ARTICLE

Rheological and Textural Properties of Texture-Modified Rice Porridge: Comparison between Starch and Gum as Thickener

H.Y. Yong, Z.A. Syahariza*, U. Uthumporn, and A.A. Karim

Food Technology Division, School of Industrial Technology, Universiti Sains Malaysia, Penang, Malaysia

E-mail: syahariza@usm.my

Thickener often plays an important role to impart desired consistency in texture-modified food which aids in reducing the risk of aspiration. An experimental study was conducted to evaluate the effects of different thickeners (tapioca, sago, xanthan, and guar) at different concentrations (1, 2, and 3% of total weight of ingredients) on rheological and textural properties of rice porridge. A commercial dysphagia-oriented porridge was used as a reference. The concentration of gum used was less than starch to reach the viscosity close to reference. This study also found that all thickeners with similar viscosity showed variation in behaviours during rheological and textural measurements. Overall, guar gum was shown to have potential to be used as an alternative thickener because its properties are almost matched to reference. Rice porridge with xanthan gum had firmer structure whereas tapioca starch with weaker structure was predicted to be easier to swallow.

.

Introduction

Modification of food texture and liquid thickness, usually prescribed as a compensatory method to manage dysphagia. Dysphagia arises when individual experiences difficulty in masticating and swallowing food and liquid. Dysphagia is more common among the elderly population and can lead to complications such as malnutrition and dehydration due to fear of choking and problems with swallowing (Forster et al., 2011). According to Hanson et al., (2012), food with increased viscosity can help to prolong oral transit time which means individuals will have more time to prepare food bolus before swallowing, resulting in safer swallowing. Hence, pureed food, a class of texture-modified food, is highly recommended for people with dysphagia because it requires minimal oral preparation and manipulation. The safe-swallow pureed food should be moist, homogenous, slippery, and cohesive in texture (Cichero, 2016).

Pureed food is prepared by blending or mashing, straining to remove lumps, and followed by the addition of thickener. The thickener used may either be starch-based or gum-based. Many of the commercial thickeners are limited to selected pharmacies and normally sold at a high price. Its high cost can be related to its processing method and the use of modified starch as the main ingredient. The starch is often modified in such it is easy and conveniently used in food preparation - able to thicken food or beverages without heat treatment. However, there were issues related to modified starch where it imparted strong starchy flavour and its viscosity continued to increase over time (Garcia et al., 2005; Lotong et al., 2003). The continuous increment in viscosity is undesirable because over-thickened food or drink may increase choking risk among people with dysphagia (Hadde et al., 2015). As a result, there has been a shift toward gum-based thickener. Gum-based thickener gained popularity over starch-based thickener because it possesses a range of desirable properties, such as having a better taste and more stable viscosity over time (Vilardell et al., 2015). Additionally, the effects of thickener depend largely on the type and concentration used and the food model in which it is used (Saha and Bhattacharya, 2010). There are still multiple sources of thickener that can be tested for their characteristics and suitability in thickening foods for dysphagia needs. The success in incorporation of starch or gum into food can help to replace existing commercial thickener in the market and greatly benefit the consumers, as it will increase its availability and reduce consumers' financial burden.

There are several analyses often used to understand the characteristics of pureed food after addition of thickener. Line spread test (LST) is an empirical test to quantify the consistency of thickened product by measuring the distance travelled across a flat surface after the sample released from a confined chamber. This test is easy, fast, and relatively cheap to use if compared with viscometer (Ettinger et al., 2014). It has also been successfully used in multiple literatures in estimating the viscosity of thickened beverage for people with dysphagia (Budke et al., 2008; Nicosia and Robbins, 2007). However, there is no standard have been developed for the use of LST in the evaluation of pureed food. Instrumental method like rheometer consists several testing modes that can be carried out on pureed food such as viscosity flow and oscillatory tests (Ahmed and Ramaswamy, 2007; Espinosa et al., 2011; Nindo et al., 2007).To date, most of the research on rheological properties of dysphagia-oriented products only focused on viscosity, without investigating the effect of elastic modulus on swallowing ability of food (Zargaraan et al., 2013). A number of studies also examined the textural properties of food using back extrusion test which is obtained from texture analyzer (Ettinger et al., 2014; Murugkar et al., 2015). Back extrusion test is one of the texture assessments that is useful for samples which have high consistency or with suspension of particles. To the best of authors' knowledge, no such study has been conducted on rice porridge for people with dysphagia.

