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Comparison among the use of hydrocolloids to obtain texture-modified Riceberry rice porridge fortified with bio-calcium and fish protein hydrolysate from salmon (*Salmo salar*) frame for elderly with Dysphagia

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Abstract

The effect of different types and concentrations of hydrocolloids (xanthan gum (XG) at 0.25, 0.50 and 0.75%, guar gum (GG) at 0.25, 0.50 and 0.75%, and modified tapioca starch (MS) at 1.0, 1.25 and 1.5%) on rheological properties of the protein hydrolysate and bio-calcium fortified Riceberry rice porridges for elderly with dysphagia was investigated. Rheological properties of porridges were as dependent on types and concentrations of the thickener, except MS. The flow behavior index (n) of all porridges was less than 1.0 which was shear thinning behavior. Increasing gum-thickener concentrations in porridges increased both apparent viscosities at a shear rate of 50 s^{-1} and consistency coefficient (K). Both XG and GG at the similar concentrations gave a similarly steady viscosity. Moreover, the viscosity at the shear point of these samples was obviously higher than that of the control ($p<0.05$). Nevertheless, the addition of MS had no effects on viscosity, K or n values of the porridges ($p\geq0.05$). Riceberry Rice porridges with XG and GG at levels of 0.25-0.75% were classified by the National Dysphagia Diet Task Force; NDD (US standard) as having a Honey-like consistency. While those with MS at levels of 1.0-1.5% had a nectar-like consistency in the similar range of the control sample (no hydrocolloids). Acceptance tests among elderly participants (n = 50) showed that porridge containing 0.25% XG, 0.25% GG, and 1.0% MS achieved the highest scores across all attributes, with liking scores ranging from 7.12–7.86, 6.94–7.64, and 6.42–7.38, respectively, depending on the hydrocolloids.

Keywords: Acceptance test, Guar gum, Modified tapioca starch, Rheology, Riceberry rice porridge, Xanthan gum

1. Introduction

The number of people aged 60 and older is growing quickly and is expected to reach 4 million by 2030, then double to 20% by 2050. More than 60% of this increase will be in Eastern and South-Eastern Asia. [1].

Oropharyngeal dysphagia is most prevalent and severe among the elderly. This condition is commonly caused by neurological or structural disorders, which help in bolus movement, and is defined by the difficulty or incapability to transfer the food bolus from the oral cavity to stomach [2]. In addition, Coronavirus disease 2019 had a negative impact on the health of hospitalized patients, causing an increase in the prevalence of oropharyngeal dysphagia (being a common complication in patients who received intubation or mechanical ventilation) and malnutrition [3]. The key to safe swallowing is the coordination between rheological attributes of the bolus, propulsive forces applied by the oropharyngeal musculature and biomechanical measures utilized for protecting the airway [4].

Since dysphagia is commonly associated with malnutrition, proteins and calcium are crucial when formulating special foods for dysphagia patients. Nowadays, the consumption of health-promoting food has become a fast-growing market. The Riceberry rice is rich in phenolic compounds, which have been known to possess a wide range of bioactivities, particularly antioxidant activities. The protein hydrolysate contains biologically active peptides which are also rich in amino acids which play an important role in the physiological activity of the human body [5]. Additionally, bio-calcium offers a greater amount of soluble calcium that is readily available for absorption, [6] which is especially beneficial for elderly individuals with dysphagia.

Moreover, the most compensatory technique for dysphagia management involves using hydrocolloids, which are hydrophilic polymers added to aqueous solutions to modify the functional properties of the fluid [7]. These substances increase transit times during swallowing, thereby altering the rate at which food is transported through the pharynx. They also enhance viscosity and cohesiveness between food particles, helping to prevent aspiration or choking in affected patients [8]. Moreover, the products were designed, following the recommended dietary characteristics of each level as indicated by the Dysphagia Diet Standardization Initiative (IDDSI) or National Dysphagia Diet (NDD) standards.

NDD testing is designed to confirm the flow and textural characteristics of food substances, providing a standardized framework to guide the development of suitable modified foods and thickened liquids. The NDD standard utilizes a rheometer to determine the viscosity values of food and liquids as the basis for categorizing into each NDD level. NDD guideline categorizes viscosity into groups of thin (1-50 cP), nectar-thick (51-350 cP), honey-thick (351-1750 cP) and spoon-thick (>1750 cP).

