

Effect of Ultra-sonication Treatment on the Quality Characteristics of Baked Eggs

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Abstract

The effect of ultra-sonication on quality characteristics and flavor of baked eggs was studied. One hundred and twenty eggs were cooked and assigned to six treatments groups (n=20 each) that were then soaked in saline solution at various concentrations (5, 10 and 18%) with/or without further ultra-sonication treatment at 35 kHz for 1 h. The pH values were lower in the ultra-sonicated samples in comparison with the non-ultra-sonicated samples ($p<0.05$). The values for texture traits were higher in the samples soaked in 10% saline solution with ultra-sonication in comparison with other remaining treatments or control ($p<0.05$). The sodium content in samples soaked in 10% saline solution with ultra-sonication was similar to that of the ones soaked in 18% saline solution without ultra-sonication. The higher flavor scores were also given for the ultra-sonicated samples in comparison with the control or non-ultra-sonicated ones. These results suggest that the application of ultra-sonication may produce a faster sodium penetration into baked eggs, simultaneously improves some textural traits (e.g., hardness) as well as flavor of the products.

Keywords: baked egg, ultra-sonication, flavor, sodium

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Introduction

Bird eggs are an excellent source of protein which provides all essential amino acids necessary for human health. The eggs therefore have been consumed from the traditional times and still constitute a major part of the diet for people over the world. The eggs are composed primarily of water, proteins, lipids, carbohydrates, and minerals (Kovaces-Nolan *et al.*, 2005). Besides, they consist of a protective eggshell, albumen (egg white), and vitellus (egg yolk), ovalbumin, conalbumin, ovomucoid and lysozyme (Mine, 2008; Stadelman and Cotterill, 2011).

Preserved eggs, known as '*pidan*' in China and salted eggs are a popular preserved form. The '*Pidan*' was prepared by pickling fresh duck and chicken eggs in a mix-

ture of alkali, salt, black tea, and metal ions at room temperature for 4 to 5 wk (Su and Lin, 1993; Wang and Fung, 1996). Processing of fresh eggs into preserved forms without any heating treatment can lead to the gel formation in both the egg white and the egg yolk and the typical characteristic of these preserved eggs is determined by the properties of its egg white gel (Tu *et al.*, 2012). However, in the commercial preservation, the egg whites gel cannot form well due to the absence of metal ions, such as copper (Ganasen and Benjakul, 2010; Ganasen and Benjakul, 2011; Tu *et al.*, 2012). An additional factor that determines the salting of egg in these products is the rate of salt penetration, the faster the salt penetration the lesser the time taking. Several ways have been applied in order to reduce the salting time for instance; washing the eggs prior to salting was reported to accelerate salt penetration and decrease the salting time (Liao and Zhu, 2008). In some countries such as Korea, the salting of eggs is carried out after cooking or baking, and the cooking and salting time generally take for approximately 36 h.

Despite the ultrasound technology has a wide range of applications in food technology area such as; for the non-destructive control of whole fruits, vegetables, and food

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packages (Floros and Liang, 1994; Mizrach *et al.*, 1994), however, no attention has been to the application of this technique in the production of baked egg products. The objective of the current study was to investigate the effects of ultra-sonication on the quality characteristics of baked eggs; the finding of this work could be useful for processors in order to reduce salting time during production of baked egg product.

Materials and Methods

Experimental design

All eggs used in this study were purchased from a local supermarket (Korea). The egg weights were between 52 and 59 g. The external surface of the eggshell was washed with a neutral solution, followed by washing with tap water. A total of 120 eggs were boiled for 12 min in a metal bath using a gas burner (RGR-290A, Rinnai, Korea), and then were equally divided into six groups that were then subjected to six different treatments. To determine the effects of ultra-sonication on the product's quality, the eggs were placed in a 35 kHz frequency ultra-sonicator (RK51 H, Bandelin, Germany) filled with the particular curing solution mixture (Table 1), and switched for 1 h. After the ultra-sonication treatment, all the eggs were baked in an Oven (OF-22, JEIO TECH, Korea) at 100°C for 5 h. The eggs made without soaking in curing solution or ultra-sonication was served as the control. The physical and physicochemical characteristics of baked eggs were analyzed after removing the eggshell and separation of the egg white and egg yolk.

