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Effect of NaCl Penetration Rate on the Granulation and Oil-Off of the Yolk of Salted Duck Egg

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Duck eggs treated with 1.0 N HCl up to 120 min to adjust the permeability of the shell were immersed in 26% NaCl (0–40 days) and subsequently heated at 85°C for 90 min to obtain the salted eggs in order to investigate the effect of NaCl on the granulation and oil-off of the yolk formed. During brining, the NaCl contents of the yolk and albumen were increased 2–10 fold due to HCl treatment of the shell. The oil-off ratio, defined as the ratio of the free lipid to the lipid content of the yolk, was also affected by the penetration rate and brining time. Eggs treated with 1.0 N HCl for 120 min showed reduced time required to achieve the maximum lipid content and oil-off ratio and had a lower maximum value of oil-off ratio than eggs treated with 1 N HCl for 0–80 min. The yolk of HCl-treated (1.0 N, 80 min) egg changed in appearance mealy form to be granulous at 5–10 days and to a soft gel at 15–20 days after brining. In comparison, the eggs without HCl treatment respectively required 20–25 and 40 days for these changes. This study suggests that sustained brining may result in the formation of a gel-state yolk, and the NaCl penetration rate affects only the time for the change in forms.

Keywords: duck egg, brining, yolk, NaCl penetration, gelation, granulation

Salted duck egg, shyandan, is a traditional and popular egg product in Taiwan. It is made by brining the egg in saturated saline or by coating with red soil paste mixed with salt for 20–30 days and subsequently heating the egg (Peh *et al.*, 1982; Lin *et al.*, 1984; Chang & Lin, 1986). In addition to supplying for regular diet as a whole-egg type, the yolks are also utilized as stuffing material in some Chinese foods such as moon cake and glutinous rice dumpling (Chiang & Chung, 1986).

Hard-cooked eggs are also used to produce salted or pickled eggs in the Occident (Angalet *et al.*, 1976; Fischer *et al.*, 1985). Hard-cooked egg yolk has a crumbly and mealy texture. Chicken eggs held in brines for up to 4 weeks are altered in appearance, and the yolk index of raw yolks changes only slightly in texture profile relative to that of cooked yolks (Woodward, 1988). The phenomena are quite different from those of shyandan which are generally considered to have excellent properties with granular texture and oil-off after cooking (Peh *et al.*, 1982; Chiang & Chung, 1986; Wang, 1992). From the standpoint of customers, the granular texture should resemble that of bean filling, and the oil-off phenomenon should resemble that of caviar. However, no scientifically defined criteria are suitable to describe the quality of shyandan.

In order to maintain the albumen functionalities, several research groups (Chiang & Chung, 1986; Chen *et al.*, 1991; Wang, 1991, 1992) have tried to manufacture the salted yolks separated from eggs. Most of these salted processes were unsuccessful in obtaining shyandan yolks. Wang (1991) indicated that the formation of shyandan yolk is probably related to the diffusion speed and final concentration of NaCl.

With heat (Woodward & Cotterill, 1987a, b; Woodward, 1988) or freeze-thawing (Kamat *et al.*, 1976; Chang *et al.*, 1977) treatments, egg yolk may become viscous and thick, a condition known as gelation. The state of the yolk is also affected by salt even at room temperature (Mahadevan *et al.*, 1969; Harrison & Cunningham, 1986). The egg shell may obstruct the penetration of NaCl into the yolk. Acid treatment of the egg shell results in a decrease in thickness and an increase in penetration (Williams & Dillard, 1973; Heath & Wallace, 1978) with cuticle protein denaturation and shell corrosion (Brown *et al.*, 1966; El-Boushy *et al.*, 1968).

In this study, fresh duck eggs treated with HCl in order to alter the shell permeability were brined in 26% NaCl over a longer time than usual. Our objective was to investigate the process of shyandan yolk formation according to the change in appearance and composition during brining by controlling the penetration rate of NaCl.

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.

Acid treatment of shell Eggs washed in water were immersed in 1.0 N HCl for 10–150 min. The treated eggs were washed to remove acid and the surfaces dried with air.

Measurement of egg shell thickness and shell weight percentage After separating the egg contents by a hand-breaking operation, the thickness of the shell was measured with a micrometer. The shell weight percentage (%) was defined as the weight proportion of the air-dried shell to the whole egg.

