This study demonstrates a novel concept of salted yolk processing using fresh duck egg yolk. Salted yolks are produced to comply with good agricultural practice and allow better traceability of the raw materials. This methodology also prevents the curing of albumin as in the normal whole-egg brining protocol, and the spare egg whites can be used as raw material for other food products. This new brining process accelerated the curing time from 4 weeks to 4 days. The brining solution was a mixture of sodium chloride and maltodextrin. The sensory results suggested that this novel separated yolk brining process generated salted yolks of similar quality to those using the traditional shell egg brining protocol.

Key words: brining method, moisture diffusion, salt diffusivity, salted yolk, separated yolk

Introduction

Salted eggs are one of the most traditional and popular preserved egg products. Salted eggs are made by brining eggs in saturated saline or by coating eggs with a soil paste mixed with salt for approximately 15–30 days (Chi and Tseng, 1998; Hwang, 2002). Generally, duck eggs are used to prepare salted eggs because their characteristics are better than those of chicken eggs (Li and Hsieh, 2004). Consumers expect more egg yolk than egg white. The desirable characteristics of a salted egg yolk include orange color, oil exudation, and a gritty texture (Li and Hsieh, 2004; Kaewmanee et al., 2009a).

Salt is a useful additive to preserve and improve the taste of a product. The yolk solidifies gradually and becomes hard during the brining process, and the egg white loses viscosity and becomes watery (Chi and Tseng, 1998). The rate of salt penetration into the egg white and yolk is governed by the salting method and may change the composition and characteristics of the egg, particularly the yolk. In addition, the salting time plays a role in the formation of a properly prepared salted egg (Kaewmanee et al., 2009a).

Egg whites from traditional salted duck eggs contain very high salt content; thus, they have few or limited food uses. However, discarding the salted egg whites pollutes the environment. In addition, the higher standard of living in Taiwan has increased awareness about health; therefore, the consumers are keen on healthy foods. Therefore, it is important to develop methods to process salted duck eggs by directly using the fresh yolks, increase the utility of egg whites, and determine the optimal pickling conditions with reduced salt content when processing salted duck eggs. Consequently, a more healthy salted duck egg could be developed to satisfy consumer need.

Several groups have separated yolks from albumen before brining to preserve the functions of albumen, but these brining processes were unsuccessful (Lai and others 1999; Hwang 2002). Although the salting time was reduced to 2–3 days, the egg yolks became watery and did not attain desirable characteristics (Chiang and Chung, 1986). Direct contact between the salt-saturated brining solution and the brined yolk imposes a large diffusion gradient, resulting in high salt content in the brined yolk after separation. Despite the advantages of the separated yolk brining process (e.g., shorter brining period and intact egg white), the main setback of the separated yolk brining process is excessive saltiness, as reported by Limpapath (2004), Laoharatanahirun (2005), and Petchutairung (2005).

Dehydration and salt content are major factors affecting the hardness of a salted yolk. However, few studies have applied osmotic dehydration (OD) to the separated yolk brining process. OD is based on the difference in osmotic pressure inside and outside of cells and is a water removal process. Various osmotic agents, such as sucrose, glucose, fructose, corn syrup, and sodium chloride, are used for OD (Azuara et al., 2002). Saeaung and others (2010) reported that egg yolks can be salted in < 1 day using a separated
chicken egg yolk. Their brining solution consisted of sodium chloride, potassium chloride, and sucrose. The results showed that the diffusion rate of sugar through the yolk was much slower than that of salt due to the higher molecular weight of sugar and that most of the sugar remained on the yolk surface, which limited salt uptake. Nevertheless, the salt concentration in the salted egg yolk was still high (4.09 ± 0.55 mg/g) and close to the high level salt content found in commercial salted yolks (range, approximately 2.84–4.15 mg/g; Saeaung et al., 2010).

Azuara et al. (2002) suggested that adding a high molecular weight solute (maltodextrin) to the osmotic solution is useful to control the incorporation of specific low molecular weight solutes into fruit tissue, obtain osmorehydrated products with better sensorial characteristics, and enhance fruit water loss. The objective of this study was to explore a maltodextrin-salt OD system for separated salted duck egg yolks and create a separated salted egg yolk with reduced salt content, good oil-off, and a gritty texture, with similar properties to traditionally prepared salted duck eggs.

