Research Paper

Quality and shell integrity of Japanese quail eggs: an assessment during storage and at market

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Abstract: Rearing of Japanese quail (*Coturnix coturnix japonica*) has created an emerging interest in recent years among the small-scale poultry farmers in Sri Lanka, and is becoming a commercial venture in the alternative poultry industry. Thus, assessment was done on quality variation of Japanese quail eggs during the storage with different methods of packaging at room temperature. In the first experiment, a total of 120 eggs from the same flock were stored using three methods, *i.e.* with paper boxes filled with paddy husks, plastic egg cartons and without package at the room temperature. The egg quality during storage was assessed using egg weight, shell thickness, shape index, yolk colour, yolk index, Haugh unit and egg weight loss at weekly intervals in a complete randomize design with three replicates. In the second experiment, one hundred Japanese quail eggs collected from five market outlets were used to evaluate the shell integrity. The results were analyzed using Analysis of Variance and descriptive statistics in the two experiments. The results revealed that the egg weight, yolk colour, yolk index and Haugh unit were significantly decreased (P<0.05) with the storage period except shell thickness and shape index. The weight loss was increased significantly (P<0.05) during the storage irrespective of the method of packaging. However, packaging significantly reduced (P<0.05) the weight loss where plastic cartons recorded the eggs with the lowest weight loss. Changes of Haugh units and yolk index plateaued towards the end of storage irrespective of the method of storage among which no significant differences were observed (P>0.05). There was a significant (P<0.05) deterioration of yolk colour after two weeks of storage in all storage methods. Plastic carton preserved high yolk colour up to week-1, and showed no difference among the methods of storage towards the end of three weeks of storage. The results of shell integrity assessment revealed that only 66% of eggs were with total integrity and the rest were with failures during the market chain. The study concludes that quail eggs stored in paper boxes or plastic cartons could preserve the quality parameters, *i.e.* minimum quality losses, at room temperature compared to those stored without package. Commercial operations need to pay attention to improve the shell integrity of quail eggs in market chain.

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Introduction

The phenomenal growth shown by the poultry industry in Sri Lanka has led to a situation where large-scale production systems becoming sustainable and more profitable than the small-scale operations. As a result, the small-scale farmers whose income was always marginal, tend

to look for alternative poultry production, which has less financial risk compared to the traditional chicken farming. This has led to the emergence of production of alternative poultry species such as quails. Japanese quail (*Coturnix coturnix japonica*) have attracted a growing interest in recent years among the small-scale poultry farmers in Sri Lanka. Thus, several quail farms have been established throughout the country for both egg and meat production, owing to many advantages of quails compared to the commercial poultry species (Priti and Satish, 2014). Quails grows rapidly and have a high rate of egg production. Nevertheless, they are robust and disease resistant, need less space and easy to keep. Yet, they are not commercially well acceptable in Sri Lanka. Shanaway (1994) reported that the species certainly deserve proper attention for promotion.

Nutritional value is one of the factors that increases the demand for quail eggs worldwide. Studies have reported that quail eggs contain essential nutrients, which play a vital role in human health and in disease prevention and curing (Bayomy *et al.*, 2017; Tunsaringkarn *et al.*, 2012). In addition, quail egg carries good quality characteristics that could positively influence the acceptability of consumers (Yannakopoulos, and Tserveni-Gousi, 1986).

Quality of an egg is determined by various standards that are imposed on the exterior (quality of the eggshell) and interior (quality of the albumen and yolk) components of the egg. Though eggs are known to possess excellent keeping quality, like all food, they have limited shelf life. Studies have reported that the declining of quality of eggs starts soon after lay and thus, egg handling and storage practices have a significant impact on the quality of eggs reaching consumers (Kul and Seker, 2004). Poor storage conditions may result in deterioration of egg quality and consequently loss and waste of eggs.

From the consumer point of view, external characteristics of eggs including freshness, cleanliness and uniformity are the most influencing factors at the point of purchase. It is essential that eggs reach the consumer with a sound, clean shell if satisfaction is to be achieved. Therefore, egg shell integrity is a critical factor that influences marketing of eggs and resulting in increased sales and consumer satisfaction. Proper storage and handling are equally and critically important in this context.

Among the dearth of information quality of stored eggs, studies on the storage stability of quail eggs are limited. In addition, egg grading standards, which are applicable to chicken eggs, are not compatible with quail eggs. Thus, a suitable framework is needed to be developed to maintain quality and price relationship and enable more orderly process of marketing of quail eggs. Therefore, a study was conducted with the aim of investigating the most appropriate method and duration of storage of Japanese quail eggs and to assess the shell integrity of quail eggs at the market in order to ensure high quality delivery of products to the consumers.

