Effect of Hydrostatic Pressure and Vacuum on Characteristics of Century Egg

Benjawan Vanmontree, Tawarat Treeamnuk, Kaittisak Jaito, and Nartchanok Prangpru
School of Agricultural Engineering, Suranaree University of Technology, Nakhon Ratchasima, Thailand
Email: {B5016815, Ball-417, miss.nartchanok}@hotmail.com, tawarat@sut.ac.th

Krawee Treeamnuk
School of Mechanical Engineering, Suranaree University of Technology, Nakhon Ratchasima, Thailand
Email: krawee@sut.ac.th

***Abstract*—The objective of this research was to investigate the internal change of century egg in production process under hydrostatic pressure and vacuum conditions. The samples of duck egg that used in century egg production were immersed in alkaline solution at hydrostatic pressure of 1 and 2 bars, and 380 and 760 mmHg of hydrostatic vacuum. The samples of egg were random to evaluate internal change of some physical and chemical properties in term of percent of specific gravity increased, hardness of albumen, pH of albumen and yolk, and visible changing with image analysis every 2 days until 12 days. The results of studies indicate that percent of specific gravity increased, pH of albumen and yolk are increase when immersion time increases every pressure, but in contrast to the hardness of albumen. The hydrostatic pressure affect on percent of specific gravity increased clearly than hydrostatic vacuum, but in contrast of pH of albumen. The immersion time affect to change the color of albumen from transparent gel to dark brown every pressure. In addition, the eggs that immersed in alkaline at 2 bars for 6 days were suitable for produce century egg.**

***Index Terms*—century egg, hydrostatic pressure, hydrostatic vacuum, immersion time**

I. Introduction

Eggs have been an important part of the human diet throughout the world. Hen and duck eggs are the most commonly eaten eggs, and are highly nutritious and economical foods containing many essential nutrients. They are quick, convenient and easy to prepare and are appetizing and easily digestible. Duck egg consumption either as fresh or preserved accounts for about 30% among the total egg consumption in the countries like China and South East Asia [1]. Century eggs or pidan is one of the least expensive preserved egg products, which has been an alkaline-fermented ethnic food for many generations in China [2] is widely consumed in most of the South East Asian countries such as, Thailand, Malaysia, Singapore and East Asian countries like China and South Korea [3]. The traditional processing of century egg can be classified into three types: the rolling powder method, the coating method and the immersion method. All of traditional processing methods are take every long time 20-45 day [2] with unique formulation of paste or solution of alkali. For immersion method, generally, century egg can be made by immersion the eggs in 4-5% NaOH and 4-5.0% NaCl with green tea, Chinese tea, and metal ions, such as lead and copper solution at ambient temperature for 20-25 days [4]-[7]. The formation of century eggs is caused by the penetration of strong alkali through the eggshell and eggshell membrane, resulting in physical and chemical changes in the egg white and yolk, which results in gelation of the albumen. Milliard reactions between the glucose of the albumen and amino acids, combined with the pigment of the tea in the fermentation ingredient, contribute to the development of the brown-colored albumen gel. Because of excessive mineral intake is harmful to human health. For example, Pb accumulation causes damage to the human nervous, digestive, and circulatory systems. Excess Cu intake causes stomach upset, nausea, and diarrhea and can also lead to chronic copper toxicity, including cirrhosis of the liver [8]. Researcher fined appropriate formulation of alkali solution without metal ion like Pb [4], [9]. Many reports has objective to observe the internal change of century egg under traditional making [1], [3], [5], [10], However, characteristic of century egg making under hydrostatic pressure (HP) and hydrostatic vacuum (HV) has been few reported. The objective of this study was to investigate the internal change of century egg under HP and HV condition.

II. Materials and Methods

A. Raw Material

Fresh duck eggs with the weight range of 70-80 g and Haugh unit 76.42±3.17 were purchased from local market in Nakhon Ratchasima province, Thailand. The eggs were cleaned with tap water and checked for any crack before immersion.

Sodium hydroxide (NaOH) and Sodium chloride (NaCl) were purchased from Witthayasom Co., Ltd. (Nakhon Ratchasima, Thailand)

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B. Preparation of Alkali-Solution

Alkali-solution was prepared following the method of [9] with 4% NaOH and 10% NaCl (w/w) for each batch of the century egg making, initial value of the pH of alkali-solution of 14.