Materials and Methods

Egg Samples

Duck eggs (Anas platyrhynchos; <5 day old; mean weight, 65–68 g) and commercial salted yolks were purchased from the Kindly Egg Product Co. (Pingtung, Taiwan).

Separated Yolk Brining Method

The shells of fresh duck eggs were broken, the egg yolks were separated manually from the whites, leaving the vitelline membrane intact, and brining using the separated yolk brining process and a brining solution consisting of saturated (26%) NaCl solution or 20% NaCl with 0%, 5%, 10%, or 20% maltodextrin in a 25°C incubator with 50% humidity. Five yolks were removed and designated as a sampling group for analysis every day. The yolks were cooked in an electric rice cooker for 10 min after washing off the brining solution carefully with distilled water.

Water Activity

Apparent water activity (aw) of the sample solution was determined by measuring relative humidity in air equilibrated with the solution using a TH2/RTD-33/ BS thermoconstanter (Novasina, Zurich, Switzerland). The unit was calibrated prior to measurements using saturated salt solutions of potassium chloride, potassium nitrate, potassium sulfate, and sodium chloride with known aw values (Greenspan, 1977). All measurements were performed at 25°C.

Physicochemical Properties

The physicochemical properties of the salted duck eggs, including water content, salt content, and oil exudation of the yolk were analyzed. Cooked egg yolks were sliced with a knife into outer, middle, and center regions. Moisture and salt contents in the egg samples were measured separately according to AOAC methods (2000). The total lipid and free lipid contents of the cooked salted egg yolks were determined using the procedure described by Lai et al. (2010). The oil exudation ratio was defined as the proportion of free lipid to lipid content.

Texture Profile Analysis (TPA) of Egg Yolk

TPA was performed as described by Kaewmanee et al. (2009b) with a TA-XT2i texture analyser (Stable Micro Systems, Surrey, England). Prior to analysis, salted egg yolks were cooked as described and the samples were compressed twice to 50% of their original height with a compression cylindrical aluminum probe (50 mm diameter). Textural analyses were performed at room temperature. Force-distance deformation curves was recorded at cross head speed of 5 mm/s and the recording speed was 5 mm/s. Hardness (N), springiness (mm), cohesiveness, gumminess (N) and chewiness (Nm) were evaluated. These parameters were obtained using the MicroStable software (Surrey, England).

Sensory Evaluation

A sensory evaluation of the salted yolks was conducted to compare the separated yolk brining and commercial salted yolk by traditional processes. The samples were served directly in random order and five attributes were evaluated (saltiness, odor, appearance, texture, and general acceptability). A sensory panel was selected from the faculty members of institute. A scale from dislike extremely (1) to like extremely (9) was used.

Statistical Analysis

A completely randomized design with three replications was used for the study. The data are expressed as mean values with standard errors. One-way analysis of variance was performed, and mean comparisons were analyzed by Duncan’s multiple range test (Steel and Torrie, 1980). The statistical analysis was performed using SPSS ver. 16.0 software (SPSS Inc., Chicago, IL, USA).

Results and Discussion

Osmotic Dehydration

NaCl migrated from the saline solution through the eggshell into the albumen and yolk during the traditional brining process. Simultaneously, the albumen and yolk dehydrated. The egg yolk started to solidify near the vitelline membrane and proceeded toward the center as the yolk hardened. However, the egg yolk became watery near the vitelline membrane and was hard in the center of the separated yolk immersed in the salt only solution (Fig. 1). Because egg yolk contains a large quantity of water-insoluble proteins, imbibition occurs, and a large volume of water enters the egg yolk. The brined yolk dehydrated in parallel with the diffusion of salts; thus, the resulting water-filled state of the yolk appeared to be due to both effects.

Hwang (2002) pickled separated duck egg yolks in a 20% salt solution with 0.3% citric acid and 0.2% ferric citrate at 25°C for 32 h. The moisture content and salt content of the salted yolk was 37% and 2.20%, respectively. This study improved the dehydration of the separated yolk but did not approach the standard of commercial salted yolks (approximately 20–25%; Saeaung et al., 2010).