Thus, the purpose of this study was to investigate the effects of adding various hydrocolloids on the steady rheological properties, color, and sensory characteristics of Riceberry rice porridge (RB) fortified with protein hydrolysate (PH) and bio-calcium (BC). This was assessed through NDD measurements and flow characteristics, ensuring the porridge is suitable for individuals with different levels of dysphagia.

2. Materials and methods

2.1 Materials

Riceberry Rice (RB, Mah Boonkrong Rice Brand, Patum Rice Mill and Granary Public Company Limited, Thailand) were purchased from local supermarket in Songkhla province, Thailand. The ingredients for chicken soup preparation consisted of chicken bone (CP brand), vegetables (Aro, Siam Makro Plc.), pepper (Nguan Soon Brand. Artchit International Pepper and Spice Co., Ltd.), rice bran oil (King rice bran oil Brand, Thai Edible Oil Co., Ltd.), dried soybean sheet, mushroom (Ek-Chai Distribution System Co., Ltd.), UHT unsweetened soymilk (Lactosoy brand, Lactasoy Co.,th), Iodized salt (Prung Thip Brand, Saha Pathanapibul Ltd.) and soy sauce (Golden Mountain green cap, ThaiTheparos PLC.).

Various hydrocolloids including xanthan gum, guar gum and modified tapioca starch (Hydroxypropyl-Distarch Phosphate (E1442)) were purchased from Chemipan Corporation Co.,Ltd, (Bangkok, Thailand), Chemipan Corporation Co.,Ltd, (Bangkok, Thailand) and Krungthepchemi Co., Ltd. (Bangkok, Thailand), respectively.

2.2 Preparation of Riceberry rice porridges with various hydrocolloid types and concentrations

Riceberry rice (Oryza sativa L.) was prepared following the method of Charoensri and Kijroongrojana (2024) and then was added 1.5% w/w protein hydrolysate powder (PH) (82.01% of protein, dry weight basis of salmon frame), 589 mg Bio-calcium (BC) (30.88% of Calcium, dry weight basis of salmon frame). Xanthan gum (XG) (0.25, 0.5 and 0.75%), guar gum (GG) (0.25, 0.5 and 0.75%) and modified tapioca starch powders (MS) (1, 1.25 and 1.5%) were gradually added to the porridge and stirred to ensure complete dispersion, then heated to simmer for 5 mins. Porridges were stored at ambient temperature in sealed containers to be reheated before analyses.

2.3 Determination of color

Color measurement of the samples was performed using colorimeter (C04-1005-631 ColorFlex, Hunter Lab Reston, VA, USA) and reported in the CIE system. L*, a*, and b* representing lightness, redness-greenness, and yellowness-blueness.

Prior to color measurements, the instrument was calibrated with light tap and white calibration tile. The standard illuminant D65 and 10° standard observers as well as a white standard plate (L*= 93.59, a*= −0.98, b*= 0.35) was used for calibration.

2.4 Determination of rheological properties

The apparent viscosity was examined using Rheometer (HAAKE RS75, Germany) with the parallel plate measuring system and 1 mm of gap between the plates. The flow curves were obtained by registering shear stress (τ) at various shear rates ($\dot{\gamma}$) ranging from 0.1-100 s^{-1} in 300 s. The power-law model was used to describe the data of shear-induced behavior of rice porridge ($\tau = K\dot{\gamma}^n$); where K is the consistency coefficient ($Pa.s^n$); n is the flow behavior index [9].

2.5 Acceptance test

Sensory evaluation was carried out by fifty panelists (n=50) with aged 60 and over who were recruited from Hatyai, Songkhla Thailand. Ethical approval for research was obtained from the Health Science Human Research Ethics Committee of the Prince of Songkla University, Thailand (HSc-HREC: 63-037-1-1). The rice porridges were assessed in a standardized tasting room with individual booths under white light and at a maintained room temperature (25±2 °C) of Faculty of Agro-Industry, Prince of Songkla University, Hatyai Campus, Thailand. The rice porridge samples were evaluated on various attributes including appearance, color, odor flavor/taste, mouth-feel, viscosity, aftertaste and overall acceptability using a nine-point hedonic scale. The samples of the porridge (20±2 g per cup) were served at 50-60 °C to each panelist in random order which were labeled with three-digit random numbers. All the attributes were scored on a scale varying from "9= like extremely", "5=neither like nor dislike", to "1=dislike extremely" [10]. Drinking water was provided to the panelists to cleanse their palates for 10 min after testing each sample [11].

