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Physicochemical and sensory properties of retort chicken curry mousse fortified with branched-chain amino acids for the elderly

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ABSTRACT

Although retort sterilization is effective in high-temperature sterilization of special nutritional products, its effect on sensorial and nutritional properties after sterilization has not been proven. The purpose of this study was to develop a BCAAs fortified chicken curry mousse (CCM) for the elderly that is easy to chew, swallow, and convenient to cook and consume at home. Additionally, it was to investigate the effect of retort processing on the sensory satisfaction and nutritional formula of the products. A viscosity thickener was added to set the thickener concentration based on the fork drip test of the International Dysphagia Diet Standardization Initiative. CCM was retort-treated at 121 °C for 30 min to evaluate its physicochemical (color, viscosity, rheology, texture, syneresis, pH, and amino acid analysis) and sensory properties. The viscosity decreased and texture changed smoothly after retorting, and the color became darker. The syneresis and pH of the retorted mousse showed fewer changes than the non-retorted during 12 days. Retorted products were increased the BCAAs, and scored high in overall acceptance in the sensory evaluation. Therefore, the BCAAs-enriched retort CCM developed in this study is expected to hedonically appeal to the elderly as well as benefitting their muscle health and nutrition.

1. Introduction

As an individual's age increases, similar to other muscle-using activities, their mastication movement declines, and muscle fatigue occurs, which decreases one's bite force and tongue movement (Kohyama et al., 2003). For this reason, the elderly prefer to eat soft foods that are easy to chew and swallow which, incidentally, may result in fewer calories consumed. If this eating pattern persists in old age, the elderly are at a higher risk of nutritional deficiencies, as their energy and nutrient requirements are less likely to be fulfilled (Forstner & Rusu, 2015, pp. 24–27). Aged populations, therefore, must eat high-quality meals to ensure that their basic nutritional needs are met.

People tend to consume ready meals to avoid the physical and mental energy necessary for preparing meals and cleaning (Scholliers, 2015). In Korea, a significant majority of the elderly, approximately 87.8%, express a preference for ready-to-eat (RTE) or ready-to-heat (RTH) cooked meals (Jang & Lee, 2017). RTE meals are packaged food products that "have a basic level of sensory and nutritional quality" for immediate consumption after opening without any additional processing (Abhishek et al., 2014; Bindu et al., 2007). RTH meals, on the other hand, can be consumed by heating them up. To ensure their long-term storage, RTE meals undergo sterilization processing, with one commonly employed method being the retort process. Retort processing has gained popularity for its ability to stabilize and preserve these types of food products, leading to a rapid commercial adoption due to its convenience, safety, and reliability (Abhishek et al., 2014).

However, food intended for the elderly should not only be convenient but also promote health and well-being. One way to increase nutritional quality is by adding branched-chain amino acids (BCAAs: leucine, valine, isoleucine), essential amino acids involved in protein synthesis, which have proven to be effective in reducing the effects of sarcopenia (Le Couteur et al., 2020). BCAAs have also been reported to improve muscle mass and function in the malnourished elderly (Buondonno et al., 2020). Despite the advantages of BCAAs, they are difficult to consume owing to their uniquely bitter taste. According to Bepary et al. (2022), since curry was highly preferred among consumers, so it was used to mask this taste. Moreover, according to previous study (Wolfe, 2017), consuming BCAAs alone without other amino acids does not effectively increase protein synthesis. Therefore, due to the necessity of consuming BCAAs alongside other high-quality proteins, we utilized chicken breasts, a source of high-quality protein, to develop an elderly-friendly and BCAAs-enriched curry.

Dysphagia refers to a swallowing disorder in which patients are at

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Abbreviations

BCAAs	branched-chain amino acids
CCM	chicken curry mousse
IDDSI	International Dysphagia Diet Standardization Initiative
KS	Korean industrial standards

risk of aspiration when consuming non-viscous foods that can pass into their bronchial tubes (Kim et al., 2022). Therefore, meals designed for the elderly should have an appropriate level of viscosity to minimize such risks. In this study, BCAAs-enriched chicken curry was ground with a blender and a viscosity thickener was added to achieve a mousse-like texture. The international dysphagia diet standardization initiative (IDDSI) developed the IDDSI framework to present a standardized system that aids patients with dysphagia in consuming different food textures, according to the severity of their symptoms. The IDDSI framework consists of eight levels (0–7), where levels 0–4 include drinks and levels 3–7 relate to solid foods (Initiative, 2019). Specifically, level 3 represents a liquid texture, while level 4 represents a puree texture. In addition, the Ministry of Food and Rural Affairs in Korea classifies information on the hardness of chewable foods for the elderly as the Korean Industrial Standard (KS). The first grade corresponds to tooth, the second to gum, and the third to tongue.

Previous studies have analyzed the effects of retort treatment on curry (Abhishek et al., 2014; Bepary et al., 2022; Gopal et al., 2001; Rajkumar et al., 2010), but to the best of our knowledge, few scientific studies add nutrients to curry and adjust the texture for the elderly to easily chew and swallow. Moreover, the existing literature on product development utilizing BCAAs is also inadequate. Hence, the primary objective of this study was to enhance the storage stability of BCAAs-enriched CCM products, aiming to create a novel food product that caters to the dietary and nutritional requirements of the elderly population. The effects of retort treatment on the CCM fortified with BCAAs were demonstrated through syneresis, color, viscosity, rheology, texture, pH, amino acid content, and sensory attributes before and after processing.