Materials and Methods

Experiment I – Investigation of the appropriate method and duration of storage:

Location of the study: All the Japanese quail eggs required for the experiment were collected from the Mawela livestock Field Research Station of the Faculty of Agriculture, University of Peradeniya, Sri Lanka. All the eggs were obtained from 12-weeks old Japanese quails, which have been managed under the intensive condition and fed with a layer mash ration. Storage and the laboratory analysis of quality characteristics of quail eggs were carried out at the Meat Science Laboratory of the Department of Animal Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka.

Collection and storage of eggs: A total of 120 freshly laid Japanese quail eggs were obtained randomly from two collections (morning and evening). On the following day of collection, eggs were randomly divided into three groups comprising of 40 eggs per group and packed in paper boxes filled with paddy

husk and plastic egg cartons. One group was kept without package. Each packaging treatment was replicated three times in a complete randomize design to have ten eggs in one carton. All the groups of eggs were stored in the laboratory at room temperature for three weeks. The egg quality characteristics were measured at the time of collection and first, second and third week of storage.

Measurement of quality characteristics of eggs: Weight loss, shape index, Haugh unit, yolk index, yolk colour and shell thickness of eggs from each package treatment were measured in weekly intervals up to three weeks. The weight of whole egg was measured individually with a balance (PA 313, Ohaus Crop, Pine Brook, NJ, USA). Ten eggs per group were measured and the weight loss of the eggs was calculated using the following equation;

$$\text{Weight loss (\%)} = \frac{(a-b)}{a} \times 100$$

where, a = Initial whole egg weight (g) before storage, at day 0, b = Whole egg weight (g) after storage (week 1, 2, 3). The length and the width of the eggs (egg shape) were measured using a vernier caliper (General Tools and Instruments, New York, USA). Shape index of eggs was calculated using the following equation.

$$\text{Egg shape index} = \frac{\text{average width of the egg (mm)}}{\text{average length of the egg (mm)}} \times 100$$

A top load balance (PA 313, Ohaus Crop., Pine Brook, NJ, USA) was used to obtain the egg weight. The height of the thick albumen (mm) was measured with an ORKA Digital Haugh Tester (Lakeview Dr, Bountiful, UT, USA). The Haugh unit was calculated using the following equation;

$$\text{Haugh unit} = 100 \log (H - 1.7W^{0.37} + 7.75)$$

where, H = observed height of the thick albumen (mm) and W = weight of egg (g).

The yolk index was calculated using the following equation.

$$\text{Yolk index} = \frac{\text{Yolk height (mm)}}{\text{Yolk width (mm)}}$$

The height of yolk was measured with ORKA Digital Haugh Tester (Lakeview Dr, Bountiful, UT, USA) and yolk width was measured using a vernier caliper (General Tools & Instruments, New York, USA). The egg yolk colour was examined and compared using the yolk colour fan (ROCHE Yolk colour fan, 1155, Switzerland). Upon the visual comparison, the most appropriate colour number was assigned. The shell thickness was measured using a vernier caliper (General Tools and Instruments, New York, USA).

Statistical analysis: Treatment means were separated using Analysis of Variance (ANOVA) and the means were compared by Duncan's Multiple Rage Test (P=0.05). The Statistical Analysis Software package version 9.0 (2012-2017, SAS Institute Inc., Cary, NC, USA) was used to analyse the data.

Experiment II - Evaluation of shell integrity of quail eggs at the market:

Egg collection and evaluation of external quality: A total of 100 Japanese quail eggs were randomly collected from five central outlets in Kandy, Sri Lanka and subjected to external egg quality analysis. All the eggs were packed in plastic cartons and were in similar shelf conditions.

Eggs were examined individually and classified according to the integrity of the shell based on four criteria. Accordingly, eggs were observed for free of defects, adhered dirt, cracked shells and broken shells and scored for intact, dirty, cracked and broken categories, respectively. The results were analysed using descriptive statistics

Results and Discussion

<u>Experiment I – Investigation of the appropriate method and duration of storage:</u>

Egg weight loss: As expected, there was a progressive increase in the weight loss with increased length of storage in quail eggs stored with different packaging. The percentage weight losses were significantly different (P<0.05) between weeks as well as among methods of packaging throughout the storage period up to 21 days. Eggs stored in plastic cartons showed the lowest percentage weight loss (P<0.05) followed by the eggs stored in the paper boxes. The highest weight loss (P<0.05) was recorded for eggs without packaging throughout the storage period (Table 1).