3. Result and discussion

3.1 Color properties of Riceberry rice porridges with various hydrocolloid types and concentrations

The color of the Riceberry rice porridges added with various xanthan gums, guar gum and modified tapioca starch concentrations is depicted in Table 1. These results indicate that the types and concentrations of hydrocolloids significantly impacted all the color parameters tested. The L^* values of all porridges added with hydrocolloids were higher than that of the control (no hydrocolloid) ($p<0.05$). The porridges with starch-based thickeners were lighter than with the gum-based ($p<0.05$). Modified starch-based thickeners produced cloudy appearance through a gelatinization process, while gum-based thickeners produced a clear appearance. The porridges with increased hydrocolloid concentrations augmented the lightness of the porridge ($p<0.05$). When compared amongst gum-based thickeners, xanthan gum (XG) added to porridge gained a higher lightness score than that of guar gum (GG) at similar concentrations ($p<0.05$). All porridges with added thickeners showed no difference in a* values, except 0.5-0.75% xanthan gum (XG) and 0.25-0.5% guar gum (GG) which had lower and higher redness values, respectively ($p \geq 0.05$). Addition of guar gum and modified tapioca starch led to an increase in b* of the porridges when compared with the control. The pale white-yellow color of the starch powders contributed to an increase in both the lightness and yellowness of the Riceberry rice porridge.

Table 1 Color properties of RB with PH and BC with various hydrocolloids

Treatments		Color properties		
Type	Concentration (%)	L*	a*	b*
Control	no addition	28.73 ± 0.19^{bxs}	8.26 ± 0.06^{azp}	7.23 ± 0.12^{azs}
Xanthan gum (XG)	0.25	28.46 ± 0.21^{b}	8.24 ± 0.16^{a}	6.70 ± 0.06^{c}
	0.50	28.19 ± 0.08^{b}	8.10 ± 0.02^{b}	7.02 ± 0.13^{b}
	0.75	29.60 ± 0.15^{a}	8.10 ± 0.03^{b}	7.15 ± 0.02^{ab}
Guar gum (GG)	0.25	27.25 ± 0.05^{y}	8.43 ± 0.05^{y}	7.30 ± 0.01^{yz}
	0.50	26.66 ± 0.08^{z}	8.46 ± 0.03^{x}	7.34 ± 0.03^{y}
	0.75	27.13 ± 0.17^{y}	8.30 ± 0.04^{z}	7.57 ± 0.13^{x}
Modified tapioca starch (MS)	1.00	31.53 ± 0.58^{r}	8.24 ± 0.04^{p}	7.75 ± 0.15^{r}
	1.25	32.87 ± 0.33^{q}	8.17 ± 0.10^{p}	7.95 ± 0.09^{q}
	1.50	34.60 ± 0.77^{p}	$8.18 \pm 0.10b^{p}$	8.30 ± 0.15^{p}

All values are means ± standard deviation (n=5). For each run, three determinations were conducted.

$^{a-f}$ Different superscript letters (a, b, c), (x, y, z), (p, q, r) in the same column indicate significant difference within the same thickener addition including control ($p<0.05$).

3.2 Rheological properties of Riceberry rice porridges with various hydrocolloid types and concentrations

Rheological properties are associated with food bolus transportation via swallowing. All samples were found to have shear-thinning behaviors in which the increased shear rate led to a decrease in the apparent viscosity as shown in Table 2. The samples were fitted to the power-law model ($\tau = K\dot{\gamma}^n$) with high determination coefficients (R^2 = 0.92-0.98).