2. Materials and methods

2.1. Materials

The ingredients used in the preparation of chicken curry are presented in Table 1. All the ingredients were purchased from E-mart (Seoul, Korea), except for the BCAAs powder and viscosity thickener (softia-G), which were sourced from Nutricost and Nutri, respectively. The BCAAs powder contained no other ingredients and was unflavored. Similarly, the viscosity thickener (a commercial product) consisted of dextrin, xanthan gum, guar gum, and other components, and exhibited unflavored characteristics.

Table 1
Ingredient composition of the chicken curry mousse.

Ingredient	Composition (%)	Manufacturer
Chicken breast	24	No brand, Korea
Butter	5.5	Peackock, Korea
Onion	8.5	Fresh
Potato	8.5	Fresh
Carrot	5.5	Fresh
Curry powder	4	Ottogi, Korea
Water	40	
BCAA	2	Nutricost, USA
l-Leucine	1	
l-Isoleucine	0.5	
l-Valine	0.5	
Viscosity thickener	2	Nutri, Japan

2.2. Chicken curry mousse cooking procedure

Potatoes, onions, and carrots were sliced to approximately 2 mm thickness. Chicken breast was cubed, and butter, chicken breast, potatoes, onions, and carrots were combined in a pan and cooked until the carrots were fully done. Water and curry powder were added and boiled at 90 °C for 30 min. After boiling, purified water was added to compensate for any evaporation, and the mixture was allowed to cool to 30 °C. The viscosity thickener and BCAAs powder were added to the cooled material and blended in a masterpiece collection blender (Electrolux, China) for 3 min. The resulting ground chicken curry was subjected to sterilization by heating at 90 °C for 30 min, and purified water was added again to compensate for any evaporated water. The CCM was prepared for the experiment by manufacturing a total of 2000 g, with 1000 g of samples subjected to retort processing and 1000 g of samples left untreated. More detailed information about the experimental steps can be found in Fig. 1.

2.3. Thermal processing

Thermal processing was conducted using an autoclave located at the Department of Food & Nutrition, College of Human Ecology, Hanyang University, Korea. The retort pouches used had dimensions of 16 cm × 19 cm. Each pouch was filled with 100 g of the mousse and sealed by removing air at a temperature of 200 °C for 30 s. The retort temperature was set at 121 °C for 30 min, and pressure was maintained at 200 ± 50 kPa throughout the entire process using steam while heating.

2.3.1. Sample preparation

In section 2.3, after the retort process, the basic samples for each experiment consisted of two types: retorted CCM and non-retorted CCM. To investigate the storage stability of the samples, syneresis and pH were observed over 0, 3, 6, 9, and 12 days. All the samples were stored in a temperature controlled chamber (Hanbaek scientific Co., Gyeonggi-do, Korea) set at 20 ± 1 °C for storage period analyses. In addition, the whole experiment was performed in triplicate.

2.4. The international dysphagia diet standardization initiative (IDDSI) fork drip test

In this study, the IDDSI fork drip test was used to determine the level corresponding to the IDDSI framework depending on the concentration of the viscosity thickener, and to set the concentration of the suitable viscosity thickener promotion for the CCM. Viscosity thickener was added at concentrations of 1, 2, 3, and 4%. The fork drip test was used to analyze the "pure" texture that can be applied consistently to paste-like foods that do not require a chewing process. Based on the results of the fork drip test, the concentration of the viscosity thickener to be added to the CCM was set. For Level 3, the viscosity was equal to that of fruit syrup, meaning that the food could be drunk from a cup, and the food flowed slowly between the prongs of the fork. For Level 4, which corresponds to pureed or thick-textured food, the material should not flow down between the prongs of the fork when the food is lifted and should be fixed in a slightly mound-like shape on the fork (Fig. 2; (Cichero et al., 2017).

2.5. Physical properties

2.5.1. Color

The color analysis of the CCM before and after retort treatment was conducted using a CR-400 Chroma Meter (Konica Minolta, Tokyo, Japan). For each sample, 6 g was placed in a 35 mm diameter Petri dish. Prior to the analysis, the instrument was calibrated using a white standard ceramic tile (Reference No. 1353123, with Y = 92.7, x = 0.3133,