Therefore, this study was designed to evaluate the suitability of two different starches (sago and tapioca) and gums (xanthan and guar) as thickener for rice porridge model at different level of addition using rheological and textural properties. These two testing methods were selected to provide objective measurements for diet management for people with dysphagia. A commercial porridge product specifically designed for dysphagia and normally used at medical institutions and nursing homes was also included as a reference.

Materials and Methods

Materials

Both starches (sago and tapioca) and gums (xanthan and guar) which used as thickener were obtained from Sim Company Sdn. Bhd. (Penang, Malaysia). The basic ingredients of rice porridge were purchased from the local wet market in Penang, Malaysia. A commercial dysphagia-friendly porridge product (Healthy Food Co., Ltd., Japan) was included as a reference. The commercial product uses polysaccharide and edible gum as thickening agent.

Sample preparation

The rice porridge was prepared in accordance with our recipe, using the ingredients as listed in Table 1. The rice grain was ground into powder form using dry mill blender (Model MX-GM1011H Panasonic, Malaysia) for 1 min. The rice powder was mixed with all the basic ingredients and cooked for 12 min using steam jacketed pot (Model TDB/6, GROEN, Unified Brands, Mississippi, USA). The starch was added during the cooking whereas gum was dispersed on the cooked porridge and mixed by using a food processor (Model MK-5087M Panasonic, Malaysia) for 2 min after cooking. The cooked porridge was then sieved (mesh size approximately 1000 µm) immediately. The control sample without any addition of thickener was also prepared for comparison. For commercial porridge product, it was prepared according to manufacturer's instructions, where the package was boiled for 4 min in hot water. All the samples were left to cool to room temperature (25°C) prior to analyses.

Line spread test

The test was conducted using a clear glass plate (19.5 cm x 19.5 cm) laid on top of a sheet marked with concentric circles spaced 1.0 cm apart from 2.0 cm to 5.0 cm radius. The testing procedure was conducted by following the method described by Budke et al., (2008) with slight modification. The rice porridge (5 g) was poured into the hollow glass cylinder (2.0 cm in diameter and 2.9 cm in height) that positioned at the centre of the circles. After 10 min, the cylinder was lifted to allow the sample to spread on the glass plate for 1 min. The average measurements of LST were made based on the sample spreading at the four quadrants of the circle. This procedure was repeated three times for each sample.

Rheological measurements

The rheological properties of rice porridge were evaluated through both stepped flow and oscillatory frequency sweep tests using controlled stress AR 1000 rheometer (TA Instruments, New Castle, DE, USA) equipped with a temperature controller. All the measurements were carried out at 37°C using parallel plate geometry (20 mm diameter) with gap of 1.0 mm. The sample was allowed to equilibrate for 30 s after loading on the rheometer plate. All the rheological measurements were performed in triplicate.

Stepped flow test data were obtained over a shear rate range from 0.1 to 100 s^{-1}. The apparent viscosity at 50 s^{-1}, as the representative shear rate for swallowing, was selected for comparison among samples (Zargaraan et al., 2013). The concentration of each thickener was selected based on the viscosity value similar to the commercial product. The data collected were then fitted to the well-known power law model (Equation 1) and Casson model (Equation 2) to describe the rheological behaviour of the samples.

$$\dot{\gamma} \qquad \text{(Eq. 1)}$$

$$\dot{\gamma} \qquad \text{(Eq. 2)}$$

where σ is the shear stress (Pa), $\dot{\gamma}$ is the shear rate (s^{-1}), K is the consistency index (Pa s), and n is flow behaviour index (dimensionless). Casson yield stress (σ) was calculated as the square of the intercept (K) which obtained from linear regression of the square roots of shear stress-shear rate data.