Shear viscosities at a shear rate of 50 s^{-1} (which is thought to be the mean oral shear rate) were averaged for each sample and compared with the standard deviation (Table 2). The apparent viscosities were dependent on types and concentrations of the thickener except the modified starch-base. Rice porridges with larger mean values are more viscous, while those with smaller mean values are less viscous. Viscosity values of gum-rice porridges at low concentrations (0.25-0.75%) were significantly higher than starch-rice porridges at 1.0-1.5% ($p<0.05$). Accordingly, viscosity values of the porridges with gum were statistically different from those without thickeners (control) ($p<0.05$). High viscosity was more predominant in xanthan gum (XG) than in guar gum (GG) due to chemical properties including high molecular weight and the rigid rod-like conformation of xanthan gum (XG). Furthermore, addition of modified starch (MS) had no impact upon the viscosity ($p\geq0.05$). The interaction of modified starch (MS) could have resulted from many factors including the presence of ions, protein, and solids. Modified starches (MS) may interact with inorganic matters like bio-calcium which resultantly impedes gel network formation. Moreover, this could be attributed to the electrostatic repulsion interaction between the negatively charged phosphate groups in cross-linked tapioca starch and the negatively charged carboxylate anion of protein hydrolysate. The relatively intact swollen granules of modified tapioca starch dispersed in rice porridge with protein hydrolysate and the electrostatic repulsion interaction between negatively charged anions of protein hydrolysate and modified tapioca starch were proposed to account for the viscosity [12] .

Comparison to National Dysphagia Diet Ranges (NDD), Riceberry rice porridge (RB) with 1.0 to 1.5% modified tapioca starch (258.07-384.45 cP) were in the range of nectar-like thickness (51-350 cP). Whilst those with 0.25 to 0.75% of gum thickener (470.08- 1277.47 cP) were in the range of honey-like consistency (351–1750 cP).

The consistency coefficients (K) or the magnitude of viscosity at a specific shear rate of the porridge increased in the gum-based thickener levels ($p<0.05$). The addition of thickeners resulted higher viscosity or more resistance to flow. Whereas the addition of modified tapioca starch led to a decrease in K value when compared to the control. Furthermore, xanthan gum-based porridges had a higher viscosity than others and offered greater resistance to flow having a shear rate of 50 s^{-1}.

The flow behavior index (n) of all thickened rice porridge was less than 1.0 which indicated that the samples are pseudoplastic fluids. The n value is correlated to the sensorial properties of the food which explained by low n values is required, if high viscosity and good mouth feel (less slimy) characteristics are desired in food. The flow behavior index values of rice porridge with thickening agents were similar to the control ($p\geq0.05$), except for that with guar gum. Rice porridges with guar gum produce shear-thinning behavior due to its long and rather rigid chainlike structure. The observed shear-thinning behavior of gum-based thickeners can be explained by disruption of the entangled polysaccharide molecule network during shearing. Moreover, the rate of disruption of existing intermolecular entanglements becomes greater than the rate of reformation of intermolecular entanglement with increasing shear rate, with a resultant decrease in apparent viscosity. The flow behavior of rice porridge with modified tapioca starch resulted from the breakage of hydrogen bonds between amylose molecules or rearrangement of starch granules [13]. This cross-linked starch could provide granule swelling without disruption and consequently control the rheological properties of starch-containing food product [12].

Table 2 Rheological properties of RB with PH and BC with various hydrocolloids

Treatments		Rheological properties			
Type	Concentration (%)	Viscosity (mPa•s) at shear rate of 50 s^{-1}	Consistency coefficient, K ($Pa.s^n$)	Flow behavior index, n	R^2
Control	0	344.60±22.86^{dzp}	4.6355±0.0606^{byp}	0.345±0.023^{axp}	0.96
Xanthan gum	0.25	602.63±35.45^{c}	6.7473±0.6871^{b}	0.392±0.012^{a}	0.94
	0.50	891.23±76.04^{b}	13.3750±3.8643^{a}	0.337±0.085^{a}	0.92
	0.75	1,117.20±103.61^{a}	14.7450±0.7567^{a}	0.348±0.010^{a}	0.97
Guar gum	0.25	492.25±22.17^{y}	4.7095±0.9425^{y}	0.433±0.054^{w}	0.97
	0.50	812.15±45.50^{x}	6.3220±0.4915^{x}	0.479±0.012^{w}	0.97
	0.75	1,197.00±80.47^{w}	9.2863±1.1836^{w}	0.478±0.024^{w}	0.97
Modified tapioca starch	1.0	338.60±35.16^{p}	4.0675±1.3800^{p}	0.386±0.048^{p}	0.98
	1.25	321.40±17.87^{p}	3.5750±0.8901^{p}	0.406±0.049^{p}	0.98
	1.5	333.63±50.82^{p}	3.3293±0.8936^{p}	0.385±0.039^{p}	0.96

