Changes in Yolk States of Duck Egg during Long-Term Brining

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To elucidate the relationship between shyandan yolk formation and NaCl penetration degree, fresh duck eggs were brined in 26% NaCl and a prolonged brining test was conducted for up to 24 weeks. Shyandan yolk was obtained from brine-cured duck shell eggs in 26% NaCl for 4−6 weeks and subsequently heated at 85 °C for 90 min. Though NaCl contents for albumen and yolk increased to 14.8 and 8.9%, respectively, during the prolonged test for up to 24 weeks, the *R* values (NaCl/water × 100) were similar (increased from 0.6 to 21) throughout the brining process. The oil-off ratio of the yolk increased rapidly from 14 to 50% (0−6 weeks) and gradually decreased during the extended brining. Granulation and gelation of yolk appeared in the different stages of the brining process. This study demonstrates that the formation of shyandan yolk was determined by the degree of NaCl penetration.

Keywords: *Duck egg; yolk; brining; oil-off ratio; granulation; gelation*

INTRODUCTION

The salted duck egg, shyandan, is one of the most traditional and popular egg products in China. It is made by brining eggs in saturated saline or by coating the egg with a red soil paste mixed with salt for ∼30 days and subsequently heating the egg (Peh et al., 1982; Lin et al., 1984; Chang and Lin, 1986). In addition to being eaten with the whole egg, shyandan yolks are widely utilized as fillings in Chinese foods such as moon cakes and glutinous rice dumplings (Chiang and Chung, 1986; Chi and Tseng, 1998). To preserve the functions of the albumen, several research groups (Chiang and Chung, 1986; Chen et al., 1991; Wang, 1991, 1992; Tseng, 1994; Chang, 1995) separated the yolks from the albumen before brining, but these brining processes were not successful with shyandan yolk. Wang (1991, 1992) indicated that the formation of shyandan yolk might be related to the diffusion speed and final concentration of NaCl.

From the standpoint of customers, cooked shyandan yolks are generally considered to have excellent properties with a granular texture as that found in bean filling and oil-off as that found in cooked caviar (Peh et al., 1982; Chiang and Chung, 1986; Wang, 1992). In our previous study (Lai et al., 1997), duck eggs treated with HCl have an increased penetration rate of 2−10-fold, which results in reduced time required to achieve the maximum oil-off ratio. The granulation of the yolk, accompanied by a high oil-off ratio, rapidly changes into a gelation state in the eggs treated with HCl. A rise in the NaCl penetration rate only accelerates the formation of gelatinous yolk.

In this study, fresh duck eggs were brined in 26% NaCl in a prolonged brining test conducted for up to 24 weeks. Our objectives were to elucidate the relationship between shyandan yolk formation to the NaCl penetration degree and whether the yolks change from a granular state into gelatinous state during long-term brining at the normal NaCl penetration rate.

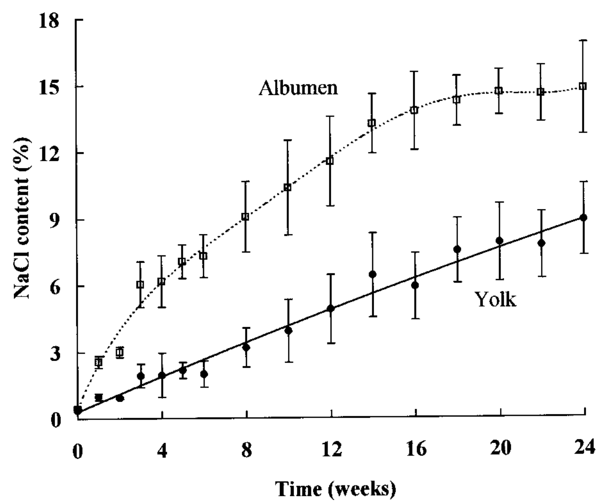

Figure 1. Change of NaCl content in albumen and yolk during long-term brining.

MATERIALS AND METHODS

Materials. Infertile eggs, 65−75 g and 43−46 mm in width, obtained from *Anas plotyrhyncus* (Tsaiya), were used within 2 days after laying.