Physicochemical analysis

The pH values were determined by homogenizing 3 g of each sample with 27 mL distilled water using a pH meter (Model 340, Mettler-Toledo GmbH, Switzerland) that was calibrated with 3 different standard pH solutions (4.0, 7.0 and 9.25).

Water activity (a_w) was determined using a water activity analyzer (Lab Master-aw, Novasina, Switzerland). The

surface color of baked egg whites was measured using a chromameter (CR-400, Minolta, Japan) standardized with a white plate ($Y=93.5$, $X=0.3132$, $y=0.3198$). Five measurements were taken and results were expressed according to the Commission International de l'Eclairage (CIE) system and reported as CIE L^* (lightness), CIE a^* (redness), CIE b^* (yellowness).

Determination of yield and sodium contents

Yield (%) was determined as a difference of raw and baked egg weight. Sodium content was determined using an inductively coupled plasma optical emission spectrometer (ICP-OES Integra XL, GBC, Australia) according to the AOAC (1990).

Texture analysis

The texture properties were analyzed using a puncture probe (6 mm diameter) attached to a texture Analyzer (Model 4465, Instron Corp, UK). For texture analysis, the samples from each treatment were sliced with 1 cm height. The speed of load cell was set at 120 mm/min and the following parameters were calculated: hardness (kg), cohesiveness (kg*mm), gumminess (kg) and chewiness (kg*mm).

Flavor sensory evaluation

Flavor intensity of the baked eggs was evaluated using a panel consists of 7 members who routinely evaluate meat and meat products. Baked eggs were split and one-half of the baked egg was served to each panelist. Flavor intensity was rated using a 9-point system (1 = extremely dislike the flavor, 9 = extremely like the flavor). Slightly acidic water was provided to each panelist for rinsing their palate between samples.

Statistical analysis

All experiments were repeated thrice. Data was collected for the determination of pH, water activity, color, texture, sodium content, and sensory evaluation. The data was analyzed using a one-way ANOVA of SAS software (SAS

Table 1. Processing conditions for baked egg manufacture used in this experiment

Treatment	Description
C	Non-soaking
T1	Overnight soaking in 18% saline solution without ultra-sonication
T2	Soaking in 5% saline solution with 1 h ultra-sonication
T3	Soaking in 5% saline + 5% soybean paste solution with 1 h ultra-sonication
T4	Soaking in 10% saline solution with 1 h ultra-sonication
T5	Soaking in 10% saline + 1% garlic powder solution and 1 h ultra-sonication

Table 2. Effect of ultra-sonication on pH of baked eggs

Treatments ¹	pH	
	Egg white	Egg yolk
C	8.41 ^A	7.17 ^A
T1	8.35 ^B	7.16 ^A
T2	8.27 ^C	6.76 ^C
T3	8.04 ^E	6.82 ^{BC}
T4	8.16 ^D	6.79 ^C
T5	8.14 ^D	6.97 ^B
SEM	0.03	0.04

¹C, non-soaking; T1, soaking in 18% saline solution without ultra-sonication during overnight; T2, soaking in 5% saline solution with ultra-sonication during 1 h; T3, soaking in 5% saline + 5% soybean paste solution with ultra-sonication during 1 h; T4, soaking in 10% saline solution with ultra-sonication during 1 h; T5, soaking in 10% saline + 1% garlic powder solution with ultra-sonication during 1 h.

^{A-E}Means with different superscripts within a same column differ significantly ($p < 0.05$).

SEM: Standard error of the mean.

Institute Inc., USA) followed by Duncan's multiple range tests to determine significant difference between the treatments ($p < 0.05$).

Results and Discussion

Effect of treatment on pH values

The effect of ultra-sonication treatment on the pH values of baked eggs are presented in Table 2. The pH values of egg white and yolk were significantly ($p < 0.05$) lower in samples treated with ultra-sonication in comparison with those of the control (not soaked in saline solution or ultrasonicated) or the samples soaked in 18% saline solution without ultrasonication. The pH of egg whites was significantly lower the samples soaked in 18% saline solution without ultra-sonication than in the control. However, no significant differences in the pH of egg yolks occurred among the samples soaked in different levels of saline with ultra-sonication. Sert *et al.* (2011) reported that the ultra-sonication treatment led to an increase in the pH of albumen. In contrast, our results showed the decreases in pH values of the egg white and yolk after ultra-sonication. It was reported that there are some physicochemical modifications taking place during storage of eggs (Kato *et al.*, 1981), and the increase of albumen pH is due to the loss of carbon dioxide from the egg through pores in the shell (Hill and Hall, 1980). Furthermore, exposure of fresh eggs to various concentrations of ammonia has been reported to affect the pH and albumen height (Benton and Brake, 2000). From our obtained results it