All values are means ± standard deviation (n=5). For each run, three determinations were conducted.
[a-f] Different superscript letters (a, b, c), (w, x, y, z), (p, q, r) in the same column indicate significant difference within the same thickener addition including control ($p<0.05$).

3.3 Acceptance test of Riceberry rice porridges with various hydrocolloid types and concentrations

Acceptability of the rice porridge samples with various thickeners types and concentrations was assessed by 50 elderly consumers aged 60 and over. The acceptance scores of Riceberry rice porridge with xanthan gum at 0.25, 0.5 and 0.75%, guar gum at 0.25, 0.5 and 0.75%, and modified starch at 1.0, 1.25 and 1.5% were demonstrated on Table 3, 4 and 5, respectively.

The porridge with added xanthan gum obtained higher scores in appearance, thickness, color, viscosity, after-taste and overall liking than the control ($p<0.05$). However, odor, taste, and mouth-feel liking scores of those added with 0.5 and 0.75% XG were similar the control (Table 3). Rice porridge with xanthan gum at 0.25% clearly showed the highest liking scores on appearance, thickness, odor, taste, mouthfeel, viscosity, and after-taste. Xanthan gum powder is a high molecular weight polysaccharide and fully soluble in hot water. The rice porridges with xanthan gum have high viscosity at low concentrations as a result from its high molecular weight and secondary structure. Additionally, the immobile molecule of xanthan gum becomes entangled in high-order networks which may cause an increase in the viscosity and thickness of rice porridges [14]. The pseudoplasticity of xanthan gum enhances the flavor and decreases the feeling of tackiness of food in the mouth, due to the low viscosity of xanthan gum during mastication, thereby improving its sensory characteristics. Moreover, the thickness and viscosity attributes were directly related to the rheological properties, which are crucial for determining the behavior of the molecules and the final characteristics of the rice porridge products. The polymer concentration, medium conditions and xanthan systems have influenced rice porridge with xanthan gum characteristics. During rice porridge preparation, heating influences the molecular conformation and ordered structure of samples. The heat in the process increases the extension of the branched structure. The double chain is disrupted, interpenetrated in the polymer network to form an additional double zone of network junction, forming a large, cross-linked network. Other types of network junctions can be present, such as nonspecific interactions and hydrogen bonds mediated by cations [15].

Similarly to the effect of xanthan gum, the addition of guar gum in the porridges led to an increase of acceptability in appearance, thickness, viscosity and overall liking scores when compared to the control ($p<0.05$). However, color, odor, taste, mouthfeel and after-taste liking scores of those with 0.5 and 0.75% guar gum were similar the control (Table 4). The porridge with guar gum at 0.25% obtained the highest liking score of all attributes. Guar gum has the highest molecular weight polysaccharides and is responsible for both hydration properties and hydrogen bonding activity. This activity was caused by the presence of hydroxyl groups in guar gum molecules. A main point in development of rice porridge for the elderly with dysphagia is viscosity characteristics. The guar gum (GG) - porridges showed very high viscosity at very low concentration similar to those with xanthan gum (XG). All concentrations in samples were recommended at below 1% concentration [16]. The rice porridge viscosities increased with increasing in GG concentrations. This is due to the interaction of the galactose side chains of guar molecules combined with water molecules. The increased concentration enhances the inter-molecular chain interaction or entanglement which leads to an increase in viscosity.

The addition of modified tapioca starch (MS) at 1.25 and 1.5% had no effect on liking scores of all attributes ($p\geq0.05$) (Table 5). Statistical analysis showed that the rice porridge with 1.0% modified tapioca starch received the highest sensory scores for appearance, thickness, color, odor, taste, mouthfeel, viscosity, aftertaste and overall liking among all the rice porridge tested ($p<0.05$). Modified tapioca starch had slight impact on viscosity as mentioned in Table 2, thereby the rheological characteristics of the obtained porridge were similar those of control.