Preparation of Salted Egg. Eggs washed in water were brined in saturated saline (26% NaC1) at 15 ± 2 °C. The ratio of eggs to the pickling solution was ca. 3:5 (w/w). Five eggs were removed every 1−2 weeks after brining for 24 weeks and heated subsequently at 85 ± 2 °C for 90 min to produce the salted products.

Analytical Methods. NaCl content was measured using a salt analyzer (Presto-Tek) according to the procedure of Wang (1992). Moisture was measured according to the method of the AOAC (1980). Lipid content and free lipid in the yolk were

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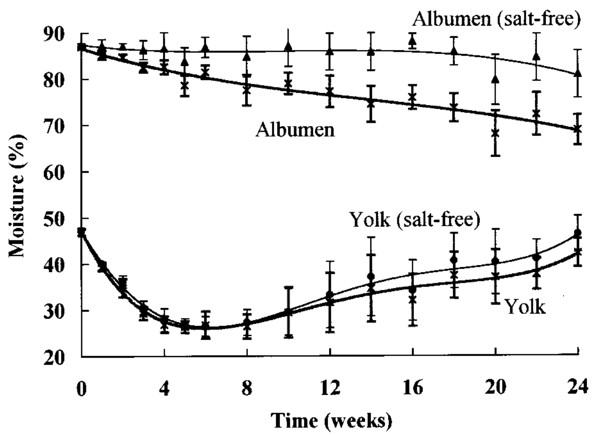

Figure 2. Change of moisture contents (with salt or salt-free) in albumen and yolk during long-term brining.

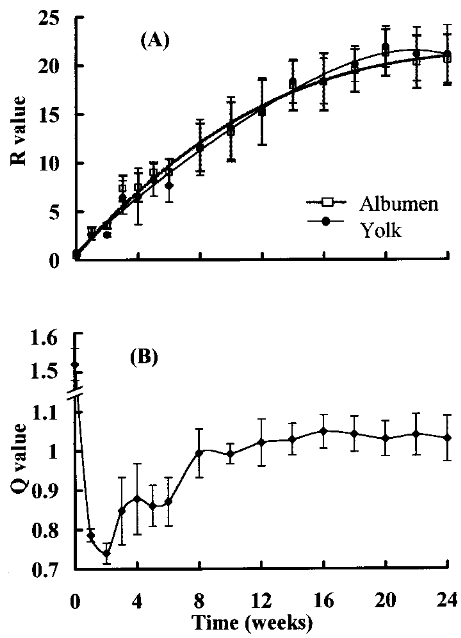

Figure 3. Change of the *R* value in albumen and yolk and of the *Q* value within albumen and yolk during long-term brining. *R* value = NaCl content/moisture content × 100; *Q* value = *R* value of yolk/*R* value of albumen.

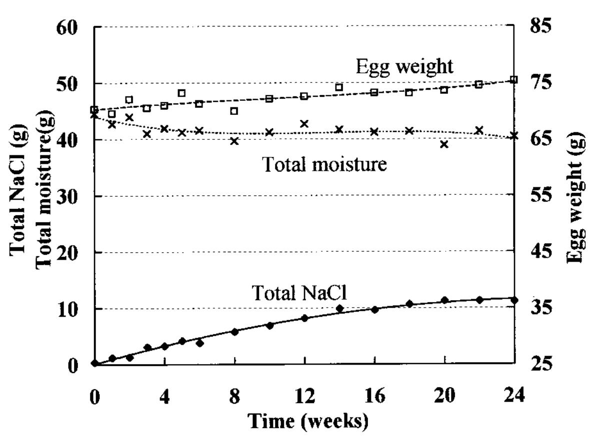

Figure 4. Change of total NaCl, moisture, and whole egg weight during long-term brining.

determined using the procedure described by Fletcher et al. (1984) with some modifications. A 3-g yolk was homogenized with 35 mL of *n*-hexane/2-propanol (3:2 v/v) at 5000 rpm (Polytron PT 3000) for 30 s. The filtrate obtained through Whatman No. 1 filter paper was evaporated in a water bath

