ISSN: 2347-467X, Vol. 13, No. (2) 2025, Pg. 826-841

Current Research in Nutrition and Food Science

www.foodandnutritionjournal.org

Development of Nutritionally Balanced Ready-to-Eat Meals in Retort Pouches for Elderly Individuals with Dysphagia and Chewing Difficulties

SUCHADA MAISONT[1], RATSAMEE SANGSIRIMONGKOLYING[2], AKUA KULPRASUTIDILOK[3], JAROENPORN CHOKBORIBAL[4] and WISUTTHANA SAMUTSRI[1]*

[1]Food Science and Technology Program, Phranakhon Rajabhat University, Bangkok, Thailand.
[2]Chemistry Program, Phranakhon Rajabhat University, Bangkok, Thailand.
[3]Department of Health Management Technology, Phranakhon Rajabhat University, Bangkok, Thailand.
[4]Materials Science Program, Phranakhon Rajabhat University, Bangkok, Thailand.

Abstract

This study aimed to develop and evaluate ready-to-eat mixed rice and fish curry products suitable for elderly individuals with chewing and swallowing difficulties. Jasmine rice and Riceberry were combined in varying ratios (4:0, 3:1, 2:2, and 1:3) and subjected to thermal sterilization at 116°C for 35 min (F_o = 6). Steamed fish curry curd was formulated with varying fish-to-egg ratios (42:8, 40:10, 38:12, and 36:14%) and sterilized at 116°C for 40 min (F_o = 6). The International Dysphagia Diet Standardization Initiative (IDDSI) Fork Pressure Test confirmed the suitability of the products for individuals with dysphagia. pH analysis, protein content via the Kjeldahl method, and syneresis analysis were performed to ensure product stability. Color measurement and texture profile analysis (hardness, adhesiveness, cohesiveness, gumminess, chewiness) were conducted. Sensory evaluation with 32 elderly participants assessed acceptability based on a 7-point hedonic scale. Statistical analysis showed significant differences ($P \leq 0.05$) among the various formulations, with optimal texture and sensory properties in the 1:3 rice mixture and 38:12 fish-to-egg ratio. Microbiological analysis confirmed compliance with food safety regulations. The findings support the potential of retorted mixed rice and fish curry as a nutritious, accessible meal option for dysphagia elderly individuals.

Article History
Received: 12 February 2025
Accepted: 26 April 2025

Keywords
Dysphagia;
Elderly Meal;
IDDSI Guideline;
Ready to Eat;
Retort Pouch.

CONTACT Wisutthana Samutsri wisutthana@pnru.ac.th Food Science and Technology Program, Phranakhon Rajabhat University, Bangkok, Thailand

Doi: https://dx.doi.org/10.12944/CRNFSJ.13.2.19

Introduction

The elderly population in Thailand is steadily increasing, rising from 17.6% in 2018 to 20% in 2024.[1] Projections suggest that by 2030 this demographic will constitute 25% of the population. This ageing trend has been accompanied by a rise in chronic illnesses such as dementia, Parkinson's disease, and stroke.[2] Additionally, age-related physiological changes often impair chewing and swallowing abilities, contributing to conditions like dysphagia, a disorder characterized by difficulty swallowing. Dysphagia is prevalent among the elderly, driven by tooth loss, reduced tongue strength, diminished saliva production, and esophagi muscle weakness.[3,4] These impairments can result in severe complications, including aspiration pneumonia and malnutrition due to insufficient food intake.[5-8] Addressing these challenges requires modifying texture and physical properties of food, such as hardness, viscosity, and adhesion. Internationally, various classification systems have been developed to standardize texture-modified foods for individuals with dysphagia, including the National Dysphagia Diet (NDD) in the United States, the texture-modified food standards in Australia, and Japan's Universal Design Foods (UDF). However, inconsistencies in classification systems across countries can lead to confusion. The International Dysphagia Diet Standardization Initiative (IDDSI) was established in 2013 to address this. The IDDSI framework categorizes foods and beverages into standardized levels based on texture and viscosity, ranging from Level 0 (Thin liquids) to Level 7 (Bite-sized foods). This system includes detailed guidelines for testing the consistency of prepared foods using simple tools like spoons and syringes.[9]

Thai jasmine rice, renowned for its aroma and soft texture, is widely consumed domestically and internationally.[10-13] A notable variant is Riceberry, a hybrid of jasmine rice and Hom Nil rice, characterized by its dark purple color and rich nutritional profile. Riceberry contains vitamins and minerals beneficial to health, including vitamin E, vitamin B, iron, calcium, and phosphorus, which support skin health, cognitive function, blood circulation, and bone strength.[14-17]

Hor Mok Pla, or steamed fish curry curd, is a traditional Thai dish that integrates fish, curry paste, coconut milk, and various herbs, steamed within banana leaf pouches. Renowned for its mild spicy flavor and aromatic herbal profile, Hor Mok Pla serves as an appetite stimulant, making it particularly suitable for elderly individuals who may experience reduced appetite or disinterest in repetitive flavors.[18] This dish is nutritionally rich, with fish serving as a source of protein and the incorporated herbs providing antioxidants[19] and other bioactive compounds that promote health.[20,21]

Retort pouches, a flexible and durable packaging solution, allow for the sterilization of foods at high temperatures, like canning. Foods processed in retort pouches can be stored at room temperature without compromising safety or quality, making them ideal for ready-to-eat meals.[22-26]

This study focuses on developing nutritionally balanced, ready-to-eat meals packaged in retort pouches with designed texture-modified diet plans for elderly individuals with chewing and swallowing difficulties under the IDDSI guidance. In addition to prioritizing the nutritional content of recipes in the diet plan, it is important to emphasize preparation methods that balance nutrition with palatability, including appearance, color, flavor, texture, and overall appeal.

Materials and Methods

Materials

The primary raw materials used for producing the ready-made mixed curry include Jasmine Rice (Hong Thong Brand) and Riceberry (Hong Thong Brand). The ingredients for the fish curry wraps, packaged in retort pouches, include red curry paste composed of 16.57% dried chilies, 5.52% dried small chilli pepper, 1.38% galangal, 20.72% lemongrass, 2.30% kaffir lime peel, 29.93% shallots, 11.51% garlic, 0.28% ground roasted coriander seeds, 0.28% ground roasted fennel seeds, 0.46% ground white pepper, 1.84% salt, and 9.21% shrimp paste. All raw materials and ingredients were procured from Siam Makro Public Company Limited.

Preparation of Retorted Mixed Rice

The Riceberry was thoroughly washed and cooked by blanching in hot water at 95°C for 15 min. Following the blanching process, the rice was removed from the water and thoroughly drained. Jasmine rice underwent a similar blanching process in hot water at 95°C for 12 min. After preparation,

the Riceberry and Jasmine rice were combined in varying ratios of 4:0, 3:1, 2:2, and 1:3. The rice mixtures were manually homogenized to ensure even distribution. Each mixture was then packaged into 150 g retort pouches. The pouches were sterilized using a water-spray retort system at 116°C for 35 min, achieving a sterilization value of F_o = 6. The chemical and physical characteristics of the rice mixtures were analyzed, along with consumer acceptance.

