener into 100 mL of liquid (2.5 g/100 mL) |
| D | Xanthan gum, starch, locust bean gum, dextrin | 3.0 g of thickener into 150 mL of liquid (3.0 g/150 mL) |

thickened hot SMS was stabilized in the incubator at 40°C for 60 minutes before being used in the rheological analysis.

Rheological analysis

The rheological properties of thickened liquids were measured at 8°C or 40°C (only for SMS) with a rheometer (Rheostress 1, Haake GmbH, Karlsruhe, Germany) using a plate-plate system (diameter: 3.5 cm, gap: 500 μm). The thickened solutions were applied between the parallel plates at 8°C or 40°C and compressed to obtain a 500 μm gap. Rheological measurements were determined after a 5-minute equilibration step. Flow measurements (shear stress, shear rate, and apparent viscosity) were conducted over a 0.1–100 s⁻¹ shear rate range. The flow curves of the thickened solutions were modeled using the power law equation (Eq.1)

$$\sigma = \dot{\gamma}^n \text{ (Eq.1),}$$

where σ is shear stress (Pa), $\dot{\gamma}$ is the shear rate (s⁻¹), K is the consistency index (Pa·sⁿ), and n is the flow behavior index. Apparent viscosity at 50 s⁻¹ ($\eta_{a,50}$) was calculated using the values of the power-law parameters K and n . All measurements were conducted in triplicate.

The dynamic properties of the thickened sample were quantified with a rheometer (AR1000, TA instruments, New Castle, DE, USA) by performing frequency sweeps over a 0.63–62.8 rad·s⁻¹ range at 2% strain via small-amplitude oscillatory rheological measurements. The TA Rheometer Data Analysis Software (version V1.76) was used to obtain the storage modulus (G'). The thickened solutions were applied between the parallel plates of the rheometer at 8°C or 40°C (only for SMS) and compressed to obtain a 500 μm gap. All samples were allowed to sit at 8°C or 40°C for 5 minutes to stabilize before conducting the dynamic rheological measurements. All measurements were conducted in triplicate.

Statistical analysis

All results were reported as mean ± standard deviation. Analysis of variance (ANOVA) was conducted using SAS version 9.1 (2004, SAS Institute, Cary, NC, USA). Duncan's multiple range test was performed to identify differences between means. A p-value less than 0.05 was considered statistically significant.

RESULTS

Table 3 summarizes the apparent viscosity ($\eta_{a,50}$), the flow behavior index (n), and storage modulus (G') values of dispersing media (BW, OJ, WM, BSM, and SMS) thickened with different commercially available thickeners (A, B, C, and D) based on the appropriate guidelines to achieve a pudding-like consistency (**Table 2**). Several thickened liquids have reportedly failed to meet the pudding-like criterion (> 1,750 mPa·s) based on NDD guidelines. Neither of the thickeners tested herein achieved a pudding-like consistency when applied to BW according to the appropriate guidelines. For thickened OJ samples, only thickener A achieved a proper pudding-like consistency. The $\eta_{a,50}$ values of all liquids with the same thickener were higher when compared to those of thickened BW. However, the $\eta_{a,50}$ values of OJ tended to be lower than protein-based liquids (WM and BSM). Thickeners A and C met the pudding-like criterion for thickened WM and BSM samples. Thickened SMS samples, which were the only samples whose rheological factors were measured above room

Table 3. Magnitudes of apparent viscosity ($\eta_{a,50}$) and flow behavior index (n) of thickened liquids prepared with different thickeners to achieve a pudding-like thickness