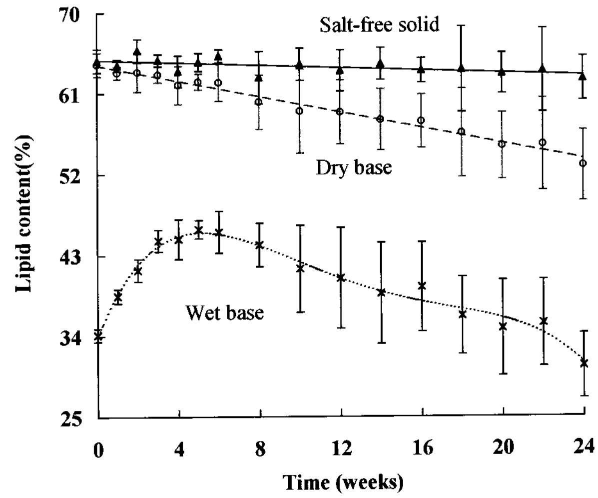

Figure 5. Change of lipid content of yolk during long-term brining.

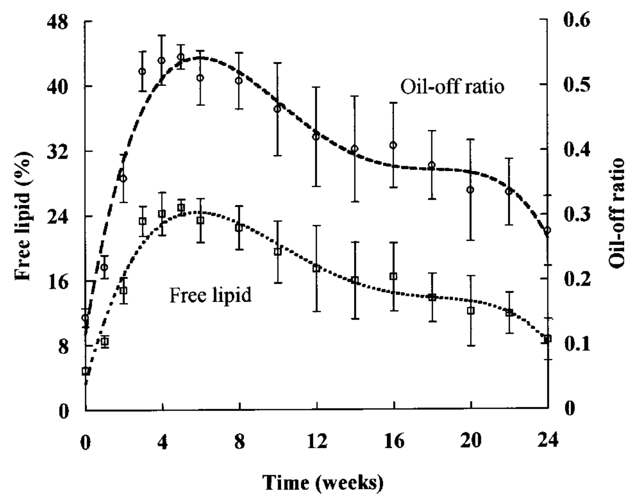

Figure 6. Change of free lipid and oil-off ratio of yolk during long-term brining.

and then dried at 105 °C to a constant weight. The residue was weighed and taken as the lipid content and expressed on wet basis. To determine the oil-off ratio, a 5-g yolk was mixed with 25 mL of distilled water and homogenized at 5000 rpm for 30 s. The homogenate was centrifuged at 9500*g* for 30 min at 25 °C (Hitachi Himac SCR 20B; rotor, RPR20-2; Tokyo, Japan), and 25 mL of *n*-hexane/2-propanol (3:2 v/v) was added to the supernatant to dissolve the float. The solvent−lipid layer thus obtained was separated using a separation funnel. The solvent in the solvent−lipid layer was evaporated in a water bath and subsequently heated at 105 °C to achieve a constant weight. The residue was weighed and taken as the free lipid. The oil-off ratio was defined as the proportion of free lipid to lipid content.

RESULTS AND DISCUSSION

Changes of Salt Content and Moisture. The NaCl contents were 0.36 and 0.44% in fresh albumen and yolk, respectively. During the brining, the NaCl in the albumen increased rapidly to 6.6% in the first 4 weeks and gradually reached 14% at the 16th week, whereas the NaCl in the yolk increased only to 8.9% after brining for 24 weeks (Figure 1), possibly due to the buffer action of the albumen. The moisture of the egg yolk decreased rapidly from 47 to 26% in the first 6 weeks caused by the increase in the NaCl content in the albumen, which was quicker than that in the yolk. However, the

