Functional Properties of Japanese Quail (Coturnix coturnix japonica) Eggs Proteins

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Abstract: The eggs of the domestic chicken (Gallus gallus domesticus) are the most consumed, but those of duck, goose, and quail are also consumed, to name a few. An egg is considered as a food rich in proteins, minerals, and lipids. Eggs generally consist of three main components: shell, white, and yolk, these have several functional properties that are used in food and other industries. The functional properties of the egg white and yolk are the ability of foaming, gelling, and emulsifying, which can be dealt with according to storage time. The objective of this work was to evaluate the functional properties of the components of the Japanese quail egg. The functional properties of eggs stored at room temperature for 1, 10, 20, 30, 40, 50, and 60 days after laying were determined. Results are analyzed using a Tukey paired comparison test. The volume of the foam of the quail egg white did not change with storage time, the emulsion capacity was 193.8 mL of oil per gram of protein from the yolk. The coagulation capacity requires a lower temperature to coagulate the quail egg proteins, due to the slower transformation of ovalbumin to its thermo-stable form (S-ovalbumin) as compared to that of chicken.

Key words: Quail eggs, proteins, functional properties.

1. Introduction

The Japanese quail (Coturnix coturnix japonica) is a domestic bird, of worldwide relevance as a laboratory animal and used commercially for the production of meat and eggs. Among its exceptional characteristics are its fast growth, early sexual maturity, short generational interval, high egg-laying rate, less space required per bird as compared to hens [1], and the food conversion to egg is more efficient than that of hens [2].

Quail eggs are multicolored, going from snow-white to completely brown. Normally, eggs are of cinnamon-brown color or dark-spotted, or brown marbled with whitish-blue spots. Each quail tends to lay an egg with a specific size, marbling, or color characteristics [3].

Eggs can be considered an almost perfect food, a source of high quality proteins, fats, vitamins (except vitamin C), and minerals. They are a basic element of the human diet, low production cost, and easily accessible for most of the world’s population, they are easy to digest, and are used to improve the nutritional value of several types of foods [4]. Usually hen (Gallus gallus domesticus) eggs are consumed, but others, like duck, goose, and quail eggs, to name a few, are also popular. The egg is constituted by three main elements: the shell, egg white, and egg yolk; these constituents have a variety of functional properties, with a wide range of applications in the food and other industries [5].

The albumen or egg white is an aqueous solution of numerous globular proteins, these are ovalbumin, conalbumin (ovotransferrin), ovomucoid, lysozyme, ovomucin, ovoglobulins (G₂ and G₃), ovoflavoprotein, ovomacroglobulin, ovoglycoprotein, avidin, ovoinhibitor, and cystatin [6]. The egg yolk consists of a dispersion of fatty particles in an aqueous phase or plasma [7]. The particles, which can be separated...
by centrifugation, represent 20% of the dry weight of the yolk and contain around 60% of proteins and 34% of lipids. The internal quality of the egg is affected by storage time, it increases the air chamber and the pH, because of this, the structures of the egg white proteins, mainly ovalbumin, change to its thermostable form, S-ovalbumin, and the ovomucin breaks its fibrous structure and dissociates from the lysozyme, losing the viscosity of the thick egg white and, hence, the IQUs (internal quality units) diminish; regarding the yolk, the YI (yolk index) diminishes with storage time, due to the migration of water from the egg whites to the yolks [8].

The functional properties of the proteins are defined as any physicochemical property that affects the behavior and characteristics of foods in which they are found or are aggregated and that contribute to the final quality of the product. These characteristics can be sensorial, nutritional, and biochemical [9]. From the point of view of the food industry, the functional properties are those attributes of the food components or additives that, at the adequate concentration and under appropriate conditions, provide desirable characteristics to the final product, mainly rheological characteristics, like viscosity, body, juiciness, texture, and aeration. Proteins show functional properties in their interactions with the solvent, ions, other macromolecules, lipids, and surface phenomena [10, 11].

The functional properties presented by the egg white and yolk are the foaming, gelling, and emulsifying capacity, aside from the color and aroma of the yolk. These properties are affected by the storage time, mainly by the changes in the egg white proteins due to the alkalization by the gaseous exchange [12].