Oscillatory frequency sweep test was carried out over the range from 0.1 to 10.0 Hz. The linear viscoelastic region for each sample was also determined from oscillatory stress sweep test at 1 Hz. TA Rheology Advantage Data Analysis software (version V5.7.0) was used to determine the experimental data of storage modulus (*G'*), loss modulus (*G"*), and loss tangent (*tan δ*).

Textural measurement

The textural properties of rice porridge were determined through back extrusion test using TA-XT2 Texture Analyzer (Stable Micro Systems, United Kingdom). Fifty-five grams of each sample was weighed into back extrusion vessel and the tests were carried out using disc plunger (diameter 35 mm) at the following settings: test speed: 1.50 mm s^{-1}, pre-test speed: 1.00 mm s^{-1}, post-test speed: 10 mm s^{-1}, distance: 15 mm, and return distance: 65 mm. The parameters obtained from the test consisted of firmness (maximum or peak force obtained as a result of compression) and cohesiveness (maximum negative force). All of the measurements were carried out at 25^{o}C and were replicated three times for each sample.

Results and Discussion

Line spread test

Fig. 1 shows the LST measurements of different samples at all concentrations involved. As expected, the measurement values were decreased with higher consistency, due to increase concentration of thickener. The shorter spreads distance on the surface, the higher its consistency. Pureed food that suitable for people with dysphagia should not be too thick or too thin. Using commercial dysphagic porridge product as a reference, rice porridge with addition of 1% gums and 2% starches were suitable for people with dysphagia. This result also indicated that gum required lower concentration to reach the target consistency compared with starch. The control sample (without addition of thickener) was quite runny and may cause choking risk for people that have difficulty in swallowing thin liquid. Based on the results, rice porridge with the addition of 3% starch and gum showed no spreading occurs hence maybe too thick for swallowing.

Flow behaviour measurements

The apparent viscosity (at shear rate 50 s^{-1}) of rice porridge prepared with different thickeners was measured to determine the suitable concentration of each thickener by using commercial product as a reference. Based on the results tabulated in Table 2, the thickening of rice porridge with 1% gums and 2% starches produced samples with close apparent viscosity to the reference sample (about 3 Pa s). Addition for both types of thickeners (gum and starch-based) at 3% were also found to increase its apparent viscosity values and higher than the reference sample. These results confirmed the findings from LST which indicates that 3% thickener may be too thick for rice porridge.

The stepped flow test data were also performed using mathematical models to study the rheological properties of rice porridge after selection of suitable concentration to use for each thickener. The shear stress-shear rate data were well-fitted to the power law model and Casson model with high determination coefficients (R^2 above 0.98), as shown in Table 3. All samples were non-Newtonian (showing shear thinning behaviour) over the shear rate range (0.1-100 s^{-1}) at 37^{o}C, since the *n* values were in the range of 0.16 to 0.34.

Table 1 Recipe used for the preparation of texture-modified rice porridge

Ingredients	Weight (g)
Rice powder	20.0
Water	474.0
Salt	2.5
Onion powder	1.4
Garlic powder	0.5
Ginger powder	0.5
Black pepper	0.1
Chicken seasoning granule	1.0
Total	500.0

The amount of thickener used was varied between 1 to 3% based on the total weight of ingredients.