Table 3. Effect of ultra-sonication on water activity of baked eggs

Treatments	Water activity	
	Egg white	Egg yolk
C	0.978 ^A	0.973 ^A
T1	0.977 ^{AB}	0.975 ^A
T2	0.972 ^{AB}	0.971 ^{AB}
T3	0.974 ^{AB}	0.972 ^A
T4	0.959 ^C	0.965 ^B
T5	0.967 ^{BC}	0.965 ^B
SEM	0.001	0.001

¹C, non-soaking; T1, soaking in 18% saline solution without ultra-sonication during overnight; T2, soaking in 5% saline solution with ultra-sonication during 1 h; T3, soaking in 5% saline + 5% soybean paste solution with ultra-sonication during 1 h; T4, soaking in 10% saline solution with ultra-sonication during 1 h; T5, soaking in 10% saline + 1% garlic powder solution with ultra-sonication during 1 h.

^{A-C}Means with different superscripts within a same column differ significantly ($p < 0.05$).

SEM: Standard error of the mean.

Table 4. Effect of ultra-sonication on surface color of baked egg white

Treatments ¹	CIE values		
	L* (lightness)	a* (redness)	b* (yellowness)
C	54.19	8.19 ^{AB}	24.62 ^B
T1	60.58	6.65 ^B	24.37 ^B
T2	54.19	9.59 ^A	27.46 ^A
T3	56.42	8.72 ^{AB}	26.06 ^{AB}
T4	56.75	8.37 ^{AB}	24.49 ^B
T5	58.14	7.97 ^{AB}	26.1 ^{AB}
SEM	0.87	0.31	0.38

¹C, non-soaking; T1, soaking in 18% saline solution without ultra-sonication during overnight; T2, soaking in 5% saline solution with ultra-sonication during 1 h; T3, soaking in 5% saline + 5% soybean paste solution with ultra-sonication during 1 h; T4, soaking in 10% saline solution with ultra-sonication during 1 h; T5, soaking in 10% saline + 1% garlic powder solution with ultra-sonication during 1 h.

^{A,B}Means with different superscripts within a same column differ significantly ($p < 0.05$).

SEM: Standard error of the mean.

could be suggested that the increased pH of baked eggs could be relevant to salt penetration after ultra-sonication.

Effect on water activity

The effect of ultra-sonication on the water activity of baked eggs is presented in Table 3. The water activity values of egg whites was significantly ($p < 0.05$) higher in control samples than in the treated samples. Comparing the water activity of egg whites among the treatments shows that the eggs soaked 10% saline solution with ultra-sonication (T4) had significantly ($p < 0.05$) lower values than

Table 5. Effect of ultra-sonication on texture of baked egg white

Treatments ¹	Hardness (kg)	Cohesiveness (%)	Springiness (mm)	Gumminess (kg)	Chewiness (kg* mm)
C	0.12 ^C	1.24	1.34 ^B	0.17 ^{AB}	0.24 ^B
T1	0.11 ^C	1.17	3.95 ^{AB}	0.13 ^B	0.79 ^B
T2	0.24 ^{AB}	1.27	3.48 ^{AB}	0.3 ^{AB}	0.87 ^B
T3	0.2 ^{ABC}	1.2	2.73 ^{AB}	0.23 ^{AB}	0.54 ^B
T4	0.16 ^{BC}	1.41	1.91 ^B	0.13 ^B	0.94 ^B
T5	0.3 ^A	1.25	4.8 ^A	0.38 ^A	1.82 ^A
SEM	0.02	0.05	0.39	0.03	0.17

¹C, non-soaking; T1, soaking in 18% saline solution without ultra-sonication during overnight; T2, soaking in 5% saline solution with ultra-sonication during 1 h; T3, soaking in 5% saline + 5% soybean paste solution with ultra-sonication during 1 h; T4, soaking in 10% saline solution with ultra-sonication during 1 h; T5, soaking in 10% saline + 1% garlic powder solution with ultra-sonication during 1 h.

^{A-C}Means with different superscripts within a same column differ significantly ($p < 0.05$).