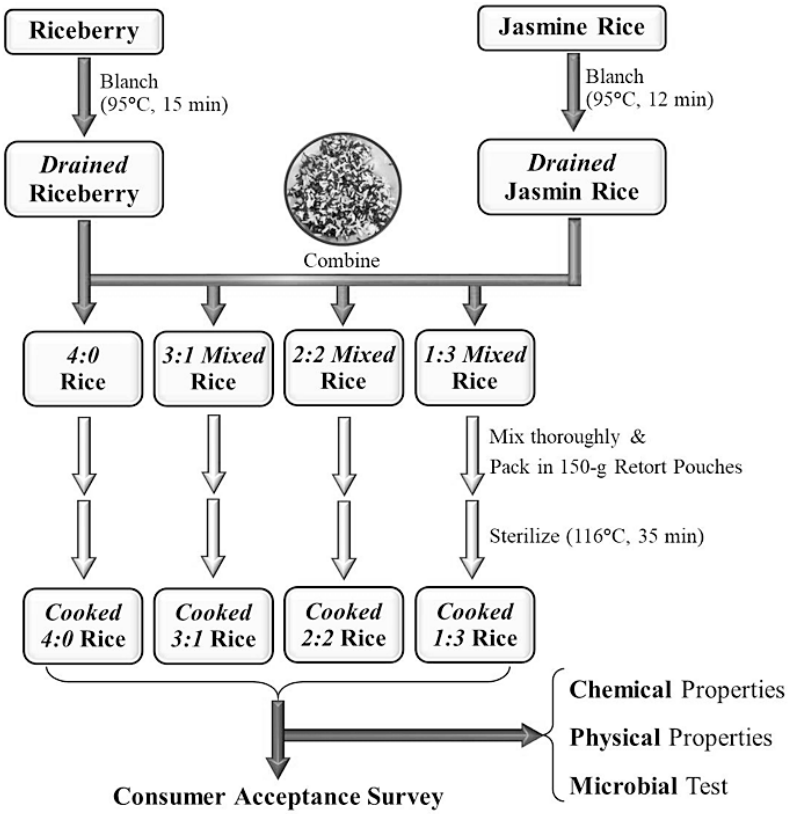


Fig. 1: Flow diagram for preparation of processed retort rice

Preparation of Steamed Fish Curry Curd

The effects of protein supplementation in steamed fish curry curd were investigated by varying the ratios of fish to eggs at four levels: 42:8, 40:10, 38:12, and 36:14%, which collectively accounted for 50% of the total formula volume. The formulation for the steamed fish curry curd included sea bass fillets, egg, UHT coconut milk (24.69%), red curry paste (4.44%), basil (7.41%), shredded kaffir lime leaves (0.30%), rice flour (1.23%), sugar (2.47%), fish sauce (2.22%), salt (0.20%), and water (7.04%). The red curry paste was prepared by grinding dried chilies, galangal, lemongrass, kaffir lime peel, shallots, roasted coriander seeds, roasted cumin seeds, pepper, salt, and shrimp paste. The preparation of the fish begins with the sea bass, which is thoroughly descaled, gutted, washed, and drained. The cleaned fish is then cut into uniform pieces, each measuring no more than 15 × 15 mm. Subsequently, the fish pieces are blanched in boiling water for 5 min, along with galangal, lemongrass, and kaffir lime leaves, to get rid of unpleasant odor. Basil leaves and kaffir lime leaves were carefully washed, drained, and prepared for use. Rice flour was dissolved in water and set aside. Concentrated coconut milk was heated in a pan, and curry paste was stir-fried until aromatic. Subsequently, the remaining coconut milk, eggs, fish sauce, sugar, and salt were added, along with the rice flour solution, basil leaves, kaffir lime leaves, and poached fish. The mixture was brought to a boil to ensure uniform incorporation of all ingredients.

The prepared curd was portioned into 150 g retort pouches and sterilized at 116°C for 40 min. The characteristics of the product were evaluated, and consumer acceptance was analyzed.

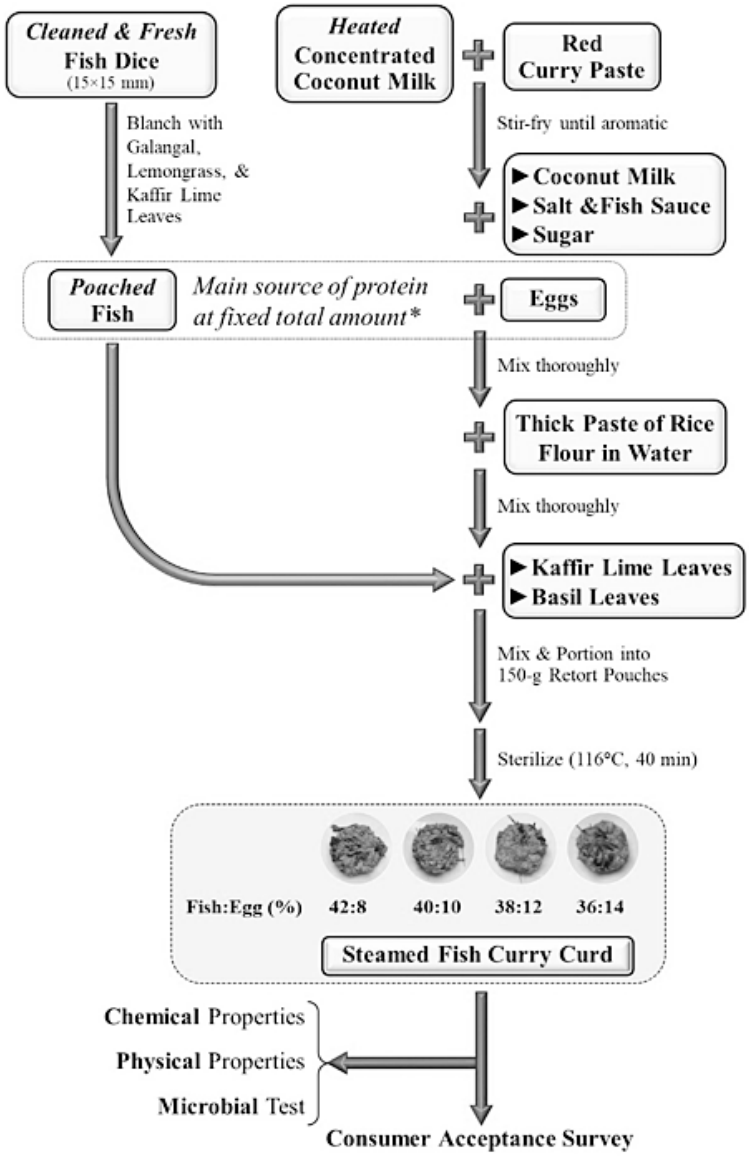


Fig. 2: Flow diagram for preparation of retort processed of steamed fish curry curd

Thermal Processing

Thermal sterilization was performed using a water spray retort sterilizer located at the Faculty of Science and Technology, Phranakhon Rajabhat University, Thailand. The pre-prepared mixed rice was packaged in clear retort pouches with dimensions of 120 × 200 × 35 mm and a weight of 150 g. The pouches were sealed using a heat sealer at 200°C and sterilized at 116°C for 35 min (F_o = 6). Similarly, the prepared fish curry was packaged in aluminum retort pouches with dimensions of 120 × 180 × 35 mm and a weight of 150 g. These pouches were also sealed at 200°C and sterilized at 116°C for 40 min (F_o = 6). During sterilization, the pressure was maintained at 1.7 bar, and a hot water system was employed to ensure consistent heating throughout the process.