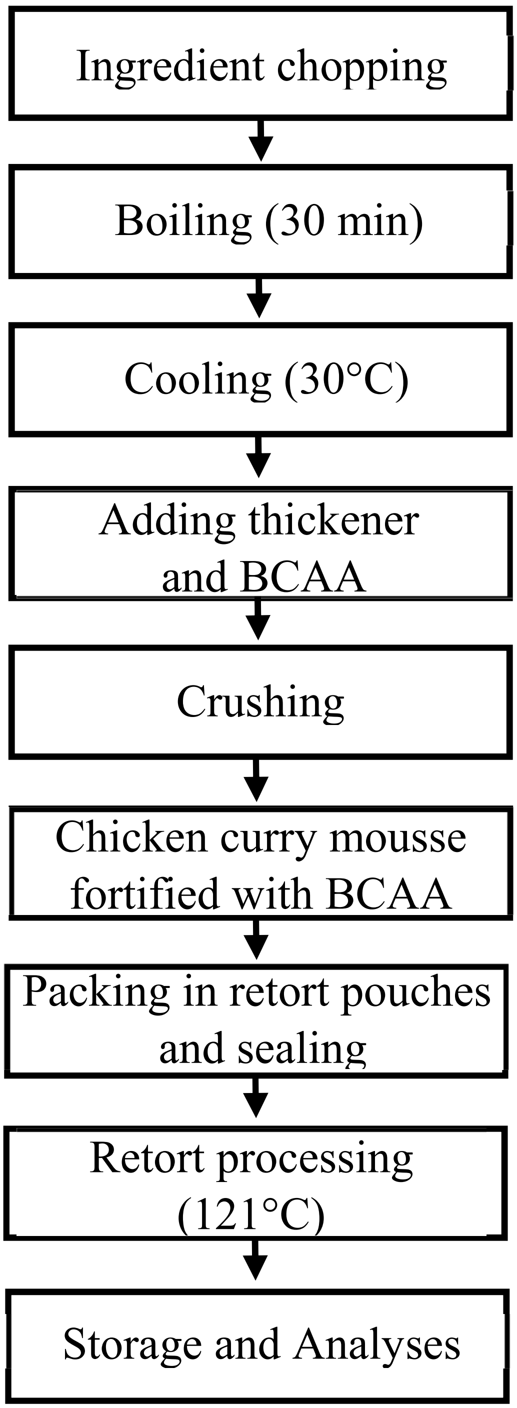

Fig. 1. Flow diagram for preparation of retort processed chicken curry mousse.

and y = 0.3193) The L* value represents the lightness of the sample, with a range from 0 (black) to 100 (white). The a* value indicates redness (+a*: redness, - a*: greenness), while the b* value represents yellowness (+b*: yellowness, - b*: blueness).

2.5.2. Analysis of viscosity

Viscosity was measured using the DV2T viscometer (AMETEK Brookfield, USA), calibrated to measure the "thickness" of the liquid at a given point in time (Garcia et al., 2005). Viscosity was calculated for a shear rate of 50 s^{-1}, which typically represents human swallowing (Garcia et al., 2010). Measurements were taken before and after retort treatment for different concentrations of the viscosity thickener (1/2/3/4%). Each 200 g sample was measured in triplicate at a temperature of 35 °C (±2 °C). By maintaining consistent temperature and shear rate conditions, comparisons were made among the samples and also with the viscosity ranges specified in the Korean industrial standards (KS). KS is divided into product properties, hardness, and viscosity, and consists of three grades. The viscosity is not defined in the first or second grades, but only the third grade, and it is set to an appropriate viscosity (≤1500 mPa s) in consideration of the physical characteristics of the elderly chewing and swallowing difficulties (Kim et al., 2022).

2.5.3. Rheological measurements

The rheological properties of the CCM by retort treatment were evaluated by measuring frequency sweep using a rotational rheometer. This was performed using a controlled-stress rheometer (TA instruments, Discovery HR-20 hybrid, New Castle, DE, USA) equipped with a parallel plate sensor (40 mm diameter, 1 mm gap) at a frequency range of 0.1–10 Hz with a constant deformation (0.5% strain) within the linear viscoelastic range (Chen et al., 2018). The software TRIOS 5.1.1 (TA Instruments, New Castle, DE, USA) was used for data analysis. This process obtained a mechanical spectrum in which the storage modulus (G′) and loss modulus (G″) were recorded as functions of the frequency (Hz) in triplicate.

2.5.4. Texture profile analysis (TPA)

To analyze the effect of retort treatment on the texture of the CCM, a method based on the analysis of chocolate mousse texture was employed (Cardarelli et al., 2008). TPA was conducted in triplicate to measure hardness, adhesiveness, cohesiveness, and gumminess using a TMS-Pilot Food Texture Analyzer 9 (Food Technology Corporation, Sterling, VA, USA). The texture parameters defined by Szczesniak (2002) were calculated using the TPA program. Individual mousse cups containing 30 g of the product were penetrated to a depth of 25 mm at a speed of 1 mm s^{-1} using a 250 N load cell and a 25 mm diameter aluminum cylinder probe. The probe then returned to the starting point at the same speed. The test involved a 50% deformation and a trigger force of 0.15 N.

2.5.5. Syneresis

For the syneresis experiment, the samples were prepared as described in section 2.3.1. The mousse was placed into a centrifuge tube, with each tube containing 15 g of the sample. Centrifugation was performed at 3000 rpm for 10 min at 25 °C, followed by an additional centrifugation at 4000 rpm for 10 min at 25 °C. After centrifugation, the liquid separated from the mousse was carefully removed, and the weight of the remaining mousse was measured. The syneresis (%) was then calculated using the following equation (Haghighi & Rezaei, 2012).

$$\text{Syneresis}\ (\%) = \frac{\text{Total weight of liquid separated mousse (g)}}{\text{Total weight of the mousse sample (g)}} \times 100$$

2.6. Chemical properties

2.6.1. pH

For the pH experiment, the samples were prepared as described in section 2.3.1. For this experiment, a 5 g sample was homogenized with 5 mL of distilled water for 1 min, and the pH was measured using a benchtop pH meter (Hanna Instruments HI5221-01, Woonsocket, RI, USA).

2.6.2. Analysis of branched-chain amino acids (BCAAs)

Amino acid analysis was conducted using an amino acid automatic analyzer to assess the amino acid composition before and after retort treatment. Amino acid analysis was conducted according to the Food Code of the Ministry of Food and Drug Safety (MFDS, 2022), and each sample was prepared in 50 g quantities. A standard solution was diluted with 0.02 N HCl of the standard stock solution (Amino Acids Mixture

Fig. 2. Levels of texture modified food (diet level 3 and 4) modified from the international dysphagia diet standardization initiative framework fork drip test, Version 2.0. Source: International Dysphagia Diet Standardization Initiative (IDDSI), 2019.