Table 2 Apparent viscosity at 50 s^{-1} for rice porridge samples containing different thickeners

Samples	Concentration (%)	Viscosity (Pa s)
Control		0.51 ± 0.02
Guar	1	2.76 ± 0.05
Xanthan	1	2.91 ± 0.09
Sago	1	1.43 ± 0.01
Tapioca	1	1.44 ± 0.05
Guar	2	4.45 ± 0.21
Xanthan	2	5.44 ± 0.07
Sago	2	3.15 ± 0.05
Tapioca	2	3.16 ± 0.05
Guar	3	11.88 ± 0.67
Xanthan	3	4.25 ± 0.27
Sago	3	6.47 ± 0.20
Tapioca	3	4.91 ± 0.22
Commercial		2.69 ± 0.02

Values are mean ± standard deviation (n=3)

The addition of each type of thickener causes no much difference in the *n* values, except for xanthan gum. The lower the *n* value, the greater the shear thinning behaviour. The greater shear thinning behaviour of rice porridge with addition of xanthan gum was related to the unique rod-like conformation and high molecular weight of xanthan gum (Seo and Yoo, 2013). On the other hand, other thickeners showed only little effect on shear thinning behaviour of rice porridge. The *n* value also can use to predict the sensory properties of the food. Marcotte et al., (2001) reported that low *n* value is required if high viscosity and good mouthfeel (less slimy) are desired in thickened food.

Table 3 Flow properties of rice porridges prepared by different thickeners at selected concentration over a shear rate range from 0.1 to 100 s^{-1}

Samples	Power Law			Casson Yield Stress
	n	*K* (Pa s)	R^2	(Pa)
Control	0.27 ± 0.01	8.46 ± 0.17	0.98 ± 0.00	6.03 ± 0.03
Guar 1%	0.34 ± 0.01	37.13 ± 0.77	1.00 ± 0.00	25.37 ± 0.68
Xanthan 1%	0.16 ± 0.01	78.55 ± 2.68	0.98 ± 0.01	67.12 ± 2.38
Sago 2%	0.26 ± 0.00	53.96 ± 1.18	0.98 ± 0.01	39.48 ± 1.22
Tapioca 2%	0.29 ± 0.01	51.46 ± 1.39	0.98 ± 0.01	37.23 ± 0.79
Commercial	0.30 ± 0.02	39.11 ± 2.47	0.98 ± 0.02	26.72 ± 2.10

Values are mean ± standard deviation (n=3).

Table 4 Storage modulus (*G'*), loss modulus (*G"*), and tan at 6.28 rad/s for different rice porridge samples

Samples	*G'* (Pa)	*G"* (Pa)	tan
Control	70.12 ± 4.90	17.14 ± 1.12	0.24 ± 0.01
Guar 1%	155.87 ± 6.25	79.57 ± 0.43	0.51 ± 0.02
Xanthan 1%	195.93 ± 3.88	37.20 ± 0.64	0.19 ± 0.00
Sago 2%	153.13 ± 10.44	29.92 ± 1.00	0.20 ± 0.01
Tapioca 2%	93.10 ± 3.38	25.98 ± 0.22	0.28 ± 0.01
Commercial	67.10 ± 2.29	27.15 ± 0.43	0.40 ± 0.01

Values are mean ± standard deviation (n=3).

Since all thickened samples had almost close values of apparent viscosity at 50 s^{-1}, *K* value and yield stress can be used to explain variability among samples. *K* is a parameter that can be related to firmness of a sample. Yield stress is defined as the minimum stress that initiating the flow of a sample which also can be used to perceive ease of swallowing (Funami, 2011). The *K* and values of all samples increased in the following order: control < guar gum < commercial < tapioca starch < sago starch < xanthan gum. This result indicates that the addition of xanthan gum resulted in the firmest texture of rice porridge and more resistance to flow. Besides, rice porridge with addition of 1% guar gum had similar *K* and value with commercial product while the addition of both starches resulted in higher *K* and σ_{oc} compared with commercial product.

The overall results showed that the thickened rice porridge with similar apparent viscosity at 50 s^{-1} gave differences in flow behaviour based on mathematical modeling method. The finding is in the lines of earlier literature of Sharma et al., (2017) that found significant variation in rheological properties, even though the particular samples had similar viscosity.

Oscillatory frequency sweep test

Table 4 presents the *G'*, *G"*, and *tan* δ of rice porridge samples at 6.28 rad/s and 37°C. All samples exhibited weak gel-like properties, as shown by values of *G'* which higher than *G"*, as well as the *tan* values ranging from 0.19 to 0.51.