Preparation of salted egg After acid treatment in 1.0 N HCl for 0–120 min, the eggs were brined in 26% NaCl at

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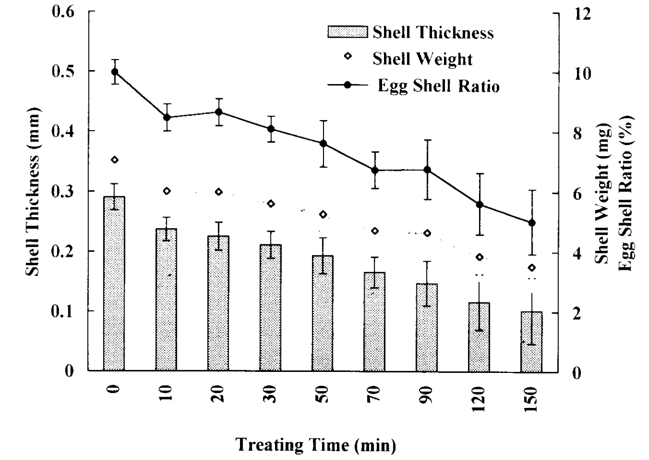

Fig. 1. The effects of 1.0 N HCl treatment on shell thickness, shell weight and egg shell ratio. Each point represents mean and standard error of 12 replicate determinations.
Egg shell ratio=(shell weight/whole egg weight)×100%.

Table 1. The effect on NaCl penetration rate[a] of shell eggs by 1 N HCl treatment in saturated saline.

Treating time (min)	Rate (%/day)	
	Albumen	Yolk
0	0.15	0.02
40	0.26	0.08
80	0.61	0.16
120	1.31	0.27

[a] The rates were regressed from the data during 30 and 10 days brining of the egg treated with 1 N HCl for 0–80 min and 120 min, respectively (R^2>0.77).

15±2°C. Then, three brined eggs were taken out every 5 days and subsequently heated at 85±2°C for 90 min to obtain the salted products. This procedure was continued for 40 days.

Analytical methods The NaCl content was measured with a salt analyzer (Presto-Tek, USA) according to the procedure of Wang (1992). The penetration rate of NaCl is expressed as the slopes obtained from a linear regression of the changes in NaCl content in the yolk and albumen during brining. Moisture was measured according to the method of A.O.A.C. (1980).

Lipid content and free lipid in the yolk were determined by the procedure described by Fletcher *et al.* (1984) with some modifications. A 3-g yolk was homogenized with 35 ml of *n*-hexane-isopropanol (3:2 v/v) at 5,000 rpm (Polytron PT 3000; Switzerland) for 30 s. The filtrate obtained through Whatman No. 1 filter paper was evaporated in a water bath and then dried at 105°C to a constant weight. The residue was weighed as the lipid content, and the wet basis percent was expressed. To determine the oil-off ratio, a 5-g yolk mixed with 25 ml distilled water was homogenized at 5,000 rpm for 30 s. The homogenate was centrifuged at 9,500×g for 30 min at 25°C (Hitachi Himac SCR 20B; rotor: RPR20-2; Tokyo), and 25 ml of *n*-hexane-isopropanol (3:2 v/v) was then added to the supernatant to dissolve the floating material. The solvent-lipid layer thus obtained was separated using a separatory funnel. The solvent in the solvent-lipid layer was evaporated in a water bath and the material subsequently heated at 105°C to a constant weight. The residue was weighed as the free lipid, and the wet basis percent was calculated. The oil-off ratio was defined as the proportion of free lipid to the lipid content.

Results and Discussion

Effect of acid treatment on egg shell Figure 1 shows that extending the time of acid treatment resulted in a greater decrease in shell thickness, weight, and egg shell ratio by soaking the egg in 1.0 N HCl, due to the high level of corrosion. This conclusion is consistent with the finding that cleaning the egg with diluted acid makes the shell thinner (Heath & Wallace, 1978), and a thinner shell promotes the penetration even for microbes (Williams & Dillard, 1973).