C. Preparation of Century Egg under HP

The thirty duck eggs were immersion in pressure tank that contained with 6 liters of alkali-solution. The pressure solenoid valve was used to control regularly pressure in the tank at 1 and 2 bars. Every 2 days the duck eggs were pick up to evaluate the characteristics change until 12 days.

D. Preparation of Century Egg under VP

The thirty duck eggs were immersion in vacuum tank that contained with 6 liters of alkali-solution. The vacuum solenoid valve was used to control regularly pressure in the tank at 380 and 760 mmHg. Every 2 days the duck eggs were pick up to evaluate the characteristics change until 12 days.

E. Evaluate the Characteristics of Century Egg

1) Percent of specific gravitity increased (%Sg) was evalate by compare specific gravity of the century egg with the fresh duck egg to observe the weight change due to effect of HP or HV. The percent of specific gravity increased could be determine by equation (1)

$$\%Sg = \frac{Sg_{ce} - Sg_{fe}}{Sg_{fe}} \; x\; 100 \tag{1}$$

where Sg_{ce} and Sg_{fe} are respectively the specific gravity of the century egg and the fresh duck egg respectively.

2) Hardness of albumen was performed using a TA-XT plus texture analyser (Stable micro system, UK) equiped with Spherical probe part No. P/0.25S, crosshead speed of 0.8 mm/s as descriped by Manochai [9]. The samples of century egg were steam for 20 minutes then equilibated with room temperature (30-32 ℃). The cape side albumen gel samples were compressed 20 mm. Pre-test speed, test speed, and post-test speed were 3.0, 0.8, and 10.0 mm/s, respectively. The hardness were record in term of F_{max}, and additionally, century egg in each making conditions were performed ten times.

3) The pH of the albumen and yolk were determined using digital pH meter (Mettler Toledo, SevenEasy, Switzerland) [12].

4) Color of albumen and yolk were determind by using image analysis method. The century egg samples were half cut and then place in the light system that performed following [13]. A color digital camera, model STYLUS XZ-2 (Olympus, Japan) was located vertically over the saples at a distance of 29 cm and covered with a black cloth to avoid the external light and reflections. The images were taken on a matte black background and using the following camera settings: manual mode with the lens aperture at f = 1.8 and speed 1/2000, no zoom, no flash, intermediate resolution of the image (3968×2976) pixels, and storage in JPEG format. All the algorithms for preprocessing of full images, segmentation from the background, and color analysis were written in MATLAB R2012a (The Math-Works, Inc., USA). Additionally, the 3 tradmark of century egg were performed similar with the century egg that making under HP and HV. The total color difference of albumen and yolk form HP and HV making and markets were determind by equation (2)

$$\Delta E = \sqrt{(L_p^* - L_0^*)^2 + (a_p^* - a_0^*)^2 + (b_p^* - b_0^*)^2} \tag{2}$$

where L_p^*, a_p^*, b_p^* are color parameters of century egg making under HP or HV condition, and L_0^*, a_0^*, b_0^* are color parameters of century egg from market.

5) Statistical analysis

The experiments were carried out in triplicate and the data was analyzed statistically using SPSS software version 14.0 (SPSS Inc., Chicago, USA) with determine by analysis of variance (ANOVA) and the means were separated using Duncan's multiple range test ($p \leq 0.05$). All the data are presented as the mean with the standard deviation.

III. Results and Discussion

A. Percent of Specific Gravity Increased

The effect of HP, HV and immersion time on percent of specific gravity increased shown in Fig. 1, clearly that under HP condition %Sg increase when increase of pressure and immersion time. This phenomenon occurs by the penetration of salt and alkaline into the egg because of hydrostatic pressure. The main components transferred between egg and solution during immersion were water and NaCl [14]. The effect of HV on %Sg not clearly observe, this result show that there are equilibrium mass transfer occurred.

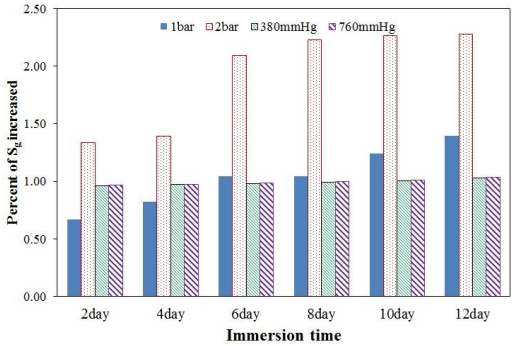

Figure 1. The Effect of HP, HV and immersion time on percent of specific gravity increased.