The IDDSI Fork Pressure Test

A fork pressure test following the Dietary Guidelines for Individuals with Swallowing Disorders is utilized to assess compliance with the IDDSI food classification system. A fork with a 15 mm-wide front surface and 4 mm prong gap is pressed onto the food sample using thumb pressure from the fork's base to the thumbnail turns pale. This test evaluates the food's behavior under pressure by observing whether it separates easily without reconstituting, indicating suitability for IDDSI Levels 5, 6, and 7 (easy-to-chew textures). The applied pressure, equivalent to 17 kPa, mimics the tongue's force during swallowing, as described by Steele *et al*.[27]

pH Measurement

10 g of cooked rice was mixed with 10 g of distilled water and ground thoroughly. The homogenized mixture was transferred to a 25 mL beaker. For the fish curry wrap sample, 20 g of the sample was ground into a homogeneous consistency and transferred to a separate 25 mL beaker. The pH of each sample was measured using a digital pH meter (FE20, Five Easy Plus, Switzerland). The pH values were recorded following AOAC (2000) 28 standards.

Protein Analysis

The protein substance was analyzed via the Kjeldahl method, following the guidelines established by the AOAC (2000).[28]

Syneresis Analysis

Syneresis analysis, adapted from Haghighi and Reaei,[29] involves the preparation of fish curry samples. Begin by weighing 15 g of the sample and placing it in a centrifuge tube. Centrifuge the sample at a speed of 3000 rpm for 10 min at a temperature of 25°C. Next, increase the speed to 4000 rpm and continue centrifuging for an additional 10 min at the same temperature. Final, the syneresis (%) was calculated using the following formula (Lee and Shin, 2023)[23]

Syneresis (%) = (weight of separated liquid (g) / initial sample weight (g)) × 100.

Color Measurement

Each food sample, weighing 3 g, was put into a petri dish, and enclosed with a clear plastic film. The samples were then evaluated for color using a colorimeter (Minolta, model CR-10, Japan). The color readings were taken at the surface of the sample. The color evaluation was carried out in triplicates based on the technique of Maisont *et al*.[30] The color parameters of the samples were obtained in CIE chromaticity coordinates. The color parameters measured were lightness (L*), redness (a*), and yellowness (b*). Lightness (L*) was determined on a scale of 0-100, where 0 represents black and 100 represents white. Redness (a*) was measured thus that positive values indicate a red undertone, while negative values indicate a green undertone. Similarly, for yellowness (b*), positive values indicated an undertone of yellow, and negative values indicated an undertone of blue. The calorimeter was calibrated using a standard white porcelain plate.

Texture Profile Analysis

Texture measurements of mixed cooked rice will be conducted using a Texture Analyzer (CTX U.S.A. model). This will involve compressing the rice through holes or an extrusion press. The Texture Profile Analysis (TPA) will utilize a sample volume of 30 g. The load cell capacity is 50 kg, with a target position set at 155 mm. The test speed will be 1 mm/s, with a deformation percentage of 30% and a trigger load of 10 g. All force values will be recorded, including hardness and surface adhesion (adhesiveness), and the ability to hold together (cohesiveness), chewiness, and gumminess. An Aluminum Cylinder probe (TA-AACC36) will be used to measure the texture of fish wraps. The sample size will be 3x3x3 cm3. The load cell will also be set at 50 kg, with a target position of 200 mm. The test speed remains at 1 mm/s, with a target distance of 10 mm and a trigger load of 10 g. All measurements will be recorded ten times to ensure accuracy. TPA curves were generated for each sample, and textural parameters such as hardness, adhesiveness, cohesiveness, gumminess, and chewiness were analyzed and defined according to established criteria.[31-33]

- Hardness (g) = Maximum peak force of the first compression
- Adhesiveness = Negative area for the first compression
- Cohesiveness = Ratio of the integrated energy required for the first and second compression

- Gumminess = Hardness x Cohesiveness
- Chewiness = Hardness x Cohesiveness x Springiness

Sensory Evaluation

A sample of 32 participants was purposively selected based on predefined criteria from elderly individuals with chewing and swallowing difficulties residing in Muang Khom Subdistrict, Chai Badan District, Lopburi Province, Thailand. The participants consumed mixed cooked rice paired with fish curry, and the organoleptic qualities of the meal were evaluated based on appearance, color, softness, taste, and overall liking. The study utilized a randomized complete block design (RCBD) along with a 7-point hedonic scale to evaluate sensory attributes. The scale ranged from 1 (dislike extremely) to 7 (like extremely), with intermediate values representing varying degrees of preference: 2 (dislike very much), 3 (dislike moderately), 4 (neither like nor dislike), 5 (like moderately), and 6 (like very much). Data analysis was performed using analysis of variance (ANOVA), and mean differences were assessed through Duncan's New Multiple Range Test (DNMRT). All statistical analyses were conducted using SPSS version 20.0 for Windows.

Research Ethics Certification

This study is a component of a larger research project titled "Development of Ready-to-Eat Food Products to Enhance Nutrition for Elderly Individuals with Chewing and Swallowing Difficulties: A Case Study of the Elderly in Chai Badan District, Lopburi Province." The project was reviewed and approved by the Ethics Evaluation Committee under project number 02.004/67 on June 4, 2024.

Microbiological Analysis

Sealed food samples were submitted for analysis of disease-causing microorganisms, including *Clostridium botulinum*, *Staphylococcus aureus*, and *Salmonella* spp., in compliance with the Ministry of Public Health Notification (No. 416) 2020 (2020)[34] concerning food quality and standards. The analysis of *Clostridium botulinum* was conducted following the FDA-BAM online protocol (2001, Chapter 17),[35] *Staphylococcus aureus* was analyzed according to ISO 6888-1:2020,[36] and *Salmonella* spp. was tested using ISO 6579-1:2017/Amd 1:2020.[37]

Statistical Analysis

The experiment was planned using a Completely Randomized Design (CRD) for chemical and physical quality analysis. All experiments were executed in at least three copies. A Randomized Complete Block Design (RCBD) was employed for sensory evaluation. The means and standard deviations were calculated for each result. A one-way analysis of variance (ANOVA) was conducted using SPSS Statistics 20.0. The differences in mean values ($P \leq 0.05$) were analyzed using Duncan's multiple-range test.