Changes in NaCl and moisture content of brined egg NaCl gradually diffused into the albumen and yolk through the pores and membrane of the shell during brining in saturated saline. Acid treatment induced a 2–10 fold increase in the NaCl penetration rate for both the albumen and yolk (Table 1). Figure 2 illustrates that the moisture content of the yolk was clearly decreased at the beginning of brining. The shell eggs became dehydrated during this period because the decrease in moisture was greater than the increase in NaCl. Similar results have been reported previously (Woodward, 1988; Chiang & Chung, 1986; Wang, 1991). The moisture in the yolk increased in the late stage of brining, and the change in moisture showed a quadratic curve during brining. This phenomenon of yolk hydration is due to the weaker yolk membrane in the later stage (Feeney *et al.*, 1956). Irregular changes were observed in the egg samples treated with 1.0 N HCl over 80 min (Fig. 2), because it is easier for the water and NaCl to diffuse through the thinner shell.

Changes in lipid content and oil-off ratio of yolk during brining The lipid content of yolks from salted eggs without HCl-treatment changed from 33% to 43% after being brined for 40 days (Fig. 3). On the other hand, the lipid content of the eggs treated with HCl for 120 min increased to 40% at about 5 days but decreased to less than 25% instantly at about 40 days of brining. The change in NaCl and moisture content of the yolk affected the ratio of its components during brining, but the total lipid level based on salt-free solids remained unchanged (62%). The alteration of the lipid content was due to the NaCl penetration and moisture hydration or dehydration.

Most lipids in egg yolk exist in low density lipoproteins (LDL) (Gilbert, 1971). Only small amounts of lipid floated on top when the cooked yolk was placed in cold water. After brining, this may occur because the structure of LDL was destroyed and part of the lipid in the cooked yolk became free, so that the more lipid could be floated in cold water. The oil-off phenomenon of salted yolk had been evaluated using free lipid before cooking (Wang, 1991). However, the lipid content was unstable (Fig. 3) as stated above, and the oil-off phenomenon of the salted yolk appeared only after cooking. Thus the oil-off ratio expressed as the floating lipid (free lipid) to the lipid content of the cooked yolk may be a more appropriate index of the oil-off property of salted yolk than the lipid content or the free lipid. The oil-off ratio of cooked