Standard Solution Type AN-II, Type B) to a suitable concentration. An Ion exchange resin #2622 PF, 4.6 mm I.D. 60 mm column was used. The moving phase consisted of a ninhydrin solution (R1), buffer solution for the ninhydrin-derived compound (R2), 5% ethanol (R3), buffer for the biological fluid PF-1 KANTO (PF-1), PF-2, PF-3, PF-4, and PF-RG. The flow rate of pump 1 was 0.350 mL/min, and that of pump 2 was 0.300 mL/min. The UV detector was set to 570 nm and 440 nm, and the main column temperature was 38–70 °C, reaction column 135 °C: The amount of sample injected was 20 L.

For sample pretreatment, paste samples underwent water extraction. Approximately 1 g of the homogeneous sample was precisely attached, and 10 times the amount of water was added, heated in a boiling water bath, solidified, and filtered to remove the water layer. The residue was washed three times with a small amount of water, and the detergent was combined with the previous water. The dissolved residue was obtained by concentrating and drying the water layer under reduced pressure in 0.02 N hydrochloric acid to obtain a test solution. The insoluble matter was then filtered through a membrane filter.

2.7. Sensory evaluation

Sensory evaluation tests were conducted to determine the effect of the retort process on the sensory characteristics of the CCM. Participants were recruited through voluntary participation at the Senior Welfare Center in Yongsan-gu, Seoul. The target population comprised healthy elderly individuals without cognitive impairments. The test was performed on 18 subjects (3 men and 15 women) aged between 61 and 91 years, considering the dropout rate (10%). Each participant received 10 g of the sample at a temperature of 35 °C, which was distributed in a white paper cup labeled with a 3-digit random number code. The sensory evaluation employed an acceptance test, where two samples were presented to each participant in a random order to minimize the influence of sequencing. Participants used a teaspoon to taste the samples and assigned scores ranging from 1 point (extreme dislike) to 9 points (extreme like) on a 9-point hedonic scale (Zargaraan et al., 2015). The color, bitterness, odor, smoothness, adhesiveness, cohesiveness, and overall acceptability of each sample were evaluated. Prior to the experiments, detailed explanations of these terms were provided to the elderly participants. Adhesiveness referred to the degree of mousse sticking to the mouth, while cohesiveness reflected the tendency of the mousse to clump together in the mouth. Higher scores (9 points) were given when the mousse exhibited greater adhesion or clumping.

2.8. Statistical analysis

The results are shown as the mean ± standard deviation of the triplicate tests. Statistical analyses were performed using SPSS software (version 27.0; SPSS Inc., Chicago, IL, USA). The data were analyzed through one-way analysis of variance (ANOVA) and t-tests. Statistical significance was confirmed at the 95% confidence level using Duncan's post-analysis ($p < 0.05$).

3. Results and discussion

3.1. Determination of the thickener concentration based on the IDDSI fork test

IDDSI tests are widely used to assess whether a dysphagia diet is appropriate for patients consuming a particular food. When a 1% thickener was included, the sample flowed between the fork prongs, indicative of a level 3 sample, whereas samples with 4% thickener formed a short tail below the fork and corresponded to level 4. The concentrations of 2% and 3% were intermediate (Fig. 3). Highly adhesive foods have been reported to be unsafe for dysphagia patients because they require greater efforts to deliver and consume from the mouth to the pharynx, thus increasing the risk of choking (Liu et al., 2021). According to a study by Choi et al. (2021), dysphagia patients prefer moist and soft textures, such as puddings and purees. However, patients stated a reduced preference for this level of viscosity because artificially adding viscosity thickener to existing foods creates unique slipperiness and changes the characteristics of the food. Chicken curry is typically consumed with rice, but the viscosity of level 3 was too watery to be eaten with rice. In contrast, level 4 was not appropriate because it was too thick. Therefore, the experiment was conducted with a viscosity thickener content set at 2%.

3.2. Effect of retort sterilization on physical properties

3.2.1. Changes in color

The effect of retort treatment on the color of the CCM is shown in Table 2. Retort processing leads to changes in the color properties of the samples, which can influence consumer perceptions. After undergoing retort sterilization, the sample exhibited a significant decrease in lightness (L*) and an increase in the a* parameter, while the b* value decreased. These changes were statistically significant ($p < 0.05$). Similar findings have been reported by Yeoh et al. (2014), where retort treatments generally resulted in decreased L* and b* values, and increased a* values. These color changes can be attributed to the addition of BCAAs and the thermal processing. Mayer-Miebach et al. (2005) reported that isomerization begins under non-oxidizing conditions when homogenized carrots are heated above 100 °C. Moreover, the thermal processing of the CCM may have increased the value of a* because the lycopene pigment of carrots was better extracted because of the pyrolysis pigment (Anese et al., 2002). During thermal processing, the free amino groups of the proteins in the CCM may react with the reducing sugars. This was a Maillard reaction, indicating that the lightness decreased, while the a* increased by non-enzymatic browning. Consequently, these changes may contribute to alterations in the texture and taste of the food (Starowicz & Zieliński, 2019).

Table 2
Color and texture characteristics of the chicken curry mousse before and after retort sterilization.