B. Hardness of Albumen

The effect of HP, HV and immersion time on hardness of steamed albumen were shown in Fig. 2, the results of studied shown that all of HP, HV and immersion time affect to hardness of albumen. At HP of 2 bars and 380, 760 mmHg of HV have decrease tend with immersion time. Heat treatment changes the transparent liquid albumen to white hard solid. While alkali changes the

transparent liquid albumen to brown solid gel of albumen at suitable pH of 11.0-11.6 [9]. Century egg making under condition 2 bars of HP as a result of accelerate alkali into albumen when immersion time increase over of alkali disrupt the albumen gel structure and cause the liquefaction of the aggregated gels, resulting in low hardness. Similar results are occurred at the condition of 380 and 760 mmHg.

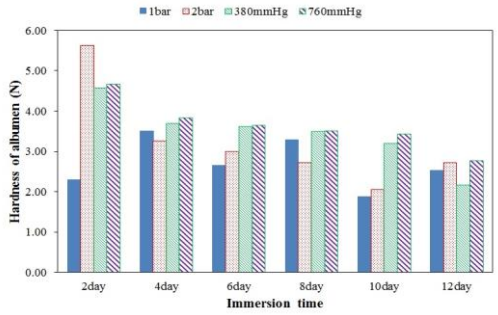

Figure 2. The Effect of HP, HV and immersion time on the hardness of albumen.

C. The pH of Albumen

The effect of HP, HV and immersion time on the pH of albumen were shown in Fig. 3, the result shown that the pH of albumen are affected to HP, HV and immersion time. The greater increase in pH during immersion indicated that HP and HV enhanced the migration of alkali from alkaline solution into egg white. The pH of albumen increased when HP and immersion time increase and influent of HV on pH of albumen more than HP after 4 days of immersion. Because of the pH is the main parameter for gelation of century egg. Prior reporting [9] found that the pH of albumen should in the range of 11.0-11.6, the higher pH disrupt the albumen gel structure and cause the liquefaction of the aggregated gels. The pH exceeds the suitable value formation to albumen gel had been found at 6 days of immersion under HV, but not been found in HP conditions. Additionally, the proper pH for gelation of egg whites found at the conditions of immersion under HP for a period of 6 days.

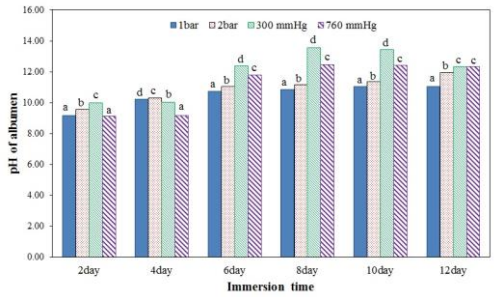

Figure 3. The Effect of HP, HV and immersion time on the pH of albumen. Different letters on the bar indicate significant differences at the same immersion time (P <0.05)

D. The pH of Yolk

The effect of HP, HV and immersion time on the pH of yolk were shown in Fig. 4, the result shown that the pH of yolk are affected to HP, HV and immersion time. The pH of yolk increased when HP and immersion time increase and influent of HV on pH of albumen more than HP after 6 days of immersion, the results in the same way of albumen. The prior reporting found that egg yolk has been changed from viscous liquid to solid at initial pH of 9.3, while considered the pH of albumen and yolk together, the appropriate condition of century egg making is under condition of 2 bars pressure and immersion period of 6 days.

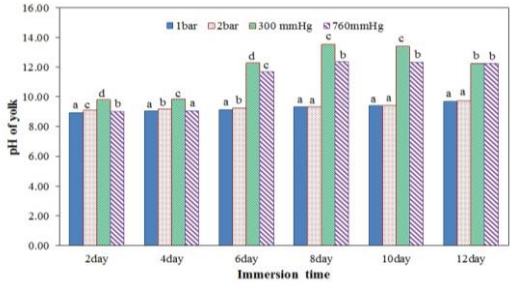

Figure 4. The Effect of HP, HV and immersion time on the pH of yolk. Different letters on the bar indicate significant differences at the same immersion time (P <0.05)

E. The Color of Albumen

The appearance of century eggs at various conditions shown in Fig. 5. The results found that HP and HV are accelerate the egg caused the cure gel strengths faster. The albumen colors are change from transparent light brown to dark brown when immersion times increase. Yolk have solid color with orange then turn to grayish green when immersion time increased at HP of 2 bar and HV of 760 mmHg. Loss of albumen observed under VP with immersion time of 6 days according to the result of pH of albumen. When observed appearance and the pH of albumen and yolk, the optimal conditions for the production of century egg is 2 bar 6 days.