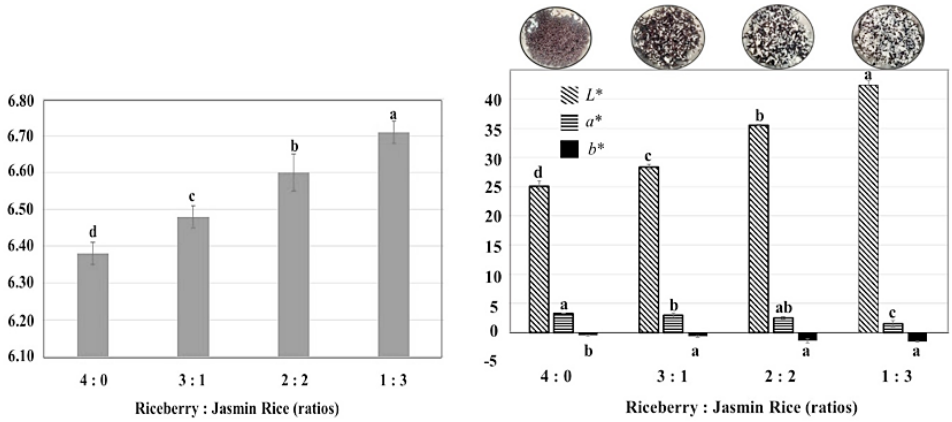
Results

The selected representative foods were commonly consumed in daily life, comprising cooked rice as the staple food and steamed fish curry curd as the meat dish. In the sterilization process, the pouches were sealed with a heat sealer at 200°C and sterilized at 116°C for 35 minutes ($F_o = 6$) for mixed rice, while the steamed fish curry curd was sterilized at 116°C for 40 minutes ($F_o = 6$). Microbiological analysis revealed that *Clostridium botulinum* (per 1g sample), *Staphylococcus aureus* (per 1g sample), and *Salmonella* spp. (per 25g sample) were undetectable for the retorted mixed rice and retorted steamed fish curry curd sealed containers without using a refrigerator (data not shown). The result of thermal processing passed the standard in compliance with the Ministry of Public Health Notification (No. 416) 2020[34] concerning food quality and standards.

Diet for a Standard Portion of Stale Food

The pH of retorted mixed rice ranged from 6.38 to 6.60 (Figure 3), indicating that all samples of retorted mixed rice were non-acidic foods (pH > 4.6). For sterilizing low-acid foods in sealed containers, high temperatures are essential to reduce the number of *Clostridium botulinum* spores.[38,39]

The L*, a*, and b* values of retorted mixed rice were significantly influenced by the varying ratios of Riceberry to Jasmine rice (Figure 3). As the amount of Jasmine rice increased, the L* value also increased, while the a* and b* values decreased. This change is attributed to the deep purple color of Riceberry; when more Jasmine rice, which is white, is added, the overall color intensity decreases.[14,16,17,40]



(a) (b)

Fig. 3: pH (a), L*, a*, and b* (b) of retorted mixed rice

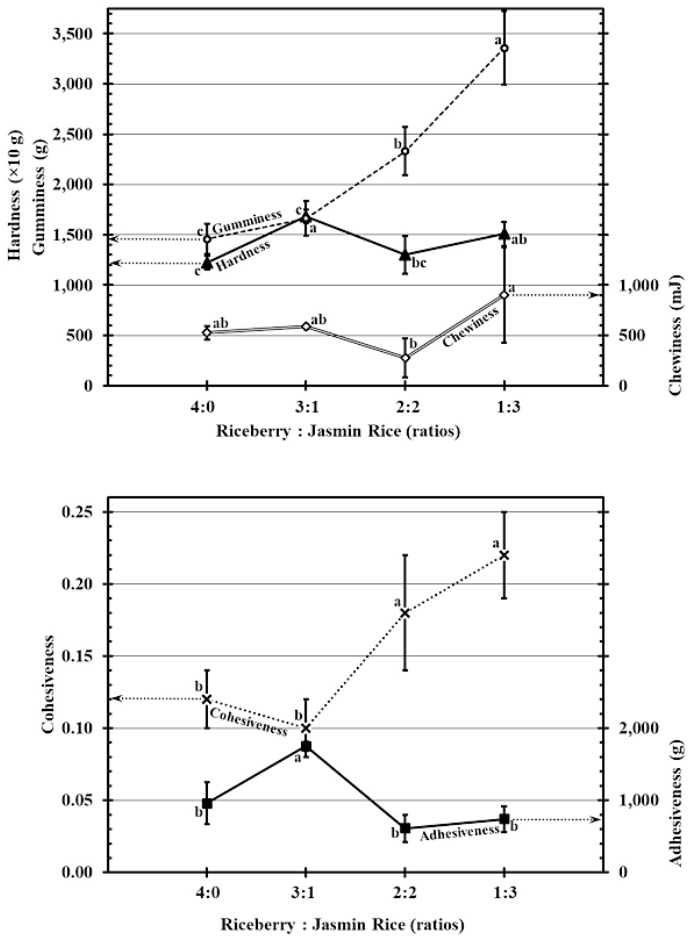


Fig. 4: extural properties of retorted mixed rice

The textural properties of retorted mixed rice are presented in Figure 4. The hardness and adhesiveness ranged from 12,250-16,809 g and 610-1753 g, respectively. It is observed that the

hardness has decreased, whereas the adhesiveness increased with increasing the amount of Jasmin rice. The cohesiveness, gumminess, and chewiness of food samples were reduced by the effects of Jasmin rice. That resulted in a decrease in cohesiveness from 3.27 to 1.50, gumminess from 3,358 to 1,459 g and chewiness from 899 to 526 mJ, respectively, for the whole mixed rice system (Figure 4).

Diet for a Standard Portion of Meat Dish

The effect of fish to egg ratios on color of retorted steamed fish curry curd is shown in Table 1. An increasing amount of egg exhibited a significant increase in lightness (L*) from 53.13 to 54.47 and a substantial decrease in the a* from 21.67 to 17.60 and b* parameters from 35.67 to 32.17. The hardness of retorted steamed fish curry curd was observed using a texture analyzer (Table 1). The texture of retorted steamed fish curry curd varies based on the amount of egg used. Curd made with a lower amount of egg exhibits more hardness compared to curd prepared with a higher amount of egg. The hardness value of retorted steamed fish curry curd typically ranges from approximately 542.33 to 846.33 g. Due to the high protein content in eggs, water retention within the structure of the retorted steamed fish curry curd is enhanced. This improved water retention can influence viscosity or contribute to gel formation in the food formula.[41]

The syneresis of retorted steamed fish curry curd is presented in Table 1. The syneresis ranged from 1.28-5.41%. As the amount of egg added increases, the syneresis of the curd decreases significantly.

Table 2 shows the pH and protein content of retorted steamed fish curry curd. The pH of retorted steamed fish curry curd ranged from 6.34 to 6.37, depending on the ratios of fish to egg. While the pH of the steamed fish curry curd did not show significant changes, the protein content decreased from 13.98% to 12.98%.

Table 1: Textural properties of retorted steamed fish curry curd

Fish:Egg (%)	color			Hardness (g·)	Syneresis (%)
	L*	a*	b*		
42:8	53.13^{c}±0.23	21.67^{a}±0.06	35.67^{a}±0.25	846.33^{a}±22.74	5.41^{a}±0.72
40:10	53.90^{b}±0.10	20.50^{b}±0.26	33.40^{b}±0.53	714.33^{b}±27.57	3.56^{b}±0.17
38:12	54.33^{a}±0.31	19.43^{c}±0.06	32.50^{c}±0.17	655.67^{b}±26.65	3.54^{c}±0.03
36:14	54.47^{a}±0.23	17.60^{d}±0.17	32.17^{c}±0.51	542.33^{c}±48.34	1.28^{d}±0.11

Mean±standard deviation values in the same column with different superscripts are significantly different ($p \leq 0.05$).