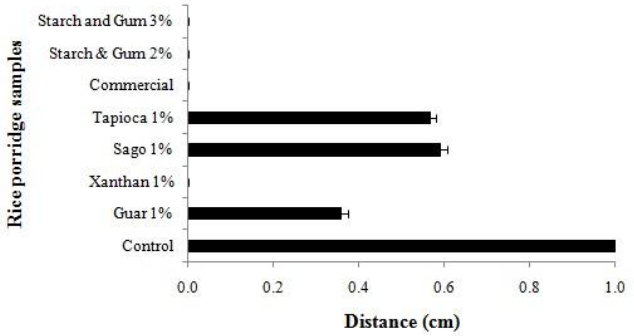

Fig. **1** LST measurements of rice porridges formulated with different thickeners at different concentrations

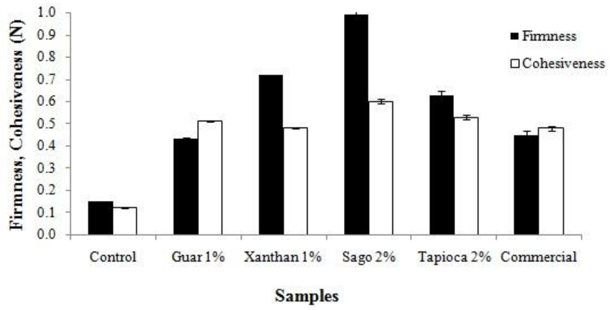

Fig. **2** Textural properties (firmness and cohesiveness) of rice porridges prepared by different thickeners

Tan δ provides information on viscoelastic properties of a sample, considering both elastic and viscous modulus (tan δ = G"/ G') (Sharma et al., 2017). Furthermore, tan δ can be one of the rheological parameters used to perceive ease of swallowing. The lower the tan δ, the higher the contribution of elastic component of the sample. It is apparent from the results that rice porridge thickened with 1% xanthan gum (with lower tan δ and higher *G'*) has more structured and more elastic gel-like behaviour compared with other samples, hence more difficult to swallow. A large difference in viscoelastic behaviour of rice porridge with xanthan gum compared to commercial product can be related to the rigid rod-like structure of xanthan gum, and its ability to form new linkages through fast and stable process (Vilardell et al., 2015).

Beside xanthan gum, it was also interesting to observe that the rice porridge thickened with guar gum showed high tan δ and *G'* value, indicating contribution of both elastic and viscous components. Addition of guar gum into rice porridge which increased tan δ value was in agreement with the results of Yoo et al., (2005). Compared with xanthan gum, rice porridge thickened with guar gum had lower *G'* value with greater contribution of viscous properties, indicating less stiff structure for easy swallowing.

For starch, there is a positive relationship between the *G'* and its amylose content. The higher the amylose content, the higher the *G'*. Sullivan et al., (2010) reported that more energy is needed to break down the linearity and extensive hydrogen bonding of amylose molecules. Since sago starch contains higher amylose content (27%) than tapioca starch (17%) (Wattanachant et al., 2002), rice porridge with sago starch showed higher *G'* value than tapioca starch. The lower *G'* value coupled with average tan δ from rice porridge with tapioca starch would suggest a weaker structure and easier to swallow compared with other thickeners.

Textural measurement

Fig. 2 demonstrates the firmness and cohesiveness of rice porridge samples obtained using back extrusion test. In general, all thickened samples showed higher firmness and cohesiveness values compared with control sample. Sample with sago starch showed the highest firmness while guar gum was similar to commercial sample. This trend was in accordance with the flow behaviour in term of *K.* Many researches suggested that foods that are soft and cohesive are more suitable and safer to swallow for people with dysphagia (Cichero, 2016; Tokifuji et al., 2013). The soft texture is preferred because it can be processed more easily by a tongue-palate compression without teeth mastication (Aguilera and Park, 2016) and improved the miscibility of the food with saliva (Sharma et al., 2017).