Perceived textures of thickened porridges modified with thickeners were important attributes for the elderly with dysphagia especially regarding thickness, viscosity and mouthfeel. Both thickness and viscosity were important in determining the overall texture perception and mouthfeel of the porridge. Thickness referred to the perceived resistance encountered when the porridge was moved or deformed with in the mouth. Factors influencing perceived thickness might result from concentration and particle size, distribution of hydrocolloids in the porridges. Furthermore, viscosity perception refers to how the porridge flows when moved or manipulated in the mouth, and it is directly related to the ease with which the porridge flows. The actual viscosity of the porridge was influenced by the rheological properties especially shear-thinning behavior as shown in Table 2. The temperature of the porridge and presence of oral lubrication directly affected perceived flow or viscosity.

The sensory characteristics of Riceberry rice porridge (RB) are closely linked to its rheological properties. The high viscosity and consistency, along with the high shear resistance provided by 0.25% xanthan gum, 0.25% guar gum, and 1.0% modified tapioca starch, positively influence the overall sensory quality of the rice porridge.

Table 3 Mean acceptance scores of Riceberry porridge fortified with 1.5% PH and 589 mg BC powders with different xanthan gum (XG) concentrations

Type	Concentration (%)	Appearance	Thickness	Color	Odor	Taste	Mouth-feel	Viscosity	Aftertaste
Control	0	6.32 ± 1.81^{b}	6.12 ± 1.95^{b}	6.80 ± 1.52^{b}	6.48 ± 1.63^{b}	6.32 ± 1.88^{b}	6.30 ± 1.93^{b}	5.76 ± 1.95^{c}	6.10 ± 1.94^{b}
Xanthan gum	0.25	7.36 ± 1.41^{a}	7.20 ± 1.41^{a}	7.22 ± 1.66^{a}	7.12 ± 1.61^{a}	7.30 ± 1.43^{a}	7.12 ± 1.48^{a}	7.22 ± 1.41^{a}	7.18 ± 1.12^{a}
	0.50	7.00 ± 1.31^{a}	6.96 ± 1.47^{a}	7.32 ± 1.33^{a}	6.80 ± 1.57^{ab}	6.66 ± 1.49^{b}	6.54 ± 1.96^{b}	6.66 ± 1.78^{b}	6.76 ± 1.69^{a}
	0.75	6.92 ± 1.83^{a}	7.02 ± 1.86^{a}	7.32 ± 1.50^{a}	6.72 ± 1.77^{ab}	6.78 ± 1.81^{b}	6.68 ± 1.65^{ab}	6.70 ± 1.74^{b}	6.76 ± 1.78^{a}

Values are expressed as mean ± S.D., n=50.
Different superscript letters in the same column indicate significant differences ($p<0.05$).
ns: non-significance, Acceptance score: 1=dislike extremely, 5=neither like nor dislike, 9=like extremely.

Table 4 Mean acceptance scores of Riceberry porridge fortified with 1.5% PH and 589 mg BC powders with different guar gum (GG) concentrations

Type	Concentration (%)	Appearance	Thickness	Color	Odor	Taste	Mouth-feel	Viscosity	Aftertaste
Control	0	6.24 ± 1.81^{c}	5.82 ± 1.84^{c}	6.70 ± 1.57^{b}	6.34 ± 1.94^{c}	6.44 ± 1.93^{b}	6.58 ± 1.69^{ab}	5.84 ± 1.99^{b}	6.30 ± 1.87^{c}
Guar gum	0.25	7.46 ± 1.23^{a}	7.12 ± 1.59^{a}	7.36 ± 1.37^{a}	7.08 ± 1.65^{a}	7.08 ± 1.51^{a}	6.94 ± 1.48^{a}	6.96 ± 1.75^{a}	7.18 ± 1.47^{a}
	0.50	7.18 ± 1.55^{ab}	6.96 ± 1.64^{ab}	7.32 ± 1.41^{a}	6.82 ± 1.52^{ab}	6.70 ± 1.72^{ab}	7.02 ± 1.52^{a}	6.86 ± 1.55^{a}	6.82 ± 1.63^{ab}
	0.75	6.86 ± 1.41^{b}	6.46 ± 1.82^{b}	6.96 ± 1.62^{b}	6.62 ± 1.77^{bc}	6.54 ± 1.73^{b}	6.38 ± 2.08^{b}	6.60 ± 1.82^{a}	6.52 ± 1.85^{bc}

Values are expressed as mean ± S.D., n=50.
Different superscript letters in the same column indicate significant differences ($p<0.05$).
ns: non-significance, Acceptance score: 1=dislike extremely, 5=neither like nor dislike, 9=like extremely.