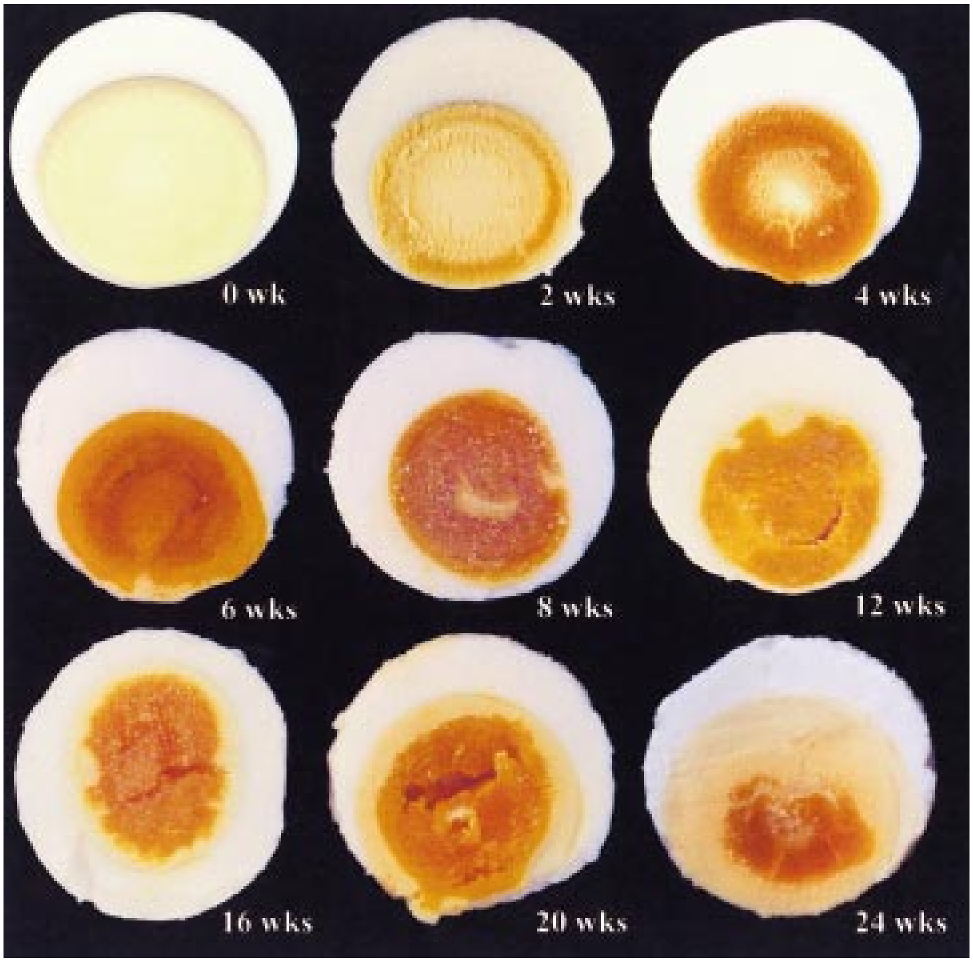

Figure 7. Cross sections of cooked salted duck eggs during long-term brining.

moisture in the yolk increased to 42% at the 24th week (Figure 2), possibly because the yolk membrane had weakened to allow the penetration of moisture from the albumen into the yolk (Feeney et al., 1956). On the other hand, albumen moisture reduced from 87 to 69% after brining for 24 weeks. The moisture decreased only to 81% when NaCl was subtracted (Figure 2). This result indicated that the dehydration was accompanied with a rise in NaCl concentration in the albumen.

Because the moisture contents were different in the albumen and yolk, a comparison of the NaCl contents between the albumen and yolk is not appropriate (Der Valle and Nickerson, 1967a,b). The ratio of NaCl/water $\times$ 100 has been defined as the *R* value, which is the NaCl concentration in the liquid phase of the sample. The ratio of yolk *R* value to albumen *R* value has been defined as the *Q* value, which is the equilibrium coefficient between the yolk and the albumen (Tseng, 1994; Chang, 1995). In this study, we found that the *R* values, 0.77 and 0.51 for fresh yolk and albumen, respectively, increased with time to ~21 at the 24th week of brining (Figure 3A). The balanced diffusion for both albumen and yolk is established at once when egg is brined in saturated saline. The *Q* value reduced rapidly from 1.52 for fresh duck eggs to 0.74 at the second week of brining due to the destruction of balanced diffusion between the yolk and albumen. However, the diffusion gradually reached equilibrium at 1.02 after 8 weeks of brining (Figure 3B). The decrease of *Q* value at the initial stage of brining resulted from the hindrance of the yolk membrane to the brine. The *Q* value gradually increased over 8 weeks of brining due to the slow penetration of brine through the yolk membrane, which was weakened (Feeney et al., 1956; Hinton, 1968; Oosterwound, 1987). As shown in Figure 4, the average weight of the egg gradually increased by ~5.7 g during brining, which resulted from an increase in NaCl (10.2 g) and a decrease in moisture (5.0 g).