Physical parameter		Before retorting	After retorting
Color	L	63.88 ± 0.00^{a}	58.06 ± 0.13^{b}
	a	-2.28 ± 0.08^{b}	1.96 ± 0.14^{a}
	b	39.81 ± 0.23^{a}	36.04 ± 0.69^{b}
Texture	Hardness	5.17 ± 0.11^{a}	4.39 ± 0.45^{b}
	Adhesiveness	8.43 ± 0.36^{a}	5.08 ± 0.40^{b}
	Gumminess	2.66 ± 0.05^{a}	2.04 ± 0.19^{b}

All values are expressed as a mean ± standard deviation (n = 3). Means with different superscripts (a-b) in each column are significantly different ($p < 0.05$) according to Duncan's test.

3.2.2. Texture of mousse before and after retort treatment

The texture of the sample was changed by retort treatment, and it was confirmed that hardness, adhesiveness, and gumminess decreased (Table 2). Similar findings have been reported by Rajkumar et al. (2010) and Bepary et al. (2022). Hardness is the force required to deform or penetrate food between the tongue and palate. The hardness decreased from 5.17 ± 0.11 to 4.39 ± 0.45 after retort treatment; this indicates that CCM became softer and smoother. The reduction in hardness may occur as a consequence of the heat treatment, which causes protein denaturation and the disruption of cell walls and softens the mechanical strength of the mousse (Bepary et al., 2022). Adhesiveness is defined as the force that leaves a sticky feeling in the mouth that is difficult to remove (Ong et al., 2018). The adhesiveness decreased from 8.43 ± 0.36 to 5.08 ± 0.40 after retort treatment. Food textures that are too sticky have been reported to be unsafe for dysphagia patients because they increase the risk of choking and require great effort to send food into and through the pharynx (Cichero, 2016). Gumminess, reflecting the force required to break down semi-solid food ready to swallow, also decreased from 2.66 ± 0.05 to 2.04 ± 0.19 after retort treatment. Previous studies have reported that foods with high gumminess are dangerous because they put dysphagia patients at risk of suffocation (Malouh et al., 2020; Momosaki et al., 2013).

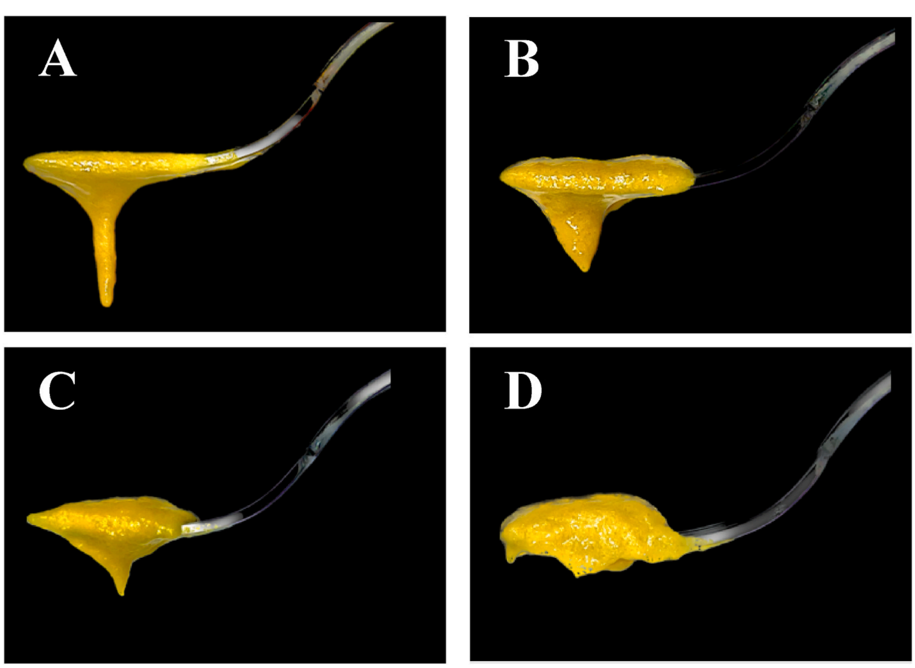

Fig. 3. IDDSI fork drip test of the chicken curry mousse a different concentration of the viscosity thickener corresponding to: (A) 1%, (B) 2%, (C) 3%, and (D) 4%.

3.2.3. Viscosity and texture of mousse based on the Korean industrial standards

Table 3 presents the viscosity results of the sample classified according to Korean industrial standards (KS). As more viscosity thickener was added, the viscosity increased. Considering the third grade of KS (Kim & Joo, 2021), it was determined that concentrations of 1/2/3/4% exhibited the appropriate viscosity for aiding dysphagia in the elderly. However, it should be noted that thickening the viscosity of the mousse negatively impacted its mouthfeel, as it became stickier and required more effort to pass from the mouth to the esophagus (Kim et al., 2022). Additionally, both the mousse texture before and after retort processing met the requirements of the third grade in the KS. The mousse viscosity is the most important attribute because it relates to the product's rheological properties, which in turn determines the product's sensory qualities and desirability among potential consumers. Therefore, it is possible to create a viscosity-suitable product for the elderly with the use of a viscosity thickener.