Dehydration is very important to prepare a salted yolk using separated duck egg yolks. OD is one of the most important complementary treatments and food preservation techniques to process dehydrated foods. Different types of
solutesthusuchasfructose,cornsyrup,glucose,NaCl,and sucrose,areusedasosmoticagentsforOD.Because theresultsofearlyexperiments(datanotshown),Iusedmalto-
dextrinandsaltasosmoticandbriningagents,respectively, toacceleratedehydrationandovercomethisdrawback. Table1showsthecompositionandawvaluesforbrining solutionsA–E. The aw value of 20% sodium chloride was 0.835 and the aw value of the brining solution declined when maltodextrinwasadded. The aw value of a solution contain-
ing 20% sodium and 20% maltodextrin was 0.776, which is near the aw of asaturated saltsolution (0.746). Iexpected that these two solutions would produce similar osmotic pressures.

The separated egg yolks were immersed individually in unsealedcontainersofbriningsolutionsA–Eina25°C incu-
batorat50%humidityfor4days. The yolks ruptured easily during brining in a salt solution containing a low maltodextrinconcentration (A, B, and E), whereas yolks groups C and D maintained their integrity. After washingoff thebriningsolutioncarefullywithdistilledwater, theegg yolk samples werecookedinanelectricricecookerfor10 minbeforethephysicochemicalpropertiesanalysisavoid rupture. Photographsofcookedduckegg yolks after un-
dergoingthe separated yolk brining process for differ-
durationsareshowninFig.2. The results reveal a watery portion near the vitelline membrane of the cooked yolk (arrowsinFig.2A,B,ande). Onlytheseparated yolks brined insolutionsCandDhardenednearthevitelline membrane of theyolk. Thewatermoleculesmovedacross themembraneintothe briningsolutionand evaporated into air from theyolk (thecontainerwastsealed), but the

Table 1. Composition and water activity values of the brining solutions

| Treatment groups | 20% salt (A) | 20% salt + 5% maltodextrin (B) | 20% salt + 10% maltodextrin (C) | 20% salt + 20% maltodextrin (D) | Saturated salt (E) |
|------------------|--------------|-------------------------------|-------------------------------|-------------------------------|--------------------|
| Composition and water activity | NaCl | 20 | 20 | 20 | 20 | 26 |
|                  | Maltodextrin | 0 | 5 | 10 | 20 | 0 |
|                  | Water | 80 | 75 | 70 | 60 | 74 |
|                  | Water activity | 0.835 | 0.821 | 0.806 | 0.776 | 0.746 |

Fig. 1. Photograph of the watery part of a salted egg yolk (arrow). A. Separated yolk immersed in 20% salt solution for 3 days.

Fig. 2. Photographs of cooked duck egg yolks after separated yolk brining for different durations. The first day results are shown in the upper panel. From left to right shows an unbrined fresh egg yolk and a salted egg yolk immersed in a solution containing 20% sodium chloride and 0%, 5%, 10%, or 20% maltodextrin. The far right shows the effects of a saturated salt solution (A–E). Lower panel shows day 4. H: hardened part of the salted egg yolk; W: watery part of the salted egg yolk.
maltodextrin molecules were too large to pass through the membrane. These results suggest that the high maltodextrin concentration increased the dewatering capacity and that maltodextrin provided the driving force for dehydration.

**Moisture and Salt Contents and Oil-exudation Ratio**

The salting process solidifies and removes moisture from the yolk. The moisture contents of the cooked salted egg yolks in different brining solutions are shown in Fig. 3. The $a_w$ value of brining solution D was 0.776, which is near the value of a saturated salt solution (0.746), suggesting that $a_w$ of the brining solution must be in this range to produce sufficient osmotic pressure. As expected, the moisture content of egg yolks brining in solution D was the lowest, as they decreased to 35.5% after 1 day and to 25.4% at the end of brining. The moisture content of a brined yolk sample was close to that of commercial salted yolks (approximately 20–26%; Saeaung, et al., 2010) and decreased faster when maltodextrin was added. However, separated yolks developed watery areas when immersed in saturated brine, and their moisture content was 38.8% on day 4. Therefore, a high percentage of maltodextrin resulted in a higher dewatering capacity and resulted in moisture content near the commercial standard.