SEM: Standard error of the mean.

other remaining treatments. We also observed that the water activity values were reduced as increasing saline concentration. Sert *et al.* (2011) demonstrated that the water activity of egg yolk and albumen decreased with increasing storage time and temperature. The ultra-sonication treatment for 1 h at 35 kHz resulted in lower water activity values in the yolk compared to non-ultrasound treatments, suggesting that the shelf-life stability of product could be improved when the ultra-sonication is applied.

Effect on surface color of baked egg white

Table 4 shows the effect of ultra-sonication on the surface color of egg whites in baked eggs. No statistical differences in the CIE L* values were found for all samples. The CIE a* values in the samples treated with ultra-sonication was significantly ($p < 0.05$) higher than the control or non-ultrasonicated samples. Regarding the CIE b*, their values in ultra-sonicated samples were not different from non-sonicated samples or control ($p < 0.05$), which agrees with the finding of Sert *et al.* (2011).

Effect on texture profile

Table 5 shows the effect of ultra-sonication on the texture of baked egg white. The hardness value was significantly ($p < 0.05$) lower in the non-ultrasonicated samples than in the ultra-sonicated ones. No significant differences in cohesiveness values were observed among the treatments. The hardness, springiness, gumminess and chewiness values were significantly ($p < 0.05$) higher in the samples soaked in 10% saline solution with ultra-sonication (T5) than in the other treatments or control. According to Zhao *et al.* (2014), the concentration of sodium hydroxide as well as the temperature clearly affected the strength of the egg white gel of preserved eggs. A high pickling tem-

Table 6. Effect of ultra-sonication on sodium concentration (%) and flavor by sensory evaluation of baked eggs

Treatments ¹	Na concentration (%)		Flavor ²
	Egg white	Egg yolk	
C	0.11 ^D	0.11 ^D	1 ^C
T1	0.31 ^A	0.29 ^A	2 ^{BC}
T2	0.2 ^{BC}	0.16 ^{BC}	4.17 ^{AB}
T3	0.16 ^{CD}	0.13 ^{CD}	3.67 ^{BC}
T4	0.23 ^B	0.18 ^B	4.71 ^{AB}
T5	0.33 ^A	0.25 ^A	6.67 ^A
SEM	0.02	0.01	0.42

¹C, non-soaking; T1, soaking in 18% saline solution without ultra-sonication during overnight; T2, soaking in 5% saline solution with ultra-sonication during 1 h; T3, soaking in 5% saline + 5% soybean paste solution with ultra-sonication during 1 h; T4, soaking in 10% saline solution with ultra-sonication during 1 h; T5, soaking in 10% saline + 1% garlic powder solution with ultra-sonication during 1 h. ²(9-point scale: 1= extremely dislike the flavor; 9- extremely like the flavor).

^{A-D}Means with different superscripts within a same column differ significantly ($p < 0.05$).

SEM: Standard error of the mean.

perature and a considerably long curing time disrupted the gel structure of the egg white and resulted in liquefaction of the aggregated gels, thereby resulting in low product quality (Yang *et al.*, 2012; Zhang, 2004). In the present study, an improved texture quality of the egg white was obtained after applying the ultra-sonication.

Sodium concentration and flavor

Table 6 shows the effect of ultra-sonication on sodium concentration and the flavor of baked eggs. The sodium concentration of the egg white and yolk were significantly ($p < 0.05$) higher in the samples soaked in 18% saline solution without ultra-sonication (T1) and those soaked in 10% saline solution and treated with ultra-sonication (T5)

compared to that in the control or other remaining treatments. This result suggested that the concentration of sodium in baked eggs was affected by the ultra-sonication. Furthermore, the use of ultra-sonication resulted in faster sodium penetration into the baked eggs than those dipped 18% saline solution without ultra-sonication.

The flavor scored was significantly ($p < 0.05$) higher in the T5 (ultra-sonicated and soaked in 10% saline and 1% garlic) in comparison to the other remaining treatments. Practically, salts, mainly sodium chloride is usually to enhance not only the self-life stability but also the sensory quality for many types of food products. Therefore, the results indicating higher flavor scores for the samples treated with ultra-sonication could be related to their higher sodium contents.

Conclusion

The application of ultra-sonication had beneficial effects on the quality of baked egg product by improving some color and texture traits, and faster salt penetration as well as flavor quality. Based on the results obtained from this work, it is clearly suggested that ultra-sonication can be applied to improve the quality and reduce the salting time of the baked eggs.

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