3.2.4. Rheological properties of curry mousse

Since the viscoelastic properties of thickened fluids cannot be adequately described only by a single viscosity value alone, they have been proposed as potential characteristic related with swallowing a food bolus (Payne et al., 2011). CCM has viscoelasticity as a semi-solid food, and a frequency sweep test was conducted to investigate the effect of retort treatment on rheological properties. Fig. 4A Shows changes in G′ and G'' of retorted CCM and non-retorted CCM as a frequency at 25 °C. The G′ and G'' values of retorted CCM were higher than non-retorted CCM. Both samples showed a typical gel structure in which the elastic component prevailed over the viscous component, thereby confirming the viscoelastic properties of the mixture (Joshi et al., 2011). The retort process, involving heating treatment, may contribute to the formation of a larger and stronger matrix, exposing more hydrophobic groups in the sample (Wi et al., 2020). Dynamic rheological parameters such as G′ and G" can be important in safe and easy swallowing of the bolus (Ishihara et al., 2011). In addition, Fig. 4B shows the complex viscosity (η*) of retorted CCM, which represents the material's resistance to flow (Tunick, 2011). While this parameter decreased linearly for both samples, the retorted sample had higher viscosity across the whole range, indicating an improvement in material rigidity due to retort processing. As a result, it was found that since foods with low viscoelasticity have a risk of aspiration, retort treatment can increase viscoelasticity.

3.2.5. 12 Days of syneresis

Syneresis refers to the phenomenon of liquid oozing out from various foods, such as jams and dairy products (Mizrahi, 2010). The results of syneresis for 12 days after retort treatment are shown in Table 4. The non-retorted CCM showed a statistically significant increase ($p < 0.05$). These results were similar to a previous study by Panesar and Shinde (2012), where the rate of syneresis was directly related to acidity and therefore the increased water release, as opposed to the decreased in pH. In contrast, the retorted CCM did not show significant differences. It has been reported by Karimi et al. (2016) that a decrease in gel pH can destabilize the gel structure, resulting in syneresis, the separation of liquid from the gel. This is because low pH can cause the gel network to break down and release bound water, resulting in a weaker gel structure and increased liquid separation. Consequently, the excessive accumulation of moisture in the non-treated samples, as opposed to the retorted samples with lower moisture release, signifies that retort treatment contributes to enhancing stability during storage.

3.3. Effect of retort sterilization on chemical properties

3.3.1. 12 Days of pH

As a result of the retort sterilization, there was a decrease in pH (Fig. 5). During the heating process, molecular vibrations increase which causes a decrease in the pH level as more free hydrogen ions are generated; this itself occurs because of the inhibition of hydrogen bond formation. Additionally, degraded by-products from the Maillard reaction and subsequent decomposition may contribute to lower pH levels (Zarim et al., 2021). Similarly, Rajan et al. (2014), in their study on Chettinad chicken curry, reported a decrease in pH during retort treatment due to protein decomposition and the vitrification of uraminic acid. The non-retorted samples showed a significant decrease in pH levels during the storage period. This may be caused by protein degradation and the liberation of free acids (Devadason et al., 2014). A previous study has reported that residual oxygen in the pouch and the degradation of glucose by-products causes the oxidation of lipid components, leading to a decrease in the pH of meat products (Jang & Lee, 2012). Generally, the pH of food products can decrease over time due to various factors, such as microbial fermentation, enzymatic reactions, chemical reactions, and storage conditions (Andrés-Bello et al., 2013). However, no significant reduction was found in retorted CCM because the pH change was not stored for long enough to be observed in retorted CCM. Both samples were stored at room temperature, which may have facilitated the oxidation of lipids in the non-retorted CCM, resulting in a rapid decrease in pH. Therefore, we suggest that retort treatment can help maintain the quality and stability of the CCM during the storage period.

3.3.2. Changes in BCAAs

Fig. 6 shows the results of BCAAs analysis. The non-retorted CCM's valine was 158.1 ± 13.5 mg, isoleucine was 155.5 ± 13.2 mg, leucine was 319.2 ± 27.2 mg. In contrast, the retorted CCM had significantly higher levels of valine (329.9 ± 32.0 mg), isoleucine (323.9 ± 32.1 mg), and leucine (660.4 ± 62.3 mg) - almost twice as much. After retort sterilization, the sample showed a significant increase in valine ($p = 0.02$), isoleucine ($p = 0.02$), and leucine ($p = 0.02$) levels compared to those before sterilization. The increase in BCAAs content after retort treatment is likely attributed to protein degradation and the release of free amino acids during thermal processing. According to a study by Khoonin et al. (2022), retort sterilization of a complete nutrition drink fortified with BCAAs and fish oil resulted in an increase in all types of BCAAs compared to the control formula. The authors suggested that this may be due to the hydrolysis of peptide bonds and the liberation of free amino acids during retort sterilization. Moreover, it has been observed that protein denaturation is more likely to occur at temperatures around 116 °C (van Lieshout et al., 2020). Therefore, our study suggests that the elderly may experience complete gastrointestinal digestion of our retort

Table 3
Viscosity and texture of the chicken curry mousse with different concentration of viscosity thickener before and after retort treatment under the classification from Korean industrial standards (KS) were measured in triplicate.