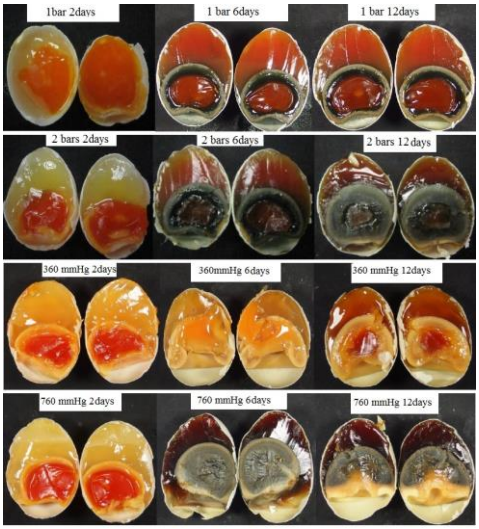

Figure 5. The Effect of HP and HV on appearance of century egg at immersion period of 2, 6, and 12 days.

The total color difference of albumin compared with the trademark century egg are shown in Table I. the result found that the 2 least total color difference of albumen at condition of 2 bar 12 days and 2 bar 10 days, but these

condition gave the higher value of pH of albumen more than suitable value. Thus the condition of 2 bar 6 days is proper to recommend. Additionally, the aging period should be study.

TABLE I. COMPARISON OF THE TOTAL COLOR DIFFERENCE OF ALBUMEN AND YOLK FROM VARIOUS TRADEMARK WITH TEST SAMPLE

Experiment Condition	MK1	MK2	MK3
1bar4day	49.63	57.46	61.70
1bar6day	37.12	41.35	44.70
1bar8day	29.99	32.05	34.88
1bar10day	28.54	32.82	36.28
1bar12day	28.62	33.19	36.74
2bar4day	19.31	27.09	31.13
2bar6day	11.85	17.40	21.34
2bar8day	17.95	20.71	23.97
2bar10day	13.17	14.20	17.19
2bar12day	13.69	11.18	13.42
360mmHg4day	45.60	53.90	58.23
360mmHg6day	45.51	53.18	57.42
360mmHg8day	30.67	35.85	39.59
360mmHg10day	29.23	31.32	34.19
360mmHg12day	21.47	22.83	25.69
760mmHg4day	44.38	52.28	56.56
760mmHg6day	15.47	17.00	20.19
760mmHg8day	47.19	54.29	58.44
760mmHg10day	29.60	34.42	38.06
760mmHg12day	16.07	15.47	18.05

IV. CONCLUSION

The characteristics of century egg are affected to HP, HV and immersion time. The results indicate that percent of specific gravity increased, pH of albumen and yolk are increase when immersion time increases every pressure, but in contrast to the hardness of albumen. The percent of specific gravity increased more affected to hydrostatic pressure clearly than hydrostatic vacuum, but in contrast of pH of albumen. The immersion time affect to change the color of albumen from transparent gel to dark brown every pressure. In addition, the eggs that immersed in alkaline at 2 bars for 6 days were suitable for produce century egg.