Table 1. Changes of different quality parameters of quail eggs during three weeks of storage at room temperature (Mean ± Standard deviation) under three separate storage conditions

Egg quality Parameter	Storage method	Weight loss (%)			
		Week 0	Week 1	Week 2	Week 3
Weight loss %	Without package	0	$2.72 \pm 1.31_x{}^a$	$4.39 \pm 1.38_y{}^a$	$6.07 \pm 1.27_z{}^a$
	Paper boxes	0	$2.16 \pm 0.60_x{}^b$	$2.92 \pm 0.51_y{}^b$	$5.21 \pm 1.08_z{}^b$
	Plastic cartons	0	$0.52 \pm 0.20_x{}^c$	$1.00 \pm 0.21_y{}^c$	$1.45 \pm 0.96_z{}^c$
Haugh unit	Without package	$83.36 \pm 2.45^a{}_x$	$74.27 \pm 3.29^a{}_y$	$75.09 \pm 4.90^a{}_{yz}$	$73.24 \pm 0.86^a{}_z$
	Paper boxes	$81.95 \pm 5.00^a{}_x$	$75.69 \pm 3.64^b{}_y$	$73.85 \pm 2.08^a{}_{yz}$	$74.57 \pm 2.59^a{}_z$
	Plastic cartons	$82.27 \pm 4.58^a{}_x$	$79.88 \pm 2.83^c{}_y$	$75.79 \pm 3.52^a{}_{yz}$	$60.84 \pm 3.29^a{}_z$
Yolk Index	Without package	N/A	$23.83 \pm 3.29^a{}_x$	$48.94 \pm 4.90^a{}_y$	$56.90 \pm 0.86^a{}_z$
	Paper boxes	N/A	$27.37 \pm 3.64^a{}_x$	$34.06 \pm 2.08^b{}_y$	$45.61 \pm 2.59^a{}_z$
	Plastic cartons	N/A	$27.63 \pm 2.83^a{}_x$	$29.34 \pm 3.52^c{}_y$	$44.07 \pm 3.29^a{}_z$
Yolk colour	Without package	$4.33 \pm 0.50^a{}_x$	$3.83 \pm 0.41^a{}_y$	$3.13 \pm 0.35^a{}_y$	$3.00 \pm 0.00^a{}_z$
	Paper boxes	$4.58 \pm 0.67^a{}_x$	$3.75 \pm 0.46^b{}_y$	$3.44 \pm 0.53^a{}_y$	$3.00 \pm 0.00^a{}_z$
	Plastic cartons	$4.43 \pm 0.50^a{}_x$	$4.22 \pm 0.67^c{}_y$	$3.28 \pm 0.48^a{}_y$	$3.00 \pm 0.00^a{}_z$
Shell thickness	Without package	$00.17 \pm 0.02_x$	$00.16 \pm 0.01_x$	$00.18 \pm 0.01_x$	$00.17 \pm 0.01_x$
	Paper boxes	$00.17 \pm 0.01_x$	$00.18 \pm 0.02_x$	$00.18 \pm 0.01_x$	$00.18 \pm 0.02_x$
	Plastic cartons	$00.18 \pm 0.02_x$	$00.18 \pm 0.12_x$	$00.18 \pm 0.01_x$	$00.18 \pm 0.00_x$
Shape index	Without package	$81.12 \pm 1.45_x$	$81.12 \pm 3.01_x$	$81.15 \pm 6.12_x$	$81.13 \pm 1.68_x$
	Paper boxes	$82.51 \pm 3.82_x$	$82.32 \pm 2.93_x$	$82.44 \pm 1.40_x$	$82.27 \pm 2.11_x$
	Plastic cartons	$82.48 \pm 2.09_x$	$82.47 \pm 0.12_x$	$82.21 \pm 2.85_x$	$81.38 \pm 1.49_x$

[abc] Within a column, means followed by same letter within each egg quality parameter are not significantly different at P=0.05.