Physical parameter		Viscosity (mPa · s)	KS	Texture (N/m^2)	KS
Concentration of viscositythickener (%)	1	7040	Grade 3 (≤1500)	–	–
	2	10880	Grade 3 (≤1500)	–	–
	3	14720	Grade 3 (≤1500)	–	–
	4	16640	Grade 3 (≤1500)	–	–
Retort processing	Before	8960	Grade 3 (≤1500)	10532.24	Grade 3 (≥20,000)
	After	7680	Grade 3 (≤1500)	8943.23	Grade 3 (≥20,000)

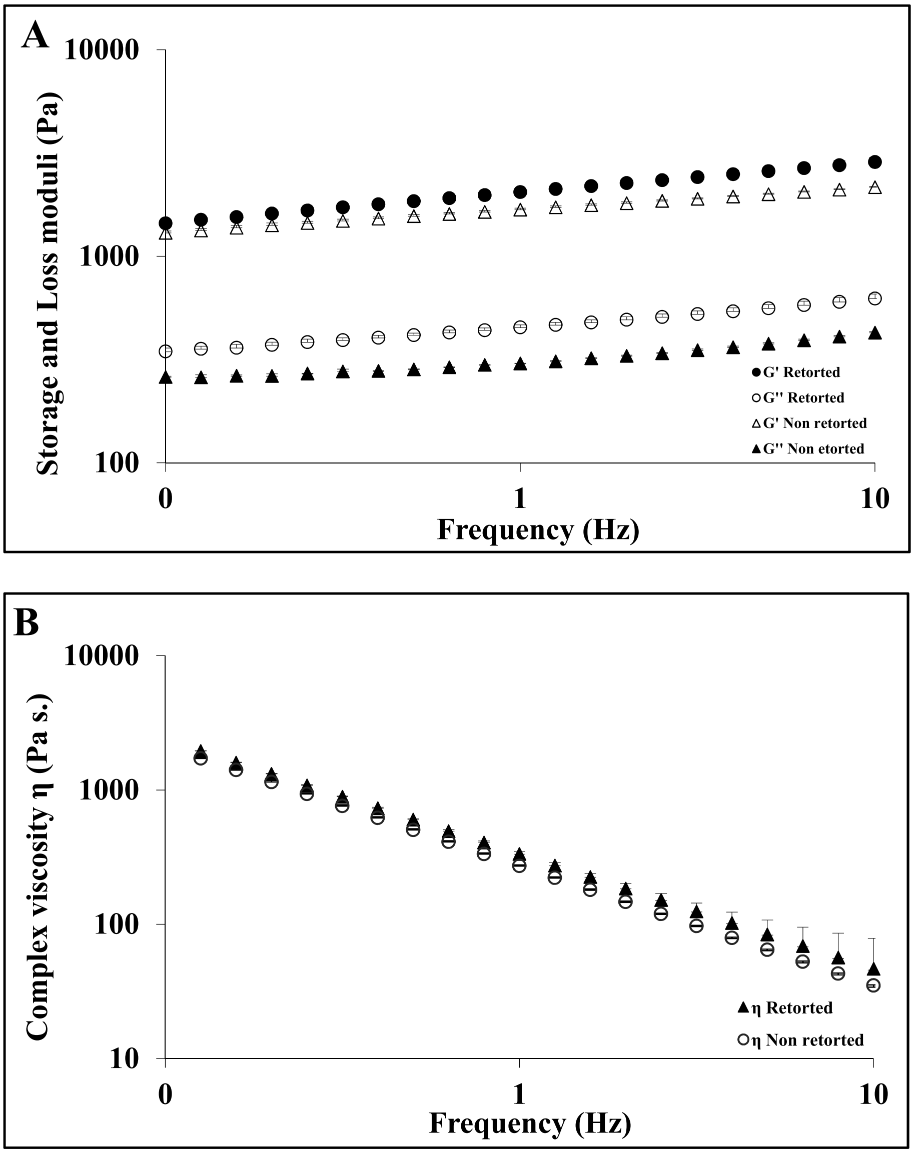

Fig. 4. Storage modulus (G′), loss modulus (G′′) (A), and complex viscosity (B) obtained from a frequency sweep of the chicken curry mousse before and after retort treatment of 121 °C for 30 min.

Table 4
Changes in syneresis of the chicken curry mousse before and after retort treatment during 12 days of storage.

Storage days	Before retorting (%)	After retorting (%)
0	0.18 ± 0.16[c]	0.75 ± 0.36
3	0.71 ± 0.30[c]	1.02 ± 0.40
6	2.53 ± 0.64[ab]	0.06 ± 0.02
9	3.84 ± 1.03[a]	0.52 ± 0.28
12	2.27 ± 0.57[b]	0.93 ± 0.30
	$p < 0.05$	$p > 0.05$

All values are expressed as a mean ± standard deviation (n = 3). Means with different superscripts (a-c) in each column are significantly different (p < 0.05) according to Duncan's test.

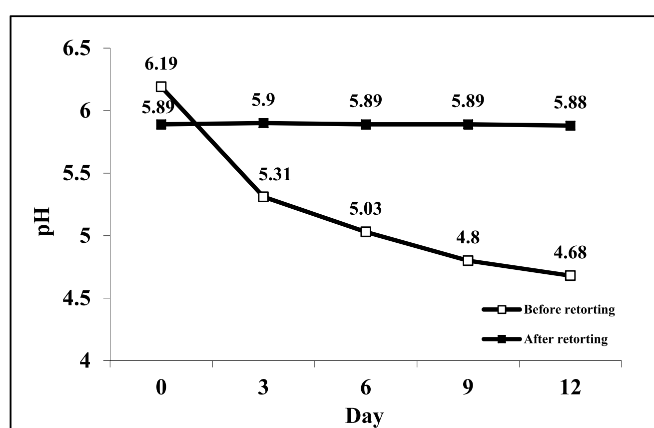

Fig. 5. The pH change after 12 days of storage of the chicken curry mousse sample before and after retort processing was measured in triplicate ($p < 0.05$).