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REFERENCES

[1] P. Ganesan, T. Kaewmanee, S. Benjakul, and B. S. Baharin, "Comparative study on the nutritional value of Pidan and salted duck egg," *Korean Journal for Food Science of Animal Resources*, vol. 34, no. 1, pp. 1-6, February 2014.
[2] J. Li and Y. P. Hsieh, "Traditional Chinese food technology and cuisine," *Asia Pacific Journal of Clinical Nutrition*, vol. 13, no. 2, pp. 147-155, June 2004.
[3] P. Ganesan and S. Benjakul, "Physical properties and microstructure of pidan yolk as affected by different divalent and monovalent cations," *LWT-Food Science and Technology*, vol. 43, no. 1, pp. 77-85, January 2010.
[4] P. Ganesan and S. Benjakul, "Effect of green tea and Chinese tea on the composition and physical properties of pidan white," *Journal of Food Processing and Preservation*, vol. 35, no. 6, pp. 907-916, December 2011.
[5] Z. Chen, J. Li, Y. Tu, Y. Zhao, X. Lou, J. Wang, and M. Wang "Changes in gel characteristics of egg white under strong alkali treatment," *Food Hydrocolloids*, vol. 45, pp. 1-8, March 2015 .
[6] P. Ganesan, S. Benjakul, and K. Hideki, "Effect of different cations on Pidan composition and flavor in comparison to the fresh duck egg," *Korean Journal for Food Science of Animal Resources*, vol. 33, no. 2, pp. 214-220, April 2013.
[7] Y. S. Zhao, Y. Tu, J. Li, M. Xu, Y. Yang, X. Nie, Y. Yao, and H. Du, "Effects of alkaline concentration, temperature, and additives on the strength of alkaline-induced egg white gel," *Poultry Science*, vol. 93, n 10, pp. 2628-2635, October 2014.
[8] R. Baos, R. Jovani, M. Forero, J. Tella, G. Gomez, B. Jimenez, M. Gonzalez, and F. Hiraldo, "Environmental toxicology relationships between T-cell-mediated immune response and Pb, Zn, Cu, Cd, and as concentrations in blood of nestling white storks and black kites," *Environmental Toxicology and Chemistry*, vol. 25, no. 4, pp. 1153–1159, April 2006.
[9] P. Manochai, "Processing of alkalized eggs without using heavy metal," M.S. thesis Dept. Food sci. and tech. Kasetsart Univ., Bangkok, Thailand, 1999.
[10] E. Eiser, C. S. Miles, N. Geerts, P. Verschuren, and C. E. MacPhee, "Molecular cooking: Physical transformations in Chinese 'century' eggs", *Soft Matter*, vol. 5, no. 14, pp. 2725-2730, April 2009.
[11] C. Li, P. Shi, C. Xu, X. Xu, and G. Zhou, "Tracing processes of rigor mortis and subsequent resolution of chicken breast muscle using a texture analyzer," *Journal of Food Engineering*, vol. 100, no. 3, pp. 388–391, October 2010.
[12] Z. Omer and K. Sukru, "Optimization of emulsion characteristics of beef, chicken and turkey meat mixtures in model system using mixture design," *Meat Science*, vol. 73, no. 4, pp. 611-618, August 2006.
[13] F. Mendoza, P. Dejmek, and M. J. Augilera, "Calibrated color measurements of agricultural foods using image analysis" *Postharvest Biology and Technology*, vol. 41, no. 3, pp. 285-295, September 2006.
[14] X. Wang, Z. Gao, H. Xiao, Y. Wang, and J. Bai, "Enhanced mass transfer of osmotic dehydration and changes in microstructure of pickled salted egg under pulsed pressure," *Journal of Food Engineering*, vol. 177, no. 1, pp. 141-150, July 2013.

Benjawan Vanmontree was born in Loei province, Thailand on February 20, 1988. She received her B.Eng. (2012) in Agricultural and Food Engineering from Suranaree University of Technology, Thailand. Currently, she is a master student in Agricultural and Food Engineering Program, Suranaree University of Technology.

Tawarat Treeamnuk was born in Nakhon Pathom, Thailand on September 3, 1976. She received her B.Eng. (1999), M.Eng. (2002), D.Eng. (2008) in agricultural engineering from Kasetsart University, Thailand. She is an Assistant Professor in Agricultural Engineering, School of Agricultural engineering, Institute of Engineering, Suranaree University of Technology. Her areas of research interests are food processing, post-harvest technology, drying.

Krawee Treeamnuk was born in Nakhon Pathom, Thailand on July 25, 1976. He received his B.Eng. (1999) in Mechanical Engineering from Srinakharinwirot University, Thailand, M.Eng.(2002), D.Eng. (2008) in agricultural engineering from Kasetsart University, Thailand. He is a lecturer in School Mechanical Engineering, Institute of Engineering, Suranaree University of Technology. His areas of research interests are

agricultural and food process machinery, post-harvest technology, automatic control.

Kaittisak Jaito was born in Songkla province, Thailand on June 20, 1988. He received his B.Eng. (2012) and M.Eng. (2016) in Agricultural and Food Engineering from Suranaree University of Technology, Thailand. Currently, he is a Ph.D. student in Agricultural and Food Engineering Program, Suranaree University of Technology

Nartchanok Prangpru was born in Nakhon Ratchasima, Thailand, on 14th of March 1986. She received her B.Sc. in agro-industry product development from King Mongkut's University of Technology North Bangkok in 2005, M.Eng. in food engineering from Maejo University in 2010. The previous job, she is a lecturer in department of Agro-industry product development, King Mongkut's University of Technology North Bangkok, Prachin Buri. Currently, she is a Ph.D. student in Agricultural and Food Engineering Program, Suranaree University of Technology.