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Storage duration impacts on nutritional composition and quality of table eggs

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ABSTRACT

This study was carried out to evaluate the effect of the duration of storage of ISA brown eggs at room temperature on the nutritional composition and quality of eggs. A total of one hundred and twenty (120) freshly laid eggs by 36 weeks old ISA brown layers were randomly collected and stored at room temperature for 21 days. On each sampling day (at week 0, week 1, week 2, and week 3 of storage), 30 eggs were broken to determine internal and external egg quality traits, proximate composition, and mineral profile. Collected data were subjected to statistical analysis. Duration of storage had a significant effect ($p<0.05$) on egg traits, proximate components, and mineral profile except for egg shape index and shell thickness. The overall egg weight, egg length, egg width, shape index, shell weight, shell ratio, and shell thickness were 56.82g, 5.69mm, 4.43mm, 78.02, 7.45g, 13.11, and 0.28mm respectively, while yolk height, albumen height, yolk weight, albumen weight, albumen ratio, yolk ratio, and Haugh unit were 13.55mm, 4.97mm, 16.32g, 33.06g, 58.11, 28.82 and 67.50% respectively. The overall means for moisture, crude protein, ash, fat, and carbohydrate were 76.27%, 12.06%, and 1.83%, 4.62%, and 4.37% respectively. Most of the minerals increased in value as the eggs increased in age. The duration of storage of eggs affected the egg quality, proximate components, and mineral profile as these parameters determine acceptability by consumers.

Introduction

Eggs have been one of the most acceptable and affordable human food. They are being referred to as nature's sources of protein foods, offering nutrients of great biological value as vitamins, minerals, and fatty acids required for the growth and maintenance of body tissues (Belitz *et al.,* 2009). However, during egg storage, some components of eggs may alter and tend to deteriorate in quality (Scot and Silversides, 2001). The main factors that affect the quality of eggs immediately after are temperature, relative humidity conditions, and storage time. An intense deterioration begins after 72 h of lay, the dense layer tends to become liquid, and consequently, albumen loses its quality (Adeogun and Amole 2004). Therefore, less time is required between laying and preservation methods, besides suitable transportation to the retail market (Oliveira, 2013). From farm to consumer's table, the egg is subjected to physicochemical changes that affect the yolk and albumen qualities which may modify flavor, freshness, and palatability. As the storage time increases, the worse will be egg internal quality because carbon dioxide is being transferred through eggshells (Oliveira, 2013). It has been reported that cold storage can preserve eggs for 6 to 9 months, with increased shelf life and subcooled storage of −1.5 °C (Belitz *et al*., 2009). Packing eggs under a modified atmosphere preserves their internal quality for up to 28 days (Giampietro-Ganeco *et al.,* 2015).

Egg qualities are those characteristics that affect acceptability by consumers; it is, therefore, important that attention is paid to the preservation and marketing of eggs to maintain their quality. One of

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the most important qualities of egg is the egg weight. It is first quality that is considered by the consumer. Other external quality characteristics including cleanliness, freshness, shell appearance and shell weight are important in consumers' acceptability of eggs (Song *et al.,* 2000; Adeogun and Amole, 2004; Dudusola, 2010). Internal qualities of the egg include yolk weight, albumen weight, yolk height and albumen height. These qualities begin to decline as soon as the egg is laid. The internal quality of egg, egg handling and storage practices are affected by how hens are managed and the diets that they are fed with (Gerber, 2012). Interior quality characteristics such as yolk index, Haugh Unit, and chemical composition are also important in egg product industry as the demand for liquid egg, frozen egg, egg powder, and oil from yolk and albumen increases (Scott and Silversides, 2001).

In Nigeria, supply of electricity is irregular and even completely absent in some areas. Eggs are stored in the stores and kitchens at room temperature; therefore necessitated the objectives of this study to evaluate the effect of duration of storage of eggs at room temperature on nutritional constituents and quality of eggs.

Materials and Methods

Climatic Condition of the Experimental Site

The experiment was executed at the Poultry Unit and Analytical Laboratory of Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State, Nigeria. Okitipupa lies between latitude $6^0 25$ and $6^0 46$ N and Longitude $4^0 35$ and $4^0 50$ E within the tropical rainforest zone of Nigeria. It covers a total land area of 636 sq. km and has an estimated population of 233.565 people. A Udic soil moisture regime and an isohyperthermic soil temperature regime prevail in the area with total rainfall often exceeding 2000mm, while the monthly mean temperature ranges between 27 ^{0}C and 28 ^{0}C, respectively.