| Liquid type | Thickener type | $\eta_{a,50}$ (Pa·s) | n (-) | G' (Pa) |
|-------------|----------------|--------------------------|--------------------------|--------------------------|
| BW | A | 1.25 ± 0.01 ^a | 0.10 ± 0.01 ^c | 70.3 ± 0.61 ^a |
| | B | 0.98 ± 0.01 ^c | 0.13 ± 0.00 ^b | 68.3 ± 0.60 ^b |
| | C | 1.15 ± 0.03 ^b | 0.15 ± 0.01 ^a | 55.8 ± 1.05 ^c |
| | D | 0.41 ± 0.03 ^d | 0.12 ± 0.01 ^b | 20.4 ± 0.24 ^d |
| OJ | A | 1.88 ± 0.03 ^a | 0.10 ± 0.00 ^d | 176 ± 2.14 ^a |
| | B | 1.28 ± 0.01 ^c | 0.16 ± 0.00 ^c | 91.9 ± 0.50 ^c |
| | C | 1.60 ± 0.15 ^b | 0.21 ± 0.01 ^a | 144 ± 6.93 ^b |
| | D | 0.64 ± 0.00 ^d | 0.18 ± 0.00 ^b | 35.0 ± 0.80 ^d |
| WM | A | 2.14 ± 0.02 ^a | 0.11 ± 0.00 ^c | 255 ± 3.40 ^a |
| | B | 1.49 ± 0.02 ^c | 0.21 ± 0.01 ^b | 121 ± 0.97 ^c |
| | C | 1.98 ± 0.03 ^b | 0.32 ± 0.01 ^a | 171 ± 0.32 ^b |
| | D | 0.60 ± 0.02 ^d | 0.21 ± 0.01 ^b | 44.1 ± 0.44 ^d |
| BSM | A | 2.35 ± 0.02 ^a | 0.16 ± 0.00 ^c | 103 ± 0.82 ^a |
| | B | 1.44 ± 0.09 ^c | 0.23 ± 0.01 ^b | 69.2 ± 1.33 ^c |
| | C | 2.15 ± 0.08 ^b | 0.26 ± 0.01 ^a | 96.6 ± 1.96 ^b |
| | D | 0.95 ± 0.11 ^d | 0.23 ± 0.00 ^b | 27.6 ± 0.22 ^d |
| SMS | A | 1.85 ± 0.03 ^a | 0.11 ± 0.00 ^b | 128 ± 1.17 ^a |
| | B | 1.09 ± 0.02 ^c | 0.19 ± 0.01 ^a | 75.4 ± 1.55 ^c |
| | C | 1.22 ± 0.03 ^b | 0.19 ± 0.01 ^a | 102 ± 2.44 ^b |
| | D | 0.48 ± 0.02 ^d | 0.19 ± 0.00 ^a | 17.1 ± 0.45 ^d |

The values represent the means of three measurements ± SD.

Means with different lowercase letters (a-e) within each column are significantly different ($p < 0.05$).

BW, bottled water; OJ, orange juice; WM, whole milk; BSM, black soy milk; SMS, sea mustard soup.

temperature, exhibited significantly lower $\eta_{a,50}$ values compared to other liquids (OJ, WM, and BSM). Thickener A was the only thickener that met the pudding-thick criterion for the thickened SMS and OJ. Overall, thickener A achieved the best performance among all tested products by satisfying the pudding-thick criterion in all liquids except for BW. Thickener B and D showed significantly low $\eta_{a,50}$, which did not meet the pudding-thick criterion in all liquid types.

The flow behavior index (n) of the thickened samples deviated from 1 and ranged from 0.10 to 0.32. Thickened WM and BSM samples exhibited similarly higher n values when compared to other thickened liquids. BW exhibited the lowest n value among all of the thickened liquids evaluated herein. Similarly, thickener A exhibited the lowest n values (0.10–0.16) among all thickened liquids and its n variability was also relatively narrow compared to other thickeners (0.13–0.23 for thickener B; 0.15–0.32 for thickener C; 0.12–0.23 for thickener D). Additionally, in thickened BW, thickener A and B showed much higher G' values when compared to thickener C and D. For thickened OJ samples, all G' values were much higher than those of BW. Particularly, the G' value (144 Pa) of thickener C was nearly three times higher than that of BW (55.8 Pa). Thickener B exhibited only a slight increase in G' value despite the solid content of OJ itself. The G' values of WM were generally higher than those of other liquids. Among all thickener types, all liquids thickened with thickener A exhibited the highest G' values. However, BSM showed significantly lower G' values when compared to BW, OJ, and WM. Thickener A and C showed similar values of approximately 100 Pa, followed by thickener B and D. SMS also exhibited similar trends. Thickeners A and C showed lower reductions in G' compared to other thickeners for thickened SMS samples. The highest G' value was obtained with thickener A, followed by thickener C, then B, and finally D. All liquids thickened with thickener D also showed significantly lower G' values when compared to other thickeners.