Table 2: pH and protein content of retorted steamed fish curry curd

Fish:Egg (%)	pH^{ns}	Protein (%)
42:8	6.36±0.02	13.98^{a}±0.50
40:10	6.36±0.04	13.68^{ab}±0.47
38:12	6.37±0.14	13.34^{ab}±0.63
36:14	6.34±0.09	12.98^{b}±0.15

Mean±standard deviation values in the same column with different superscripts are
significantly different ($p \leq 0.05$).
ns Mean ± standard deviation in the same row with different superscripts are non-significantly different ($p > 0.05$).

The IDDSI Fork Pressure Analysis

The food levels and piece sizes were tested according to IDDSI food standards, resulting in the following findings. Based on the IDDSI fork pressure test, the retorted cooked mixed rice with a ratio of Riceberry to Jasmine rice of 1:3 and retorted steamed fish curry with a ratio of fish to egg of 38:12 was classified as Level 6 (soft food & small pieces) (Data not shown). Thus, the mixed rice with a ratio of Riceberry to Jasmine rice of 1:3 and steamed fish curry curd with a ratio of fish to egg of 38:12 were chosen for further study.

Nutritional Value of The Standard Portion of Stale Food and A Meat Dish

The mixed rice with a ratio of Riceberry to Jasmine rice of 1:3 and steamed fish curry curd with a ratio of fish to egg of 38:12 were chosen to represent typical meal components, ensuring consistency with portion sizes and nutrition patterns for elderly individuals. The nutritional value of the whole food recipe was assessed using the INMUCAL V.4.0 program. The Nutritional value of retorted mixed rice and retorted steamed fish curry curd is presented in Table 3. The diet consisting of standard portions of stale food and meat dishes exceeds the recommended daily intake for Thai people (Thai RDI),[42] for individuals aged 6 years and older, based on an energy requirement of 2,000 calories per day. The recommended criteria include entire carbohydrates at 300 g, protein at 50 g, total fat at under 65 g, saturated fatty acids at under 20 g, cholesterol at under 300 mg, dietary fiber at 25 g, and sodium at under 2,400 mg. Following these guidelines helps ensure a balanced diet that meets nutritional needs.

Table 3: Nutritional value of retorted mixed rice and retorted steamed fish curry curd.

Nutrients	Retorted mixed rice	Retorted steamed fish curry curd
Energy (kcal)	108.11	118.34
Moisture (g)	73.20	63.13
Protein (g)	2.07	9.67
Fat (g)	0.27	5.98
Carbohydrate (g)	24.35	6.45
Dietary fiber (g)	0.32	0.50
Ash (g)	0.11	1.57
Calcium (mg)	1.67	42.14
Phosphorus (mg)	13.82	91.42
Magnesium (mg)	3.80	5.48
Sodium (mg)	5.45	293.25
Potassium (mg)	24.05	138.83
Iron (mg)	0.22	1.05
Copper (mg)	0.03	0.69
Zinc (mg)	0.34	0.44
Beta-Carotene (µg)	6.30	178.10
Retinol (µg)	0.00	30.68
Vitamin A (RAE)	0.53	45.63
Thiamin (mg)	0.04	0.04
Riboflavin (mg)	0.00	0.09
Niacin (mg)	0.33	0.69
Vitamin C (mg)	0.00	1.41
Vitamin E (mg)	67.80	0.11
Vitamin B6 (mg)	0.00	0.03
Vitamin B12 (µg)	0.00	0.09
Sugars (g)	0.01	3.14
Cholesterol (mg)	0.00	71.72

The prescribed dosage was determined using the INMUCAL V.4.0 program.

Figure 5 presents sensory preference scores for foods designed for elderly individuals with dysphagia after sterilization, specifically Riceberry mixed with jasmine rice and steamed fish curry curd (Hor Mok Pla). Panelists' preference levels for the parameters of color, flavor, taste, softness, viscosity, chewability, ease of swallowing and overall liking of retort mixed rice and steamed fish curry curd was analyzed using the Hedonic scale 7-point method. The chosen Riceberry mixed with jasmine rice with a ratio of Riceberry to Jasmine rice of 1:3 received an average preference score of 6.66, attributed to its vibrant color, pleasant aroma, soft texture, and ease of chewing. Similarly, the chosen steamed fish curry curd with a ratio of fish to egg of 38:12 achieved an average preference score of 6.50.

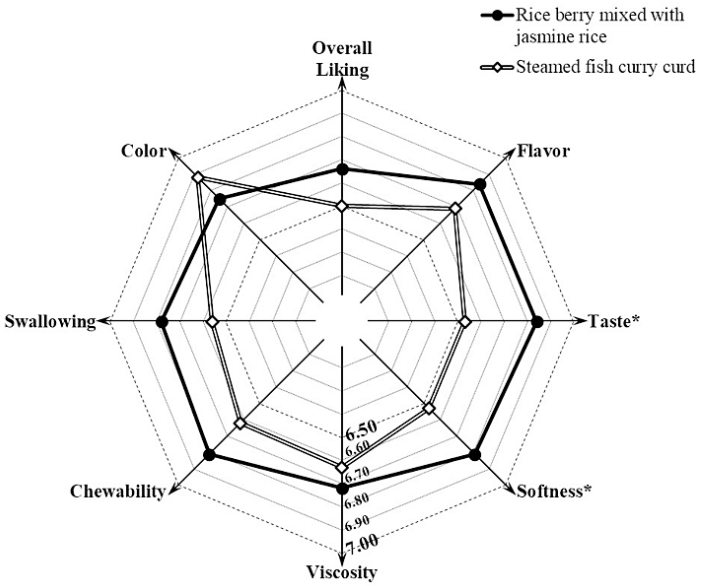


Fig. 5: Sensory evaluation means scores for the retorted mixed rice with a ratio of Riceberry to Jasmine rice of 1:3 and the retorted steamed fish curry curd with a ratio of fish to egg of 38:12

Discussion

Based on the traditional Thai dietary framework: staple food and meat dishes, two standard dishes were selected to represent typical meal components, ensuring consistency with the portion sizes and dietary patterns of individuals. These foods were particularly chosen to align with the dietary habits of Thai elderly folks. They were modified in volume and nutrient density to meet the specific needs of older adults with dysphagia. Following the classification guidelines of the IDDSI, the development of texture-adapted foods adhered to the principle of equivalent food exchange.[23,43]

Chromaticity coordinates L*, a*, and b* describe color properties. The L* coordinate indicates lightness on a scale from 0 to 100, where 0 represents black and 100 represents white. The a* coordinate measures the intensity along the red-green axis; positive a* values indicate a red undertone, while negative a* values indicate a green undertone. The b* coordinate measures intensity along the yellow-blue axis; positive b* values signify a yellow undertone, whereas negative b* values signify a blue undertone.[30] The increased amount of Jasmine rice results in greater lightness, a stronger red undertone, and enhanced blue intensity compared to samples with less Jasmine rice. The higher the addition of egg, the more the brightness of the retorted steamed fish curry curd increases significantly. Additionally, the a* and b* values of the retorted steamed fish curry curd decreased as the amount of egg added increased. The high carotenoid pigments present in the egg yolk contribute to the brightness of the retorted steamed fish curry curd[44] while reducing the red color of the curry paste used in the recipe.