Cohesiveness defined as the degree to which sample hold together in a mass, is another parameter to determine the ease of swallowing since a “scattered” bolus may cause choking easily (Pascua et al., 2013; Ishihara et al., 2011). Result shows that the cohesiveness values were close to each other among all thickened sample, implying that the addition of thickener can help to increase the cohesiveness of rice porridge. The results also showed that rice porridge with addition of starch had slightly higher cohesiveness values than gum.

Conclusions

Each thickener has its own synergistic effect with rice porridge. One of the most significant findings from this study is that the concentration used for gum was less than starch in thickening rice porridge to achieve viscosity that close to reference sample. Meanwhile, LST proven to be a useful screening tool to evaluate consistency of prepared samples and to compare its viscosity measurements at 50 s^{-1}. In order to provide objective measurements to describe food consistency following addition of different thickener, both rheological and textural analyses were carried out. It is important to characterize the rheological and textural properties of thickener, to ensure the right consistency and viscosity for safe swallowing. Addition of guar gum in rice porridge showed similar effect as the commercial product. The strong structure of rice porridge with xanthan gum, evident through high yield stress, high *G'*, low tan δ, and high firmness indicates its difficulty to swallow. Rice porridge with tapioca starch which exhibited similar flow properties as sago starch had weaker structure (lower *G'* and firmness) may ease swallowing. Textural measurement showed that firmness of rice porridge was influenced by different types of thickener. Overall, addition of starch or gum as thickener in rice porridge would help to produce safe swallowing food at cheaper cost for people with dysphagia.

Acknowledgements

This study was funded by Fundamental Research Grant Scheme under Ministry of Higher Education Malaysia with Grant No. 203.PTEKIND.6711435 and 203.PTEKIND.6711530. The first author appreciates financial assistance from MSM Malaysia Holdings Berhad and Kuok Foundation.

Conflict of Interest

All the authors declare that they have no conflict of interest.

References

1 Aguilera, J. M. and Park, D. J. (2016). Texture-modified foods for the elderly : Status, technology and opportunities. Trends in Food Science and Technology, 57, 156–164.

2 Ahmed, J. and Ramaswamy, H. S. (2007). Dynamic and steady shear rheology of fruit puree based baby foods. Journal of Food Science and Technology, 44, 579–585

3 Budke, J., Garcia, J. M. and Chambers IV, E. (2008). Comparisons of thickened beverages using line spread measurements. Journal of the American Dietetic Association, 108, 1532–1535.

4 Cichero, J. A. Y. (2016). Adjustment of food textural properties for elderly patients. Journal of Texture Studies, 47, 277–283.

5 Espinosa, L., Nina, T., Symoneaux, R., Renard, C. M. G. C., Biau, N., and Cuvelier, G. (2011). Effect of processing on rheological, structural and sensory properties of apple puree. Procedia Food Science, 1, 513–520.

6 Ettinger, L., Keller, H. H. and Duizer, L. M. (2014). Characterizing commercial pureed foods: Sensory, nutritional, and textural analysis. Journal of Nutrition in Gerontology and Geriatrics, 33, 179–197.

7 Forster, A., Samaras, N., Gold, G., and Samaras, D. (2011). Oropharyngeal dysphagia in older adults: A review. European Geriatric Medicine, 2, 356–362.

8 Funami, T. (2011). Next target for food hydrocolloid studies: Texture design of foods using hydrocolloid technology. Food hydrocolloids, 25, 1904–1914.

9 Garcia, J. M., Chambers IV, E., Matta, Z., and Clark, M. (2005). Viscosity measurements of nectar- and honey-thick liquids: Product, liquid, and time comparisons, 20, 325–335.

10 Hadde, E. K., Nicholson, T. M., and Cichero, J. A. Y. (2015). Rheological characterisation of thickened fluids under different temperature, pH and fat contents. Nutrition and Food Science, 45, 270-285.