Alteration of Total Lipid Content and Oil-off Ratio. The change in the total lipid content of the egg during brining is related to NaCl absorption and moisture gain and loss, as has been previously proposed (Lai et al., 1997). The total lipid content, on a wet basis of yolk, increased from 34 to 46% in the first 6 weeks and then reduced to 31%, whereas the total lipid content, on a dry basis, decreased from 64 to 53%. The total lipid, based on salt-free solids, was unchanged (Figure 5). This illustrates that total lipid content was not changed during brining.

The free lipid content increased in the first 6 weeks and decreased afterward. Most lipids in the egg yolk exist in low-density lipoproteins (LDL) (Gilbert, 1971). Only small amounts of lipids floated on top when the cooked yolk was placed in cold water. After brining, this may occur because the structure of the LDL was destroyed and part of the lipid in the cooked yolk became free, so that more lipid could float in cold water (Lai et al., 1997). However, when the egg is brined over 8 weeks, maybe the weakened yolk membrane (Feeney et al., 1956) causes the albumen moisture to penetrate into the yolk and the diluted free lipid−proteins (weakened lipoprotein) form a gel after heating. Similarly, the oil-off ratio clearly increased from 0.14 to 0.54 (0−6 weeks) and then gradually reduced to 0.28 (Figure 6).

On the basis of the quality indicator, a high oil-off ratio was accompanied with granular yolk formation, and 4–6 weeks was the optimum brining period for shyan-dan product preparation.

Changes in Appearance of Yolk. The color of cooked yolk is yellow before brining. From the outer region to the center, the cooked yolk gradually changes into a yellowish brown, dark brown, reddish orange, and light yellow during 24 weeks of brining. The changes in the yolk color of cooked eggs during brining is related to moisture gain or loss and the amount of free lipids in the yolk. The moisture affects the concentration of the pigment, and the free lipid affects the extracted pigment (Tseng, 1994). In general, granular and oil-off yolk is obtained after brining for 4 weeks. Although the brining period can be reduced by increasing the NaCl penetration rate as discussed in previous studies (Lai et al., 1997), gelation may result if brining is sustained. As in the high NaCl penetration rate sample (Lai et al., 1997), the change in the states of the yolk proceeded as crumbly and mealy, granular, and a gelatinous state over long-term brining with a normal NaCl penetration rate (Figure 7). Compared with a previous study (Lai et al., 1997), it is concluded that the NaCl penetration rate did not alter the brining process but affected the period at which the changes in yolk states occur.

Conclusions. A high oil-off ratio of yolk occurred after 4–6 weeks of brining. This phenomenon may be related to the solidification of yolk protein with low NaCl content (∼2%) and low moisture (<30%) (Chi and Tseng, 1998). Lipids in the yolk, released after heating, result in oil-off and granular yolk. On the other hand, the yolk proteins are emulsified with lipids in the condition of high NaCl content (>3%) and high moisture (>30%) over long-term brining. The yolk under these conditions becomes gelatinous after heating. Many factors influence the formation of salted egg yolk. Compared with the previous study (Lai et al., 1997), the NaCl penetration rate affects only the time period for the yolk state changes and does not alter the brining process. Therefore, this study suggests that the degree of NaCl penetration, instead of the NaCl penetration rate, should be carefully controlled during brining. In addition to the control of NaCl penetration, the destruction of the yolk membrane should be avoided as much as possible if salted yolk is to be produced from yolks separated from whole eggs.

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