[xyz] Within a row, means followed by the same letter within each egg quality parameter are not significantly different at P=0.05

Park *et al.* (2003) reported that the change in egg weight during storage is mostly due to the evaporation of moisture through the numerous pores in the eggshell surface. It is an indicator of the deterioration of egg quality. Further, losses could be due to loss of carbon dioxide, ammonia, nitrogen, hydrogen sulphide gas and water from the eggs (Haugh, 1937). Several strategies are being adopted in minimizing the egg weight losses. For example, Dudusola (2009) reported oiling of eggs as effective in minimizing egg weight loss. Thus, avoiding the exposure of shell pores during storage helps the keeping quality of eggs. In the present study, the two packaging methods, paper boxes and plastic cartons, have acted as a barrier in exposing eggs to the surrounding environment and thus, has minimized moisture and gas losses and thereby helped preserving the egg quality. However, the weight loss in the present study observed in the third week was higher than the values recorded for quail eggs (5.4% – 5.9%) in the previous studies (Dudusola, 2009; Imai *et al.*, 1986). As reported by Dudusola (2009), the weight loss of eggs stored in the black polythene has recorded a higher weight

loss of 2.6% than the weight loss of eggs stored in plastic carton in the present study (1.45 %) at week-3.

Haugh unit: The Haugh values have shown a decreasing trend (Table 1) with increasing storage time in eggs under all storage methods. However, there was a drastic reduction (P<0.05) of Haugh value during the first week of storage in all the storage methods, and then plateaued off towards the end of 21 days of storage. A significant difference (P<0.05) in Haugh unit among storage methods was observed only in the first week of storage where eggs stored in plastic cartons showed a significantly higher (P<0.05) Haugh value than those packed in paper boxes and control group. Though not significant (P>0.05), there was a great reduction of Haugh value of eggs packed in plastic cartons in the third week. Decrease of Haugh value after lay is a biological activity of albumen protein, which could be aggravated by high temperature during storage (Travel *et al.*, 2011). The eggs packed in plastic carton may have caused an increase in internal egg temperature during storage leading to the breakdown of the protein structures of the thick albumen and vitelline membrane faster than that of eggs packed in paper boxes and control groups.

A higher Haugh unit indicates better egg quality (Haugh, 1937), *i.e.* the egg protein quality. There are several factors that the affect albumin quality. Roberts (2004) has reported that the albumen quality declines with bird age, and also affected by the strain of bird and genetic selection. Studies have recommended that Haugh unit value of 75% and above for excellent quality eggs and 50% and below for stale eggs (Dudusola, 2009). Accordingly, an excellent egg quality was recorded in this study up to week-2, and was in good standards up to week-3 except for those in the plastic cartons. The drastic reduction of Haugh unit of eggs stored in the plastic carton could be due to the combined effect of time and the temperature (Samli *et al.*, 2005) as the plastic carton tends to develop comparatively high temperature compared to the other two storage conditions. This could be further supported by the observation of Adamaski *et al.* (2017) who reported an excellent Haugh unit even after 7 weeks of storage of quail eggs at low storage

temperature (4 °C). Thus, when the period of storage increased, the egg quality deteriorated and the deterioration rate increased with temperature. As the present study was carried out under room temperature, egg quality parameters could be further improved with cold storage conditions.

Yolk index: As the egg deteriorates, the yolk index decreases due to breakdown of the fibrous glycoprotein ovomucin. It was also indicated that the egg yolk size increased with storage time due to movement of water from the albumen to the yolk as a result of osmotic pressure differences (Haugh, 1937). Thus, yolk index measures the egg quality. In the present study, the yolk index of the fresh eggs (week 0) ranged 0.53 - 0.34 and 0.18 - 0.24 at the end of three week storage. These observations were comparable with Imai *et al.* (1986) who reported a decrease of yolk index from 0.34 to 0.26 during three weeks of storage at room temperature. The reduction percentages of yolk index were increasing significantly (P<0.05) with the time of storage indicating the progressive deterioration of the egg quality. There was a significant difference (P<0.05) in reduction of yolk indices among packaging methods in the second week (Table 1) where the eggs without package showed the highest reduction. However, the three storage methods showed no significant differences (P>0.05) in the reduction of yolk indices at the end of the third week. Results of the present study is supported by Dudusola (2009) who reported that yolk indices of quail eggs stored using oiling or packed in black polythene bags showed low reduction of yolk index during 21-days storage compared to that of eggs kept without packaging at room temperature.

Yolk colour: The results revealed that the yolk colour values were significantly decreasing (P<0.05) with the storage time (Table 1). There were no significant differences (P>0.05) in yolk colour values according to packaging methods throughout the storage period except in the first week, where eggs stored in plastic carton preserved the yolk colour better than those in the other two storage methods. However, there was no difference in yolk colour of eggs under different storage methods at the storage period. Yolk colour deteriorates during storage and this may be due to

oxidation of carotenoid pigments. Akter *et al.* (2014) did not observe significant yolk colour changes in chicken eggs.