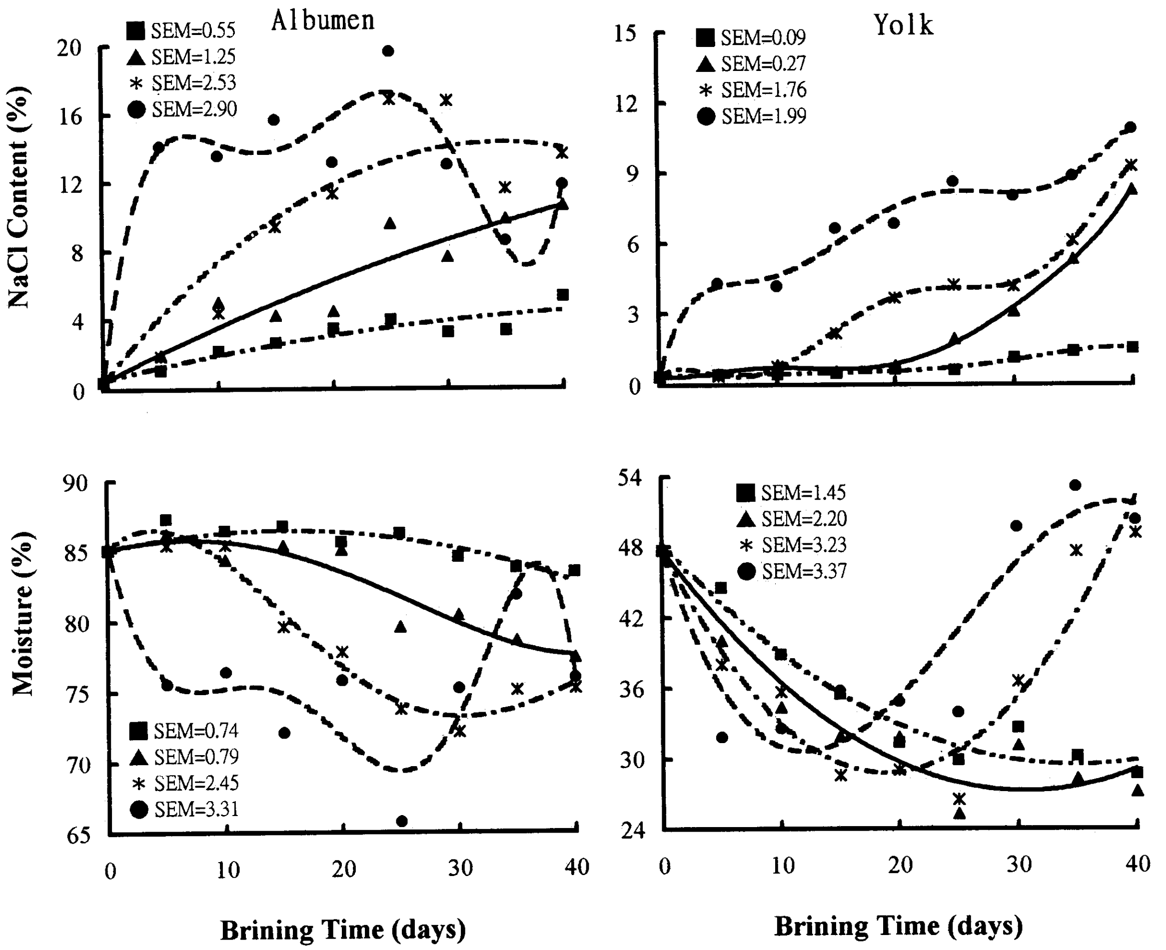

Fig. 2. The effects of 1.0 N HCl treatment on NaCl and moisture content of albumen and yolk during brining. SEM, standard error of means. ■ Not treated with acid; ▲ 1 N HCl, 40 min; ∗ 1 N HCl, 80 min; ● 1 N HCl, 120 min.

yolks without HCl treatment was 0.11 which was increased to a maximum (0.55) at 40 days after brining (Fig. 3). The results showed that a high penetration rate of NaCl reduced the time required to achieve the maximum lipid content and oil-off ratio and produced lower maximum values. The oil-off ratio is closely related to the oil-off phenomenon in the appearance of egg yolk. Formation of granular yolk is generally accompanied by a high oil-off ratio. In this study, a low oil-off ratio was observed with a less granular (mealy) texture at the initial period of brining and with a gelation texture after over-brining (Fig. 3).

Changes in appearance of yolk during brining Watery albumen with orange and firm yolk was found in each egg which was brined for 4 weeks. After cooking, the albumen was soft, and the yolk was orange, oily and coarse (Trongpanich & Dawson, 1974). Figure 4 shows that the yolk became granulated gradually from the outside to the inner part during brining. In addition, the high penetration rate of NaCl reduced the brining time for granulation of the yolk but rapidly resulted in gelation. For HCl-treated (1.0 N, 80 min) eggs, the yolk changed from a mealy form to be granulous form between 5 and 10 days and to a soft gel form between 15 and 20 days of brining. In comparison, the control eggs required 20 to 25 and 40 days for the changes, respectively. The oil-off phenomenon appeared on the 30th day of brining. The soft gel yolk, which is quite different from the traditional

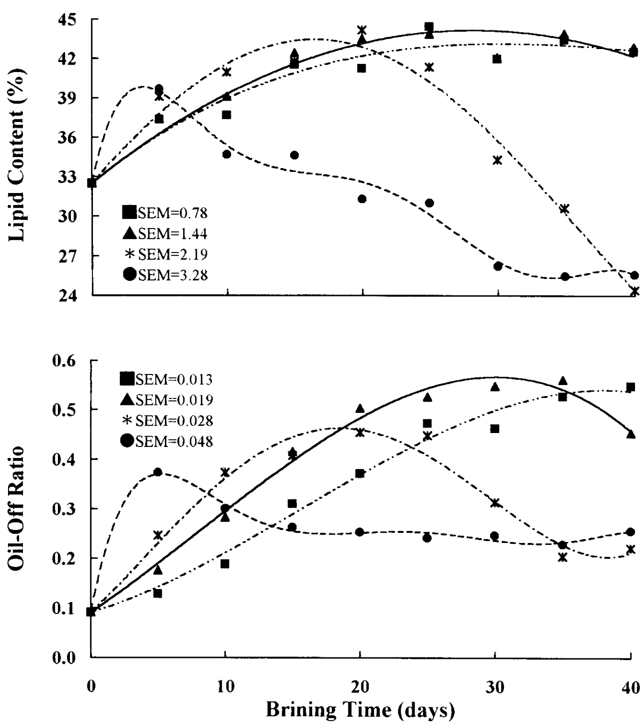

Fig. 3. The effects of 1.0 N HCl treatment on lipid content and oil-off ratio of yolk during brining. SEM, standard error of means. ■ Not treated with acid; ▲ 1 N HCl, 40 min; ∗ 1 N HCl, 80 min; ● 1 N HCl, 120 min.