Table 5 Mean acceptance scores of Riceberry porridge fortified with 1.5% PH and 589 mg BC powders with different Modified tapioca starch (MS) concentrations

Type	Concentration (%)	Appearance	Thickness	Color	Odor	Taste	Mouth-feel	Viscosity	Aftertaste
Control	0	5.90 ± 1.94^{b}	5.64 ± 1.99^{b}	6.40 ± 1.97^{ab}	6.04 ± 1.88^{c}	6.22 ± 2.14^{b}	6.06 ± 2.06^{b}	5.92 ± 2.13^{b}	5.82 ± 2.20^{b}
Modified tapioca starch	1.00	6.86 ± 1.83^{a}	6.42 ± 2.03^{a}	6.82 ± 1.96^{a}	6.86 ± 1.69^{a}	6.92 ± 1.82^{a}	6.78 ± 1.66^{a}	6.48 ± 2.05^{a}	6.82 ± 1.89^{a}
	1.25	6.28 ± 1.84^{b}	5.72 ± 2.03^{b}	6.36 ± 2.03^{b}	6.58 ± 1.80^{ab}	6.54 ± 1.63^{ab}	6.54 ± 1.79^{ab}	5.72 ± 2.01^{b}	6.24 ± 1.88^{b}
	1.50	6.14 ± 1.95^{b}	5.76 ± 2.05^{b}	6.46 ± 2.02^{ab}	6.40 ± 1.81^{bc}	6.42 ± 1.94^{ab}	6.42 ± 1.76^{ab}	5.72 ± 2.04^{b}	6.10 ± 1.97^{b}

Values are expressed as mean ± S.D., n=50.
Different superscript letters in the same column indicate significant differences ($p<0.05$).
ns: non-significance, Acceptance score: 1=dislike extremely, 5=neither like nor dislike, 9=like extremely.

4. Conclusion

The addition of hydrocolloids with starch-based or gum-based thickeners in Riceberry rice porridge (RB) fortified with 1.5% protein hydrolysate and 589 mg bio-calcium affected its physical and sensory characteristics. The addition of xanthan gum (XG), guar gum (GG) and modified tapioca starch (MS) could improve textural properties of food leading to safer swallowing for individuals with dysphagia. The addition of 0.25% xanthan gum, 0.25% guar gum, and 1.0% modified tapioca starch to Riceberry rice porridge, along with protein hydrolysate and bio-calcium powders, resulted in the highest level of acceptability. Furthermore, rheological equations can effectively describe the pseudoplastic or shear-thinning behavior of the rice porridge. The flow behavior indexes (n) of all rice porridges were less that 1.0 indicating that the samples were pseudoplastic fluids. The consistency index (K) increased with the increased gum-thickeners. Riceberry rice porridge containing xanthan gum and guar gum at concentrations of 0.25% to 0.75% was classified as having a honey-like consistency according to the National Dysphagia Diet Task Force (NDD) standards in the U.S. In contrast, porridge with modified tapioca starch at concentrations of 1.0% to 1.5% was classified as having a nectar-like consistency.

5. Ethical approval

Ethical approval for the study was obtained from the Human Research Ethics Committee of Prince of Songkla University, Thailand (HSc-HREC: 63-037-1-1).

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7. Author contributions

Pakanun Charoensri: Methodology-review and editing, Validation, Formal analysis, Investigation, Data curation and evaluation, Writing – original draft.; Kongkarn Kijroongrojana: Conceptualization, Validation, Resources, Writing – review and editing, Supervision, Funding acquisition; Sineenath Sukkwai: Investigation, Methodology

8. Conflicts of interest

The authors declare no conflict of interest.

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