11 Hanson, B., O'Leary, M. T., and Smith, C. H. (2012). The effect of saliva on the viscosity of thickened drinks. Dysphagia, 27, 10–19.

12 Ishihara, S., Nakauma, M., Funami, T., Odake, S., and Nishinari, K. (2011). Swallowing profiles of food polysaccharide gels in relation to bolus rheology. Food Hydrocolloids, 25, 1016–1024.
13 Lotong, V., Chun, S. S., Chambers IV, E., and Garcia, J. M. (2003). Texture and flavor characteristics of beverages containing commercial thickening agents for dysphagia diets. Journal of Food Science, 68, 1537–1541.
14 Marcotte, M., Taherian Hoshahili, A. R. and Ramaswamy, H. S. (2001). Rheological properties of selected hydrocolloids as a function of concentration and temperature. Food Research International, 34, 695–703.
15 Murugkar, D. A., Gulati, P., Kotwaliwale, N., Gupta, C., Chakraborty, S. K., and Aiman (2015). Optimization of nutritionally rich instant porridge with sprouted legumes, malted millets and papaya and its comparison with conventional porridge in terms of textural, rheological and partical size properties. International Journal of Food and Nutrition Sciences, 4, 49-58.
16 Nicosia, M. A. and Robbins, J. (2007). The usefulness of the line spread test as a measure of liquid consistency. Dysphagia, 22, 306–311.
17 Nindo, C. I., Tang, J., Powers, J. R., and Takhar, P. S. (2007). Rheological properties of blueberry puree for processing applications. LWT - Food Science and Technology, 40, 292–299.
18 Pascua, Y., Koc, H. and Foegeding, E. A. (2013). Food structure: Roles of mechanical properties and oral processing in determining sensory texture of soft materials. Current Opinion in Colloid and Interface Science, 18, 324–333.
19 Saha, D. and Bhattacharya, S. (2010). Hydrocolloids as thickening and gelling agents in food : a critical review. Journal of Food Science and Technology, 47, 587–597.
20 Seo, C. W. and Yoo, B. (2013). Steady and dynamic shear rheological properties of gum-based food thickeners used for diet modification of patients with dysphagia: Effect of concentration. Dysphagia, 28, 205–211.
21 Sharma, M., Kristo, E., Corredig, M., and Duizer, L. (2017). Effect of hydrocolloid type on texture of pureed carrots: Rheological and sensory measures. Food Hydrocolloids, 63, 478–487.
22 Sullivan, P., O'Flaherty, J., Brunton, N., Gee, V. L., Arendt, E., and Gallagher, E. (2010). Chemical composition and microstructure of milled barley fractions. European Food Research and Technology, 230, 579–595.
23 Tokifuji, A., Matsushima, Y., Hachisuka, K., and Yoshioka, K. (2013). Texture, sensory and swallowing characteristics of high-pressure-heat-treated pork meat gel as a dysphagia diet. Meat Science, 93, 843–848
24 Vilardell, N., Rofes, L., Arreola, V., Speyer, R., and Clavé, P. (2015). A comparative study between modified starch and xanthan gum thickeners in post-stroke oropharyngeal dysphagia. Dysphagia. https://doi.org/10.1007/s00455-015-9672-8.
25 Wattanachant, S., Muhammad, S. K., S., Hashim, D. M., and Rahman, R. A. (2002). Suitability of sago starch as a base for dual-modification. Songklanakarin Journal of Science and Technology, 24, 431–438.
26 Yoo, D., Kim, C. and Yoo, B. (2005). Steady and dynamic shear rheology of rice starch-galactomannan mixtures. Starch/Starke, 57, 310–318.
27 Zargaraan, A., Rastmanesh, R., Fadavi, G., Zayeri, F., and Mohammadifar, M. A. (2013). Rheological aspects of dysphagia-oriented food products: A mini review. Food Science and Human Wellness. https://doi.org/10.1016/j.fshw.2013.11.002.