Texture Profile Analysis (TPA) is used to assess various textural attributes through compression. This technique mimics the biting action of the

mouth through a two-cycle compression process and assesses hardness, chewiness, adhesiveness, cohesiveness, and springiness in a single test. The texture-modified foods were designed to mimic the volume of regular food portions typically consumed by the elderly while satisfying nutritional requirements, texture specifications, and sensory appeal. Special emphasis was placed on preserving the taste, appearance, and flavor of the original ingredients to stimulate appetite and promote a pleasurable dining experience. TPA parameters are divided into two categories: primary and secondary. The primary parameters—hardness, springiness, adhesiveness, and cohesiveness—are directly measured from the force/time graph produced during testing. In contrast, secondary parameters—gumminess, chewiness, and resilience—are calculated based on the primary parameters.[45] The reduction in hardness of the mixed rice and the steamed fish curry curd was observed when the amount of Jasmin Rice and egg increased. The cohesiveness, gumminess, and chewiness of mixed rice samples were also diminished by the increase of Jasmin rice. There has been a report that sticky food textures can be insecure for dysphagia patients as they increase the risk of choking and require significant effort to pass through the pharynx.[23] Gumminess, reflecting the force required to break down semi-solid food ready to swallow.[43] have also reported that foods with high gumminess are dangerous because they put dysphagia patients at risk of suffocation. Highly adhesive foods are considered unsafe for dysphagia patients because they require more effort to move from the mouth to the pharynx, thereby increasing the risk of choking.[46] According to a study by Lee and Shin (2023).[23] Patients with dysphagia prefer moist and soft textures, for example, chicken curry mosse. The texture of a meal is its most important attribute, as it relates to the product's rheological properties, which ultimately influence its sensory characteristics and appeal to consumers. Consequently, it is feasible to modify the texture of a product to make it more suitable for the elderly by adjusting the ingredient ratios.

The recipe for the staple food was developed based on traditional Thai cuisine, specifically cooked rice. This study prepared the standard portion of staple food using mixed rice rather than plain jasmine rice. Additionally, Riceberry was incorporated into the rice preparation process to enhance the nutritional profile. This modification aimed to ensure that each portion of the staple food provided an adequate amount of dietary fiber while maintaining compatibility with texture-modified food processing methods.[16] Moreover, the ingredients for each portion of the selected food meat dish were prepared to align with the nutritional requirements and typical meal volumes based on the eating habits of the elderly volunteers. The meat dish chosen for this study was steamed fish curry curd. Adjustments were made to the proportion of eggs in the recipe to ensure the standard portion of the meat dish met the required protein content (Table 2). As a result of the diet for a standard portion of meat dish, this variation provides an appropriate protein level per unit of steamed fish curry curd, supporting the dietary needs of the target population. The fish fillets and eggs were made to 50% of the total steamed fish curry curd recipe. Steamed fish curry curd is usually consumed with rice; however, the consistency at level 5 was too watery to pair well with rice. On the other hand, level 7 was unsuitable because it was too thick for the elderly who have dysphagia and difficulty chewing. Therefore, the experiment was the desired texture of food meal with the level based on IDDSI at 6.

Syneresis is the process in which liquids separate from food, as observed in products like jams and dairy items.[23] The reduction in syneresis of retorted steamed fish curry curd can be attributed to the high content of eggs, which improves water retention within the structure of the curry curd.[47-50] This significant water retention leads to a decrease in syneresis, resulting in less liquid separation from the gel. Thus, the excessive moisture accumulation in the samples, indicates that retorted steamed fish curry curd with high egg content enhances stability during storage.

It is well known that pH directly affects the growth of C. botulinum. The rice pouches were sterilized at 116°C for 30 min (F^{o} = 6). However retort pouch packaging, characterized by its thin and flexible structure, offers a significantly higher surface area-to-volume ratio compared to traditional metal containers. This design enhances the rate of heat penetration into food, allowing for reduced heat exposure during processing while still achieving commercial sterility. Consequently, it minimizes heating time and energy costs, promoting sustainability. Furthermore, this

method preserves the highest quality factors of food products, including flavor, texture, and nutritional value, making it a superior choice for modern food preservation techniques.[51]

The preparation of the food has been improved by modifying the method and reducing the size of the ingredients. Various types of vegetables and pure fish meat have been cut into smaller pieces. For the steamed fish curry curd, the ratio of fish and eggs was optimized to increase the protein content. Additionally, the right balance between Riceberry and jasmine rice was determined for the steamed rice based on the IDDSI standard. The IDDSI method is commonly used to evaluate whether a dysphagia diet is suitable for patients consuming certain foods. The retorted cooked mixed rice, made with a Riceberry to Jasmine rice ratio of 1:3, along with the retorted steamed fish curry, which has a fish to egg ratio of 38:12, was classified as Level 6 (soft food and small pieces) The classification of food level based on the IDDSI test indicates that the food can be pressed into smaller pieces with a fork. Specifically, the food can be broken into pieces about the size of a thumbnail (15×15 mm) using the base of the fork. Once broken, the food cannot return to its original shape.

A comprehensive sensory evaluation revealed high overall preference scores for both foods, mixed rice with a ratio of Riceberry to Jasmine rice of 1:3 and steamed fish curry curd with a ratio of 38:12. Panelists noted that the texture of the food was soft and easy to chew, with a balanced, mellow flavor profile that was neither salty nor spicy, making it suitable for consumption in larger quantities. In terms of texture preference results, participants sensed the retorted fish curry curd as having softness, chewability and easy-to-swallow properties. These results may suggest that elderly individuals prioritize texture over taste or visual appeal. A similar result was observed in the study of Lee and Shin (2023)23.

Conclusion

The development of retorted mixed rice and steamed fish curry curd based on the IDDSI framework successfully produced texture-modified meals suitable for elderly individuals with dysphagia. The study demonstrated that adjusting the ratio of Riceberry to Jasmine rice and fish to egg significantly influenced color, texture, and sensory properties. The selected formulations (1:3 Riceberry to Jasmine rice and 38:12 fish to egg) met IDDSI Level 6 standards, ensuring ease of chewing and swallowing while maintaining nutritional adequacy. Sensory evaluation confirmed high acceptability, highlighting the importance of balancing texture modification with palatability. Overall, the study underscores the potential of retort processing in developing safe, nutritious, and appealing ready-to-eat meals tailored for the aging population.

Acknowledgement

The authors thank Thailand Science Research and Innovation for financial support and Phranakhon Rajabhat University for providing equipment support in this research work.

Funding Sources

This study was financially supported by the Thailand Science Research and Innovation (TSRI) with grant number 02.004/2567

Conflict of Interest

The authors declare no conflict of interest.

Data Availability Statement

This statement does not apply to this article.

Ethics Statement

Project No.02.004/67. The Ethics Evaluation Committee of the Faculty of Science and Technology, Phranakhon Rajabhat University, Thailand.

Informed Consent Statement

Informed consent was obtained for the experimentation, ensuring compliance with the standards currently applied in Thailand. The privacy rights of human subjects were always observed.