The albumen or egg white of the hen is composed of three main layers, which represent, in average, 23% (outer layer), 57% (thick layer), and 17% (inner layer) of the total mass. These proportions vary as a function of the animal’s race, amount of eggs laid, size of the egg, and storage time [13]. The thick layer, gellified, is the one remaining bound to the yolk when the raw egg is broken on a flat surface. The proteins of the egg white lead to foaming and coagulation, which are important for meringues, soufflès, decorating, and breads [14].

Yolks are spherical bodies, of ca. 20 µm in diameter, and contain smaller-sized (around 1.3 µm) granules. They have a high ionic strength, these granules dissociate into globules (0.03 to 0.1 µm), as well as other elements that can be observed under an electronic microscope. Lipoproteins, specifically lipovitellins α and β, constitute 70% of the dry mass of the particles, whereas a phosphoprotein, the phosphovitin, and the LDLs (low-density lipoproteins) represent 6% and 12% of this dry mass, respectively. The plasma contains a soluble globular protein, the livetin, and a low-density lipoprotein fraction that represent 11% and 66%, respectively, of the dry mass of the yolk. The yolk contains most of the lipids of an egg; they are essentially triglycerides (66%) and phospholipids (28%, mainly phosphatidylcholine). Cholesterol and cholesterol esters and others represent 6% of the lipid fraction. The intensity of the yolk’s color depends on the content of carotenoids [6, 15].

The egg yolk is well known for being a natural emulsion of oil in water. Due to its multifunctional properties, the yolk is widely used in the food, medical, pharmaceutical, and cosmetic industries [16]. It is also used to create oil emulsions in water, like mayonnaise, dressings, and creams [17]. Based on the aforementioned, the objective of this work was to determine the functional properties of the proteins of the Japanese quail egg.

2. Materials and Methods

2.1 Procurement of Samples

One hundred and fifty Japanese quail (Coturnix coturnix japonica) eggs were obtained from an egg-producing farm located in the borough of Tlalpan, in Mexico City. Quails were 4 months old, fed ad
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* libitum with a formulated food that contained 22% of proteins, at a 14-h photoperiod, RH (relative humidity) between 69% and 76%, and a temperature between 18 and 31.6 °C.

We chose 84 eggs, of which 12 were assigned randomly to each of the 7 times of storage (1, 10, 20, 30, 40, 50, and 60 days), and maintained between 18 and 23 °C and RH between 57% and 70%. Their FC (foaming capacity), FS (foaming stability), and emulsifying capacity were assessed. All assessments were performed in triplicate.

2.2 FC

The FC was determined according to a modification of the method described by Doi and Kitabatake [18]. Briefly, 10 mL of deionized water plus 2 mL of egg white was placed in a 100-mL Erlenmeyer flask, using a stainless steel propeller agitator (IKA RW20), the mixture was agitated at 6,000 rpm for 1 min. The FC was expressed as the volume of foam in stable condition.

2.3 FS

The FS was determined by measuring the liquid drained due to the action of gravity on the foam (which remains in the surface of the cylinder); this was measured directly in the flask after 12 h and was calculated as the stability of the foam against the drained liquid [19].

2.4 Emulsifying Capacity of the Yolk

This was determined using the electrical resistance principle described by Webb et al. [20] with modification. For it, 10 mL of deionized water plus 5 g of liquid yolk was placed in a 250-mL flask, this was placed on an agitation plate (IKA/C-MAG) at 5,000 rpm/min; the electrodes of one unit of resistance sensor (multimeter) were placed inside the flask, and the corn oil was left to flow slowly using a separation funnel at a speed of 148 mL/min.

2.5 Coagulation due to Heat

The Donovan and Mapes [21] differential scanning calorimetry was determined. We recorded the temperature at the point when the reaction is endothermic, that is, when it reaches a point of “stability”, which is the time when temperature does not increase. The coagulation temperature corresponds to the final temperature of the complete proteins denaturation process. The coagulation temperature equals the final temperature of the process [18]. The differential scanning calorimetry was performed with a micro DSC (differential calorimeter Meter-Toledo). To this purpose, 840 µg of undissolved egg white was placed in the aluminum cell of the equipment and the same volume of deionized water was used as witness. The speed of heating (β) was of 2 °C/min.