The NaCl contents of yolks increase with brining time using the traditional method (Chi and Tseng, 1998; Lai et al., 2010). However, the salt contents of the outer, middle, and center regions of cooked salted egg yolks brined in a saturated salt solution increased rapidly to 4.93%, 3.19%, and 2.03% after 1 day, respectively (Fig. 3) but decreased rapidly to 3.77%, 1.45%, and 0.87%, respectively the next day. Spheres, granules, and low-density lipoproteins suspended in the protein solution or plasma of the egg yolk can form gels (Woodward and Cotterill, 2006). Thus, salted duck egg yolks turn into an elastic gel after a prolonged salting period. Kaewmanee et al. (2013) showed a change in network structure as the NaCl concentration increased from 0% to 3.0% (w/w), and a sol–gel transition occurs at a 1.5% (w/w) salt concentration. Telis and Kieckbusch (1998) reported that gelation decreases as NaCl concentration is increased to 4%, possibly due to increased resistance of

Table 2. Changes in whole oil exudation of cooked duck egg yolks after undergoing the separated yolk brining process for different durations

| Brining solution | Third day | Forth day |
|------------------|-----------|-----------|
| A                | 0.219<sup>a</sup> | 0.245<sup>d</sup> |
| B                | 0.144<sup>a</sup> | 0.221<sup>a</sup> |
| C                | 0.186<sup>b</sup> | 0.201<sup>b</sup> |
| D                | 0.283<sup>d</sup> | 0.315<sup>e</sup> |
| E                | 0.192<sup>b</sup> | 0.234<sup>c</sup> |

The compositions of brining solutions A–E are shown in Table 1. **Different superscripts in the same column indicate significant difference ($P<0.05$).** All values are means of five cooked salted egg yolks.
molecules to get close to each other because of the higher ion concentrations. The structure of egg yolks immersed in a high concentration of pure salt solution may disintegrate, resulting in a water-filled state. The NaCl content of the outer regions of cooked salted egg yolks brined in 20% maltodextrin and 20% salt solution began at 0.87% and increased gradually to 2.9% on day 4, which is similar to the result observed using the traditional method. The maltodextrin molecules were too large to pass through the membrane, and I propose that maltodextrin also retard the permeation of salt, this result in salt content of salt and maltodextrin group increased gradually, but salt content of yolk in salt only group increased rapidly. Maybe osmotic equilibrium was reached at the next day, no more salt enter the egg yolk, thus the salt content of yolk decreased. This requires further experiments.

Table 2 shows the changes in the oil-exudation ratio of separated salted egg yolks during brining. The oil-exudation ratio values of yolks in the different brining solutions increased significantly ($P < 0.05$) with brining time. Again, the oil-exudation ratio of egg yolks brining in 20% maltodextrin and 20% salt solution was highest and increased to 31.5% at the end of brining.

**Texture Profile Analysis (TPA) and Sensory Evaluation of Salted Yolks**

Texture profiles of the salted egg yolks brined in 20% maltodextrin and 20% salt solution and commercial salted yolks are shown in Table 3. No differences in hardness were found between both methods ($P \geq 0.05$). The result suggested that the structure of salted egg yolk became more solidified using the proposed process. Salted egg yolk was more dehydrated and could form the gritty texture. Grittiness is the major factor affecting consumer acceptance of salted egg product (Chi and Tseng, 1998).

These two group cooked yolks were applied to test color, odor, texture, saltiness, and general acceptability by panelists using a 9-point hedonic scale and compared to commercial salted yolks. The sensory evaluation scores of 42 non-trained sensory panels are summarized in Fig. 4. The sensory results showed a little difference when the salted egg yolks from the proposed process were used to compared with commercial salted yolks using the traditional process. The difference observed was color, and the panelists preferred the salted yolk prepared by the traditional process over that from the proposed process. The other one was saltiness, and the panelists preferred the salted yolk prepared by the proposed process over that from the traditional process.

**Conclusion**

This study demonstrated a novel approach to improve saltiness of salted yolks cured using the separated yolk brining process. Maltodextrin was used as a dewatering agent and salt suppressant. A 20% (w/w) concentration of maltodextrin was added to the hypertonic brining solution to prevent over-salting of the brined yolks and produced salted yolks with reduced salt content that were near the low salt level of commercial salted yolks. The sensory and physicochemical evaluation of the salted yolks suggested that they had the same overall characteristics as commercial salted yolks.

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Supplementary Material

Salting Yolks Directly Using Fresh Duck Egg Yolks with Salt and Maltodextrin

Tseng-Hsing Wang

Fig.S1. The pictures of special shape of salted yolk. Heart, square, plum flower shape model were used in the new brining process of these salted yolk.