DISCUSSION

Thickened liquids prepared with commercial XG-based food thickeners are commonly used for the treatment of dysphagic patients who have difficulty swallowing liquid food. Therefore, confirming whether the manufacturers' guidelines for the thickening of food and beverages meet the desired rheological properties is crucial for the effective treatment of patients with dysphagia. Among the different rheological parameters, $\eta_{a,50}$ values are highly associated with the flow velocity of the food bolus [10], and n values are associated with a slimy mouthfeel, both of which affect the swallowing process [13]. **Table 3** shows the $\eta_{a,50}$ and n values of various pudding-thick liquids prepared with different food thickeners. Neither of the thickened BW samples tested herein satisfied the pudding-thick criterion ($> 1,750$ mPa·s). Given that BW does not contain solid materials, it does not react with the gum components present in thickeners, thus resulting in low $\eta_{a,50}$ values. This suggests that the guidelines recommended by the manufacturers of commercially available thickeners are largely beverage-oriented. In general, the $\eta_{a,50}$ values of protein-based liquids (WM and BSM) tended to be higher than those of OJ due to their higher protein content. In the case of thickeners A and C, their $\eta_{a,50}$ values were higher due to the strong interaction between constituents in milk and XG in the thickener, as noted by Yoon and Yoo [10]. Particularly, the $\eta_{a,50}$ value of thickener D was much lower than those of other thickeners. This was the only starch-containing thickener among the products evaluated herein, and starch is known to alter the viscosity of thickened liquids [14]. Generally, the $\eta_{a,50}$ values of all thickened liquids increased in the presence of thickeners in the following order: $A > C > B > D$. From these observations, it was found that the guidelines provided by the thickener manufacturers for the preparation of thickened liquids with the desired thickness level can often be lacking or misleading.

All thickened samples exhibited shear-thinning behavior with low n values ranging from 0.10 to 0.32 (**Table 3**). The n value is a well-known criterion for measuring the stickiness of thickened liquids and high n values result in a sticky mouthfeel [13]. The n values of BW were considerably lower than those of other thickened liquids containing solids, indicating that the solids in the thickened liquids led to stickiness. Particularly, protein-based food liquids (WM and BSM) thickened with all food thickeners showed higher n values when compared to other liquid samples. This results in a sticky mouthfeel and, in turn, difficulty swallowing in dysphagic patients, as noted by Park and Yoo [15]. For all thickened liquids prepared with different thickeners, the n values (0.10–0.16) of thickener A were significantly lower than those of other thickeners, indicating that thickener A resulted in a smoother mouthfeel. In contrast, the n values (0.15–0.32) of thickener D were significantly higher, indicating that the addition of thickener D to liquids increased the organoleptic sliminess of all thickened liquids. Based on these results, we concluded that the n values of thickened liquids are strongly influenced by the thickener type.

The storage modulus (G') of thickened liquids is a crucial rheological parameter, as it relates to the ease of swallowing the food bolus [10]. The G' value is considered as an indispensable parameter because the elastic property is a decisive variable for bolus formation, which results in easy and safe swallowing. According to **Table 3**, most G' values increased in the presence of liquid containing solid contents (OJ, WM, BSM, and SMS) when compared to BW. Additionally, similar results have been reported by Cho and Yoo [4] for cold thickened liquids prepared with XG-based thickeners. The G' values of thickened WM samples were much higher than those of other samples. These results suggest that the elastic properties of thickened liquids prepared with different XG-based thickeners are greatly affected by the

constituents of liquid foods, which interact with the XG in the food thickener. The G' values of thickened liquids (OJ, WM, BSM, and SMS) with solid contents significantly increased in the presence of the thickeners in the following order: thickener A > C > B > D, indicating that thickened liquids have different rheological effects depending on the thickener type.