2.6 Statistical Analysis

Results were analyzed considering a completely random model with the storage time as fixed factor, using variance analysis and a paired Tukey test to determine differences among means, considering the following model:

\[ Y_{ij} = \mu + T_i + \epsilon_{ij} \]

where: \( Y_{ij} \) = the assessed variable, \( \mu \) = the mean of the assessed variable, \( T_i \) = the effect of the \( i \)th storage day, \( \epsilon_{ij} \) = the effect of the experimental error.

Results are expressed as the average of three replicates.

3. Results and Discussion

3.1 FC

The foam volume did not have significant differences (P > 0.01) with storage time (Fig. 1). On day 1, there was a lesser FC (1.25 mL foam/mL of white), perhaps due to a greater dissolution of proteins in the white; in contrast, on day 60 a higher FC was observed (1.75 mL/mL) compared to the previous storage days, this could be due to the loss of water and to the solubility of the ovomucin of the thick egg white. In the hen egg, the volume of foam is of 1.4 mL/mL; Hamayakawa et al.
[22] found that there is a decrement in the foam volume as the storage time increases over 23 days at 19 °C; whereas Ternes [23] stated that in eggs with longer storage times, their whites produce a better foam than fresh eggs, this is due to the molecular dissociation of the ovomucin-lysozyme complex during storage.

Damodaran et al. [24] infer that the foam volume can increase if the temperature of beating increases due to the partial denaturation of the ovoalbumin of the hen egg white. On the other hand, the ovomucoid protein influences the thermal coagulation because it is thermostable, making it possible for the foam to be baked and maintain its stability. The foam volume is correlated with the concentration of globulins, lysozymes, G2 and G3.

3.2 FS

Regarding the stability of the foam against the liquid drained as a function of the storage time, a significant ($p < 0.01$) effect was observed, but this is not shown clearly on days 1, 10; the eggs with 50 and 60 days of storage have a low FS (0.08 mL), shown in Fig. 2. On the other hand, eggs stored for 20, 30, and 40 days showed the highest stability, $0.13 \pm 0.02$, $0.17 \pm 0.02$, and $0.13 \pm 0.01$ mL drained liquid/mL of initial egg white, respectively. In the hen egg, the stability of the foam against the drained liquid is of $0.08 \pm 0.01$ mL/mL, according to Hammershøj et al. [19], who considered that the variation in stability could be due to the change in the pH of the white, which influences directly the surface properties of foams; at different pH, different diameter bubbles are produced, which determines stability. However, Ternes [23] indicated that the longer the time of egg storage, the stability of the foam is lower due to the triglycerides of the yolk, which cross the vitelline membrane as the storage time goes on, exerting a destabilizing effect on the foam of the hen egg white.

3.3 Emulsifying Capacity

Results regarding the emulsifying capacity of the quails egg yolk as a function of storage time are depicted in Fig. 3, significant differences were found ($p < 0.01$), which can be observed towards the end of the storage time, on days 50 and 60, with the lowest values (114.4 mL). On the other hand, the emulsifying capacity depicted intermediate values on days 10, 20, and 40; however, the maximum emulsifying capacity was recorded close to day 30 of storage, in which the highest values were recorded (193.8 mL of oil per gram of protein from the yolk).
Mine [25] concluded that the low-density lipoproteins are the main factor for the emulsifying properties of the yolk, they contribute mainly to stabilizing the emulsion. Likewise, Kiosseoglou [17] considered that the egg yolk during storage undergoes some chemical changes, like for example, the pH, which affects the functional properties of LDL, which are an excellent emulsifier at pH between 7.0 and 9.0, to which the slight changes obtained in the emulsifying capacity could be attributed. In turn, Ternes [23] states that another factor that contributes to the diminution in emulsion along time is the diffusion of the yolk’s constituents through the vitelline membrane, that is, triglycerides and lipoproteins that contribute to the emulsion.