Clinical Trial Registration

This research does not involve any clinical trials.

Permission to Reproduce Material from Other Sources

Not Applicable.

Author Contributions

- **Suchada Maisont:** Conceptualization, Funding Acquisition, Data Collection, Analysis, Writing – Review.
- **Ratsamee Sangsirimongkolying:** Supervision, Project Administration.
- **Akua Kulprasutidilok:** Questionnaire, Ethics submission
- **Jaroenporn Chokboribal:** Visualization, Supervision
- **Wisutthana Samutsri:** Methodology, Analysis, Writing Original Draft & Editing.

References

1. Department of Older Persons. Situation of the Thai Older Persons 2023. Bangkok, Thailand: Amarin Corporations Public Company Limited; 2023.
2. World Health Organization. World Health Statistics 2024: Monitoring Health for the SDGs, Sustainable Development Goals. *World Health Organization*; 2024.
3. Ekonomou S. I., Hadnađev M., Gioxari A., Abosede O. R., Soe S., Stratakos A. Ch., Advancing dysphagia-oriented multi-ingredient meal development: Optimising hydrocolloid incorporation in 3D printed nutritious meals. *Food Hydrocoll.* 2024;147:109300. DOI:10.1016/j.foodhyd.2023.109300
4. Cho S. Y., Choung R. S., Saito Y. A., Schleck C. D., Zinsmeister A. R., Locke G.R., Talley N. J., Prevalence and risk factors for dysphagia: A USA community study. *Neurogastroenterol Motil.* 2015;27(2):212-219. DOI: 10.1111/nmo.12467
5. Engh, M. C. N., Speyer, R. Management of dysphagia in nursing homes: Anational survey. *Dysphagia*, 2022;37(2):266–276. DOI:10.1007/s00455-021-10275-7.
6. Schache A., O'Rourke A., Dysphagia. In Evidence-based laryngology 2021:175–195. *StatPearls Publishing.* DOI:10.1007/978-3-030-58494-8_9
7. Smith R., Bryant L., Hemsley B., The true cost of dysphagia on quality of life:The views of adults with swallowing disability. *Int J Lang Commun Disord.* 2023;58(2):451–466. DOI:10.1111/1460-6984.12804
8. Kim D.-S., Iida F., Joo N., Feasibility of elder-friendly food applications of lingonberry (Vaccinium vitis-idaea L.) according to gelling agent as thickening additives. *Int J Food Prop*. 2022;25(1):1862–1874. DOI:10.1080/10942912.2022.2112049
9. Techasukthavorn V., Charoenporn P., Aungsanam P., Standards of A Texture Modified Diet for Elderly and Dysphagia Patients. *Thai JPEN.* 2019;27(2):40–56.
10. Dixon W. R., Morales-Contreras B. E., Kongchum M., Xu Z., Harrell D., Moskowitz H. R., Wicker L., Aroma, Quality, and Consumer Mindsets for Shelf-Stable Rice Thermally Processed by Reciprocal Agitation. *Foods.* 2020;9(11):1559. DOI:10.3390/foods9111559
11. Daygon V. D., Prakash S., Calingacion M., Riedel A., Ovenden B., Snell P., Mitchell J., Fitzgerald M., Understanding the Jasmine phenotype of rice through metabolite profiling and sensory evaluation. *Metabolomics*. 2016;12(63):12–63. DOI:10.1007/s11306-016-0989-6
12. Maleki C., Oliver P., Lewin S., Liem G., Keast R., Preference mapping of different water-to-rice ratios in cooked aromatic white jasmine rice. *J. Food Sci.* 2020;85(5):1576-1585. DOI: 10.1111/1750-3841.15120
13. Sripum C., Kukreja R. K., Charoenkiatkul S., Kriengsinyos W., Suttisansanee U., The effect of extraction conditions on antioxidant activities and total phenolic contents of different processed Thai Jasmine rice. *Int. Food Res. J.* 2017;24(4):1644-1650
14. Salee N., Niranjan K., Cheng Q., Ghawi S. K., Naruenartwongsakuld S., Chaiyana W., Inpramoon A., Utama-ang N., Influence of Thermal Processing Conditions on the Physicochemical Properties, Stability and Antioxidant Activities of Rice Milk containing a Co-Encapsulated Powder of Black Rice and Green Tea. *Food Appl Biosci J.* ;12(3):1-21.
15. Yamuangmorn S., Dell B., Prom-u-thai C., Anthocyanin and phenolic acid profiles in purple, red and non-pigmented rice during

germination. *CMU J Nat Sci.* 2020;19(4):865-878. DOI:10.12982/CMUJNS.2020.0054

16. Chusak C., Pasukamonset P., Chantarasinlapin P., Adisakwattana S., Postprandial Glycemia, Insulinemia, and Antioxidant Status in Healthy Subjects after Ingestion of Bread made from Anthocyanin-Rich Riceberry Rice. *Nutrients.* 2020;12:782. DOI:10.3390/nu12030782
17. Settapramote N., Laokuldilok T., Boonyawan D., Utama-ang N., Physiochemical, Antioxidant Activities and Anthocyanin of Riceberry Rice from Different Locations in Thaland. *Food Appl Biosci. J*. 2018;6:84-94.
18. Chitokkia S., Pruksa S., Pheerakamol J., The Development of Local Food Recipes for Elders with Diabetes in Loei Province. *J. South. Technol.* 2022;15(1):29-38.
19. Siwarungson N, Lertpringkop P. Comparison of antioxidant and anti-aging activities in selected Thai curry pastes and dishes using water extraction and simulation of gastrointestinal digestion In vitro experiments. International. *Int J Food Sci Nutr.* 2016; 1(3):06-09.
20. Siwarungson N., Lertpringkop P., Evaluation of thrombosis in selected Thai curry pastes and dishes using In Vitro experiments. *Int J Food Sci Nutr.* 2016;1 (3):24-26.
21. Siwarungson N., Lertpringkop P., Evaluation of Fibrinolytic activity in selected Thai curry pastes and dishes using In vitro experiments. *Int J Food Sci Nutr.* 2016; 1(3):27-29
22. Wiriyawattana P., Quality Improvement of Marinated Pork Stew in Retort Pouch for the Elderly. *Current Applied Science and Technology.* 2021;21(4):698-711.
23. Lee E-B., Shin W-S., Physicochemical and sensory properties of retort chicken curry mousse fortified with branched-chain amino acids for the elderly. *LWT.* 2023;185(4):115133. DOI: 10.1016/j.lwt.2023.115133
24. Abhishek V., Kumar R., George J., Nataraju S., Lakshmana J. H., Kathiravan T., Madhukar N., Nadanasabapathi S., Development of retort process for ready-to-eat (RTE) soy-peas curry as a meat alternative in multilayer flexible retort pouches. *Int Food Res J.* 2014;21(4):1553–1558.
25. Bepary R. H., Wadikar D., Vasudish C., Semwal A., Sharma G., Ranking based formula optimization, quality investigation, and real-time shelf-life prediction of ready-to-eat ricebean (Vigna umbellata) curry. *J Food Sci Technol.* 2022;59(11):4390–4404. DOI:10.1007/s13197-022-05519-9
26. Bindu J., Ravishankar C., Gopal T. S., Shelf life evaluation of a ready-to-eat black clam (Villorita cyprinoides) product in indigenous retort pouches. *J Food Eng.* 2007;78(3):995–1000. DOI:10.1016/j.jfoodeng.2005.12.040
27. Steele C. M., Molfenter S. M., Pe´ladeau-Pigeon M., Polacco R. C., Yee C., Variations in Tongue-Palate Swallowing Pressures When Swallowing Xanthan Gum-Thickened Liquids. *Dysphagia*. 2014;29:678-684. DOI 10.1007/s00455-014-9561-6
28. AOAC International, Official methods of analysis of the association of official analytical chemists: Official methods of analysis of AOAC International (17th ed), AOAC International, Washington DC, 2000.
29. Haghighi M., Rezaei K., General Analytical Schemes for the Characterization of Pectin-Based Edible Gelled Systems. *The Scientific World Journal.* 2012;2012:967407. DOI: 10.1100/2012/967407.
30. Maisont S., Samutsri W., Putthongsiri P., Effects of encapsulation substances on drying of gac fruit: physicochemical properties and storage stability. *Research Journal Phranakhon Rajabhat: Science and Technology.* 2024;19(2):93-108.
31. Samutsri W., Thimthuad S., Optimizing Young Jackfruit (Artocarpus heterophyllus Lam.) Processing for Plant-Based Meatballs: Impact of Thermal Treatments on Quality Parameters and Organoleptic Properties, *International Journal of Food Science,* 2025; 2025(1):2106508. DOI:10.1155/ijfo/2106508.
32. Schreuders F. K. G., Schlangen M., Kyriakopoulou K., Boom R. M., van der Goot A. J., Texture methods for evaluating meat and meat analogue structures: A review. *Food Control,* 2021;127:108103. DOI:10.1016/j.foodcont.2021.108103.
33. Wang X., Rong L., Shen M., Yu Q., Chen Y., Li J., Xie J., Rheology, Texture and Swallowing Characteristics of a Texture-Modified Dysphagia Food Prepared Using Common Supplementary Materials.