In conclusion, various thickened liquids prepared with four different XG-based thickeners marketed in Korea exhibited significant differences in their rheological properties. For all rheological parameters ($\eta_{a,50}$, n , and G'), thickener A manufactured in Korea showed the best results, which satisfied the pudding-like viscosity range for all tested liquids except for BW. Moreover, this thickener exhibited lower stickiness and higher bolus formation ability for easy and safe swallowing when compared with other thickeners (B, C, and D) manufactured in Japan. Our findings thus suggest that thickened liquids must be carefully prepared with commercial thickeners in order to achieve the correct NDD thickness levels for the treatment of dysphagic patients. However, as demonstrated in this study, the manufacturers of the thickening products tested herein failed to provide detailed information regarding the amount of thickener and preparation procedure of various thickened liquid foods based on their rheological properties.

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REFERENCES

1. Triggs J, Pandolfino J. Recent advances in dysphagia management. *F1000 Res* 2019;8:8.
[PUBMED](#) | [CROSSREF](#)
2. Panebianco M, Marchese-Ragona R, Masiero S, Restivo DA. Dysphagia in neurological diseases: a literature review. *Neurol Sci* 2020;41:3067-73.
[PUBMED](#) | [CROSSREF](#)
3. Seo CW, Yoo B. Steady and dynamic shear rheological properties of gum-based food thickeners used for diet modification of patients with dysphagia: effect of concentration. *Dysphagia* 2013;28:205-11.
[PUBMED](#) | [CROSSREF](#)
4. Cho HM, Yoo B. Rheological characteristics of cold thickened beverages containing xanthan gum-based food thickeners used for dysphagia diets. *J Acad Nutr Diet* 2015;115:106-11.
[PUBMED](#) | [CROSSREF](#)
5. Giura L, Urtasun L, Belarra A, Ansorena D, Astiasarán I. Exploring tools for designing dysphagia-friendly foods: a review. *Foods* 2021;10:1334.
[PUBMED](#) | [CROSSREF](#)
6. Lee HY, Yoon SR, Yoo W, Yoo B. Effect of salivary reduction time on flow properties of commercial food thickeners used for dysphagic patients. *Clin Nutr Res* 2016;5:55-9.
[PUBMED](#) | [CROSSREF](#)
7. Payne C, Methven L, Fairfield C, Bell A. Consistently inconsistent: commercially available starch-based dysphagia products. *Dysphagia* 2011;26:27-33.
[PUBMED](#) | [CROSSREF](#)
8. Glassburn DL, Deem JE. Thickener viscosity in dysphagia management: variability among speech-language pathologists. *Dysphagia* 1998;13:218-22.
[PUBMED](#) | [CROSSREF](#)
9. Kim SG, Yoo B. Viscosity of dysphagia-oriented cold-thickened beverages: effect of setting time at refrigeration temperature. *Int J Lang Commun Disord* 2015;50:397-402.
[PUBMED](#) | [CROSSREF](#)

10. Yoon SN, Yoo B. Rheological behaviors of thickened infant formula prepared with xanthan gum-based food thickeners for dysphagic infants. *Dysphagia* 2017;32:454-62.
[PUBMED](#) | [CROSSREF](#)
11. Kim YH, Jeong GY, Yoo B. Comparative study of IDDSI flow test and line-spread test of thickened water prepared with different dysphagia thickeners. *J Texture Stud* 2018;49:653-8.
[PUBMED](#) | [CROSSREF](#)
12. Kim SG, Yoo W, Yoo B. Effect of thickener type on the rheological properties of hot thickened soups suitable for elderly people with swallowing difficulty. *Prev Nutr Food Sci* 2014;19:358-62.
[PUBMED](#) | [CROSSREF](#)
13. Szczesniak AS, Farkas E. Objective characterization of the mouthfeel of gum solutions. *J Food Sci* 1963;27:381-5.
[CROSSREF](#)
14. Fernandes JM, Araujo JF, Vieira JM, Pinheiro AC, Vicente AA. Tackling older adults' malnutrition through the development of tailored food products. *Trends Food Sci Technol* 2021;115:55-73.
[CROSSREF](#)
15. Park J, Yoo B. Particle agglomeration of gum mixture thickeners used for dysphagia diets. *J Food Eng* 2020;279:109958.
[CROSSREF](#)