3.4 Coagulation due to Heat

The obtained thermograms of the assessed proteins from the quail egg white are depicted in Fig. 4. Using the analysis program of the equipment, we obtained the values corresponding to the final temperatures of the process (Table 1), at which the complete denaturation process of the proteins from the egg white occurred; this temperature is considered the
coagulation temperature \( (T_{\text{final}} = T_{\text{coagulation}}) \). The egg whites from day 1 of storage presented a coagulation

![Diagram of egg white coagulation](https://example.com/diagram.png)

**Fig. 4** Analysis through DSC in quail egg white as a function of storage time. Quail egg white stored between 18 and 23 °C, RH of 57%-70% for 1, 5, 11, 20, 30, 50, and 60 days and heat flow of 2 °C/min.

**Table 1** Start, maximal, and final temperatures of the endothermic process of the quail egg white in relation to storage time.

| Storage time | Peak 1 | Peak 2 | Peak 3 |
|--------------|--------|--------|--------|
|              | \( T_i \) | \( T_{\text{max}} \) | \( T_{\text{final}} \) | \( T_i \) | \( T_{\text{max}} \) | \( T_{\text{final}} \) | \( T_i \) | \( T_{\text{max}} \) | \( T_{\text{final}} \) |
| 1 d          | 57.9   | 65.3   | 67.4   | 67.4   | 75.3   | 85.9   | 77.9   | 87.6   |
| 5 d          | 55.3   | 65.6   | 68.3   | 68.3   | 74.3   | 84.3   | 81.7   | 87.6   |
| 11 d         | 55.5   | 65.1   | 68.7   | 68.7   | 77.9   | 87.9   |        |        |
| 20 d         | 57.0   | 65.1   | 69.4   | 69.4   | 78.3   | 88.3   | 82.1   | 88.3   |
| 30 d         | 56.4   | 65.0   | 68.7   | 68.7   | 77.6   | 87.6   | 80.8   | 88.0   |
| 50 d         | 57.9   | 64.7   | 69.8   | 69.8   | 77.6   | 87.6   | 81.3   | 88.9   |
| 60 d         | 57.4   | 64.2   | 68.9   | 68.9   | 76.6   | 87.6   | 82.1   | 89.8   |

\( T_i \) = starting temperature; \( T_{\text{max}} \) = maximal temperature of the peak; \( T_{\text{final}} \) = final temperature of the process; \( d \) = storage time.
temperature of 85.9 °C, whereas in those eggs stored for 11 and 20 days, the coagulation temperature was 87.6 °C, and the temperature of the eggs stored for 50 and 60 days was 88.9 and 89.8 °C, respectively. The increase of the coagulation temperature of the egg white as a function of storage time is due mainly to the transformation of ovalbumin to S-ovalbumin, which is more stable to denaturation by heat.

Donovan and Mapes [21] assessed through colorimetry the hen egg white, in which the coagulation temperature of the fresh egg white at day 0 was 96 °C; for an egg stored for 7 days, it was 98.4 °C; in those stored for 14 and 24 days, it was 100.5 °C; finally, at 38 days of storage the total coagulation of the egg white reached 102.3 °C, this is due to the faster formation of the thermoresistant form of ovalbumin, i.e., S-ovalbumin, after storing the eggs.

Hence, the quail egg white, in general, has a lower coagulation temperature, this is very useful as less energy is required, resulting in savings at the time of processing a product when using the coagulation property of the egg.

The difference in the conversion rate of the ovalbumin to S-ovalbumin between the quail egg white and that of the hen could be related to the differences in the physicochemical properties of ovalbumins, as is the fast pH change in the hen egg.

4. Conclusions

The capacity to foam was not affected by storage time, however, it was more stable at 30 days of storage. In contrast, the emulsifying capacity of the yolk diminished along time. Regarding gelling and coagulation of the quail egg white, less heat was needed for the eggs to coagulate as compared to the hen egg whites.

Conflict of Interests

Authors declare that they do not have any conflict of interest to declare.

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