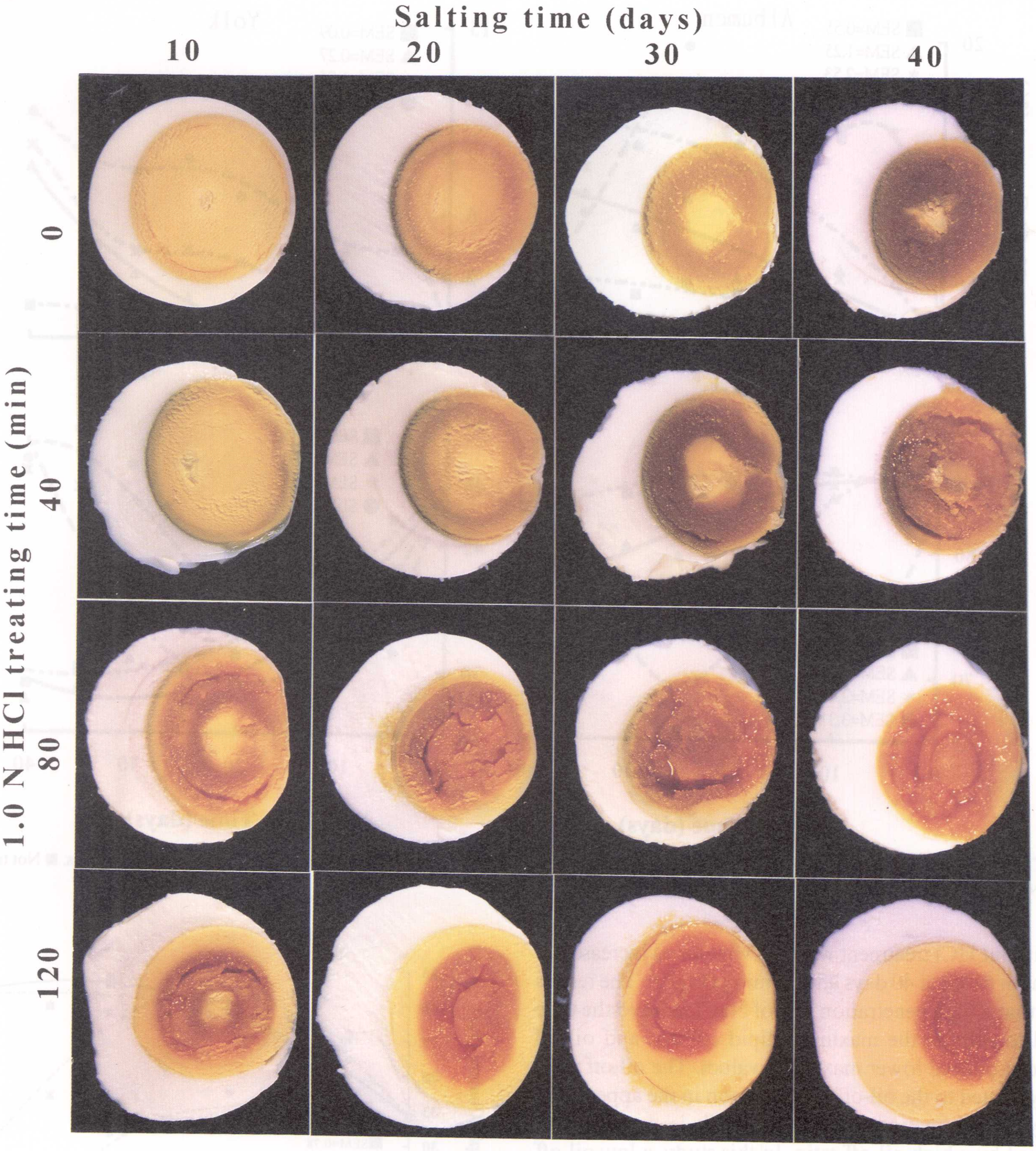

Fig. 4. The cross sections of salted duck eggs after heating.

shyandan yolk, was formed by long-term brining of eggs not treated with acid. Both the granulation state and the gelation state of yolks may result if brining is sustained. The NaCl penetration rate affected only the time for the change in forms.

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