Foods. 2023;12(12):2287. DOI:10.3390/foods12122287.

34. Notification of the Ministry of Public Health on the regulation for microbial (No. 416) B. 2020. (2020). The Ministry of Public Health.
35. FDA. Chapter 17: *Clostridium botulinum*. In: Bacteriological Analytical Manual (BAM). *U.S.A. Food and Drug Administration;* 2001: Available at: https://www.fda.gov/food/laboratory-methods-food/bam-1.
36. ISO. 6888-1:2020. Microbiology of food and animal feeding stuffs - Horizontal method for the enumeration of coagulase-positive staphylococci (*Staphylococcus aureus* and other species) -Part 1: Technique using Baird-Parker agar medium. *International Organization for Standardization;* 2020:Available at: https://www.iso.org/standard/72857.html.
37. ISO. 6579-1:2017/Amd 1:2020. Microbiology of the food chain-Horizontal method for the detection, enumeration and serotyping of *Salmonella* spp.- Part 1: Detection of *Salmonella* spp. *International Organization for Standardization*; 2020: Available at: https://www.iso.org/standard/66269.html.
38. Wiruch P., Naruenartwongsakul S., Chalermchart Y., Textural Properties, Resistant Starch, and *in Vitro* Starch Digestibility as Affected by Parboiling of Brown Glutinous Rice in a Retort Pouch. *Curr Res Nutr Food Sci.* 2019;07(2):555-567. DOI:10.12944/CRNFSJ.7.2.24
39. Praharasti A. S., Nugroho J., Rahardjo B., Nurhikmat A. Evaluation for sterilization of rendang packaged by flexible retort pouch using finite difference method. *International Symposium on Air Breathing Engines Proceedings.* 2016; 9-11 August 2016, C03-1-7.
40. Poosri S., Thilavech T., Pasukamonset P., Suparpprom C., Adisakwattana S., Studies on Riceberry rice (Oryza sativa L.) extract on the key steps related to carbohydrate and lipid digestion and absorption: A new source of natural bioactive substances. *NFS Journal.* 2019;17:17-23. DOI: 10.1016/j.nfs.2019.10.002
41. Nurrahman, Suyanto A., Ayuningtyas R. A., Yonata D., Physicochemical and Sensory Characteristics of Instant Pumpkin Soup with Variations of Porang Flour as A Thickener. *Current Research in Nutrition and Food Science.* 2024;12(2):730-739. DOI: 10.12944/CRNFSJ.12.2.19.
42. Notification of the Ministry of Public Health (No. 445) B.E. 2566 (2023) Issued By the Virtue of Food Act B.E. 2522 (1979) Re: *Nutrition Labelling.*
43. Malouh M. A., Cichero J. A. Y., Manrique Y. J., Crino L., Lau E. T. L., Nissen L. M., Steadman K. J., Are medication swallowing lubricants suitable for use in dysphagia? Consistency, viscosity, texture, and application of the international dysphagia diet standardization initiative (IDDSI) framework. *Pharmaceutics*, 2020;12(10):924. DOI:10.3390/pharmaceutics12100924.
44. Réhault-Godbert S., Guyot N., Nys Y., The Golden Egg: Nutritional Value, Bioactivities, and Emerging Benefits for Human Health. *Nutrients.* 2019;11:684. DOI:10.3390/nu11030684
45. Novaković S., Tomašević I., A comparison between Warner-Bratzler shear force measurement and texture profile analysis of meat and meat products: a review. *IOP Conf Ser: Earth Environ Sci.* 2017;85:012063. DOI:10.1088/1755-1315/85/1/012063
46. Liu Z., Bhandari B., Guo C., Zheng W., Cao S., Lu H., Mo H., Li H., 3D printing of shiitake mushroom incorporated with gums as dysphagia diet. *Foods,* 2021;10(9):2189. DOI:10.3390/foods10092189.
47. Lai K. M., Chuang Y. S., Chou Y. C., Hsu Y. C., Cheng Y. C., Shi C. Y., Chi H. Y., Hsu K.C., Changes in physicochemical properties of egg white and yolk proteins from duck shell eggs due to hydrostatic pressure treatment. *Poult Sci.* 2020;89(4):729-737. DOI:10.3382/ps.2009-00244
48. Puglisi M. J., Fernandez M. L., The Health Benefits of Egg Protein. Nutrients. 2022;14(14):2904. DOI:10.3390/nu14142904
49. Matsuoka R., Sugano M., Health Functions of Egg Protein. *Foods*. 2022;11:2309. DOI: 10.3390/foods11152309
50. [Koç M., Koç B., Susyal G., Yilmazer M. S., Ertekin F. K., Bağdatlıoğlu N., Functional and physicochemical properties of whole egg powder: effect of spray drying conditions. *J Food Sci Technol.* 2010;48(2):141–149.

DOI:10.1007/s13197-010-0159-1

51. Gulcimen S., Ozcan O., Çevik S. B., Kahraman K., Uzal N., Comparative life cycle assessment of retort pouch and aluminum can for ready-to-eat bean packaging. *J. Mater Cycles Waste Manag*. 2023;25(2):3723–3733. DOI:10.1007/s10163-023-01791-9