CCM since denatured proteins have easier access to enzymes. However, further clinical studies are needed to validate this hypothesis.

3.4. Sensory analysis

In the sensory evaluation, seven scores were used to assess the impact

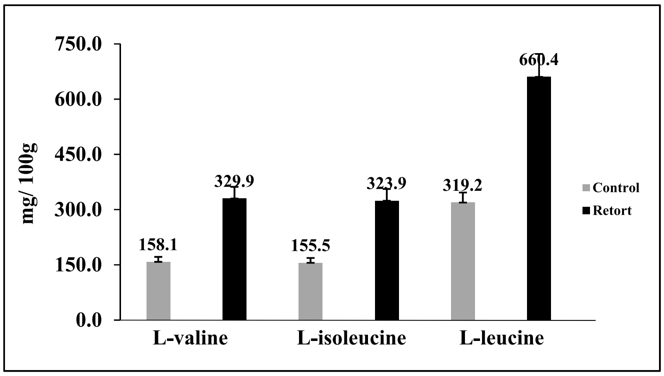

Fig. 6. Effect of retort sterilization on the content of branched-chain amino acids in the chicken curry mousse sample with and without retort processing ($p = 0.02$).

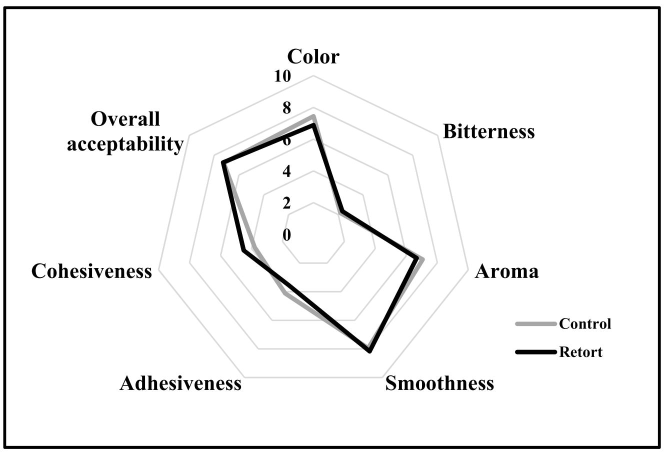

Fig. 7. Sensory attributes of the chicken curry mousse with and without retort processing measured with a 9-point hedonic scale (n = 18).

of retort treatment on the sample (Fig. 7). The effect on color preference was observed, as the mousse became darker after retort treatment. The non-retorted CCM had a score of 7.44 ± 1.54, while the retorted CCM scored 6.89 ± 1.85. However, this difference was not statistically significant ($p > 0.05$). The results regarding the unique bitter taste of BCAAs showed a slight increase after the treatment (2.33 ± 1.89) compared to before (2.17 ± 1.98), but the difference was not statistically significant. Additionally, participants reported a minimal perception of bitterness. The effect of BCAAs-specific aroma on intake was confirmed, and as a result, it was 7.06 ± 1.13/6.67 ± 1.01 close to the good aroma (9 points). In terms of smoothness, similar to the texture analysis results, participants perceived the retorted CCM as having smoother physical properties. The difference in overall preference was small between the two samples; however, the retorted CCM scored higher. These results may indicate that the elderly prioritized a suitable texture over taste or aesthetic appearance. Overall, the sensory properties were not significantly affected by the retort treatment. Moreover, the differences in preference during consumption are expected to be minimal.

4. Conclusion

The aim of this study was to develop a CCM that can be easily consumed at home by the elderly who have difficulty chewing and swallowing. To provide a smooth texture, the chicken curry was ground using a mixer, and a viscosity thickener was added. The results of viscosity and TPA demonstrated that the mousse became softer through retort treatment. In the rheological properties, the heat treatment process formed the matrix of the CCM larger and stronger, thereby improving cohesiveness. Although the color of the mousse darkened after retorting, there was no significant difference in color preference compared to the non-treated CCM in the sensory evaluation. The retorted CCM during the 12 days of storage did not show significant change in syneresis and pH, in contrast to the non-treated sample. This suggests that retort treatment enhances the storage stability of the CCM. The BCAA content did not decrease during the retort treatment. Sensory evaluation results indicated that while there was no significant difference between the pre- and post-retorting samples, the overall acceptance of the mousse was higher after retorting, suggesting that retort treatment did not significantly impact consumer preference. In conclusion, retort treatment improves the storage stability of the CCM, enhances its chewability for the elderly, and fortifies it with BCAAs to help prevent muscle loss in this population. As a result, this study suggests that this product has the potential to meet the market demand for convenient and ready-to-eat (RTE) products. Future research can focus on establishing a safe consumption period for consumers based on the confirmed storage stability achieved through retort processing. Additionally, bioavailability studies can be conducted to validate the effectiveness of this product in the human body.

Ethics and informed consent

This study was approved by the Institutional Review Board of Hanyang University (IRB number: HYUIRB-202211-002). The informed consent from all study participants was obtained for experiments on human subjects.

CRediT authorship contribution statement

Eun-Bee Lee: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing - Original Draft, Writing - Review & Editing, Visualization. **Weon-Sun Shin:** Conceptualization, Validation, Resources, Data curation, Writing - Review & Editing, Supervision, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. [Record #61 is using a reference type undefined in this output style.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.lwt.2023.115133.

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