*Shell thickness***:** Eggshell weight and thickness are physical variables that correlate with the eggshell strength. In the present study, shell thickness remained unchanged with the increased storage period regardless of the storage methods (Table 1). Similar observation was reported by Adamski *et al.* (2017) indicating that the storage of Japanese quail eggs at low temperatures had no visible effect on the shell weight, its thickness and density. Eggshell quality is influenced by a wide range of internal and external factors, which collectively influence the final product at the time of lay. The main internal factors are time of oviposition, age, and genotype whereas the external factors include housing system, nutrition, microclimate, etc. (Ketta and Tůamová, 2016). Thus, egg shell characters tend to be stable after lay. However, the shell thickness observed in the present study is comparable to the values reported by several authors (Dudasola, 2009; Imai *et al.*, 1986), and lower than the value (0.21 mm) reported by Adamski *et al.* (2017).

Shape index: The shape index is the ratio of the width to length of the egg. It explains the oval shape of the egg and it is an important criterion in determining egg quality. As reported by Duman *et al.* (2016) there are certain correlations between the shape index and a range of egg quality factors such as shell thickness, egg albumen length, egg yolk width, egg yolk height and egg yolk colour. More importantly, proper shape index is required in packaging and transportation of eggs. The shape index found in the present study varied between 81.12 - 82.51, indicating that the quail egg presents a spherical form, and is higher than the range (76.8 – 80) reported by Alasahan and Copur (2016). Results of the present study showed that the shape indices of quail eggs remained unchanged (P>0.05) during the storage period (Table 1).

Experiment II - Evaluation of shell integrity of quail eggs at the market:
Shell integrity is an indication of the quality handling of eggs from farm up to the consumer. During marketing process, egg handling practices can be helpful in completely retain the quality of eggs to the time of consumption (Stadelman, 1995). Results of the present market study have revealed the shell integrity of quail eggs at the market (Figure 1).
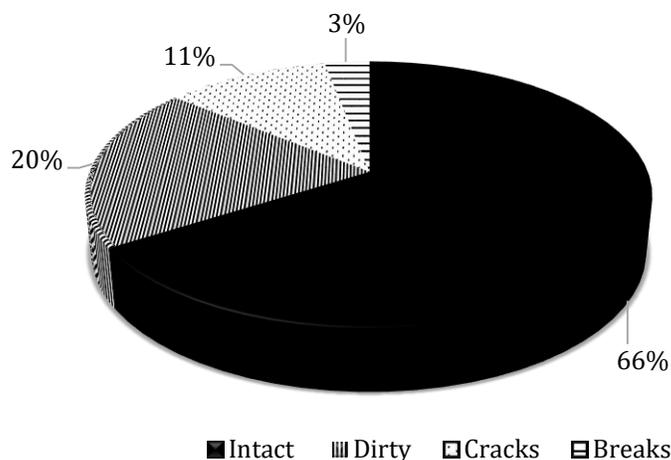

Figure 1 Shell integrity of Japanese quail at the market

It was found that only 66% of eggs were free of exterior defects. Rest were found with dirt (20%), cracks (11%) and breaks (3%). The total integrity of 66% is a low value for an industry, also indicating the poor handling in value addition and market chain. Given the inherently weak shell structure

and the thin shell thickness, preserving the shell integrity of quail eggs at high level is a challenging task. However, González Sánchez *et al*. (2009) reported 90% shell integrity under packed condition prior to the market chain activities.

The reasons for the present observation may be due to lack of attention in egg handling activities such as egg cleaning, transportation and improper handling. A similar study has been conducted in Colombo market by Jayasena *et al*. (2012) on chicken eggs where the quality of eggs has been evaluated based on quality range specified in SLS 959:1992 (SLSI, 1992). The overall shell quality of the sample was considered based on shell cleanliness, defects and shape. However, for quail eggs has quality specifications established in Sri Lanka. Hence, the results of the present study were presented in comparison with data from elsewhere.

Conclusion

The study concludes that the quail eggs stored in paper boxes and plastic cartons were with minimum quality losses, and could be used for storage of quail eggs at room temperature with an optimum storage period of around two weeks. Low shell integrity was observed at the market samples and hence, there is a great potential in the industry to improve egg handling in the value chain and market supply chain of quail eggs. If quail production is to be improved as an alternative poultry industry, a standard egg grading manual needs to be developed for quail eggs to maintain the quality and price relationship, and to enable organized marketing of quail eggs in the future.

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