Acquisition of the Eggs

A total of six scores (120) of freshly laid eggs were randomly collected in a batch from thirty-six (36) weeks old exotic chickens (ISA Brown) kept at Poultry Unit, Teaching and Research Farm of the University. On the first sampling day, thirty (30) eggs were selected at random to determine the internal and external egg quality traits, proximate and mineral profile of the eggs within twenty- four hours of laying. For other sampling days eggs were kept at room temperature on laboratory desk and at weekly interval thirty eggs were randomly selected till the 21st day of storage for analysis of proximate, mineral profile and internal and external parameters.

Determination of egg quality

Egg weight was individually weighed to 0.01g accuracy using a laboratory balance Owa Labor (VEB Wägetechnik Rapido, Germany). Egg length and egg width were measured with a micrometer (Wägetechnik Rapido, Germany). Egg Shape index was determined as the ratio of egg width to egg length (%) by a method of Anderson *et al*., (2004). Shell ratio was calculated as the ratio of egg shell weight and egg weight according to (Olawunmi and Ogunlade, 2008). Following Anderson's procedure, shell weight (with membrane) was determined as stated above using a laboratory scale Owa Labor and the shell percentage in the egg was evaluated. Shell thickness was determined at the large end and small end of the equatorial parts of each egg using Vernier Caliper (Wägetechnik Rapido, Germany). Shell thickness is determined from the average values of these three parts. The albumen weight was gotten from the difference between the weights of egg, yolk and shell. The ratio of the albumen in the egg was also evaluated. Albumen index (%) was measured according to Alkan *et al*. (2010) by determining the percentage of the albumen height (mm) measurement taken to the average of width (mm) and length (mm) of this albumen with 0.01mm accuracy × 100 taken by the micrometer. Individual Haugh Unit score (Haugh, 1937) was obtained using the weight of an egg and thick albumen height. The Haugh Units were derived for each egg using the Haugh equation (Monira *et al.,* 2003):

$HU = 100 \log (H - 1.7w0.37 + 7.57)$; where: HU – Haugh Unit, H – Observed height of thick albumen in mm, w – Weight of egg in g.

Yolk weight was measured using a laboratory balance Owa Labor and its percentage was derived from the reading. Yolk index (%) was determined by dividing the value of the yolk height (mm) by that of the yolk width (mm) according to Funk (1948) using micrometer with 0.01 mm accuracy.

Proximate Analysis

Proximate nutritional analysis such as moisture, protein, fat, ash and carbohydrate were studied and determined according to AOAC method (AOAC, 2005). Moisture of egg is determined by drying an egg sample at an elevated temperature approximately 105 ^{0}C and determining the change in weight in terms of moisture loss. Protein constituent in the egg is determined as done by AOAC method (AOAC, 2005). The fat content determined by Soxhlet method (Soxhlet, 1879). Ash in the egg is readily determined by incineration from dried sample at about 750°C for 8 hours by muffle furnace. The carbohydrate content was evaluated by subtracting the other food value i.e. Crude protein, Fat, Moisture, Ash through direct deduction method (Lilla *et al*., 2005). The energy content was determined from the formula given by Eknayake *et al*., (2014).

Minerals content

The sample was subjected to chemical extraction using a 1:3 mixtures of concentrated hydrochloric and nitric acid (AOAC, 2004). The clear digested solutions were made of 50 mL using double-distilled water, and stored in plastic bottles. The Ca, Cu, Mn, Mg, K, Na, Zn and Fe concentrations were obtained using a Varian ICP-optical emission spectrometer 720-ES. Calibration curve for each focused element was drawn by using suitable standard solutions prepared from the stock solutions. For all measured elements, good correlation was derived to be within the R2>0.995 range. The reproducibility expressed as relative standard deviation for replicated analysis of the calibration standard for all calculated amount of metals varied from 1.99 to 3.89%. The detection limit of each element was determined from the values of replicated measurements of low value of concentration samples and derived from their standard deviation. Phosphorus concentrations in eggs (albumen and yolk) was measured utilizing flame spectrophotometry applied by Haraguchi and Fuwa (1976).

Statistical Analysis

Data collected was subjected to Analysis of variance (ANOVA). The experimental design was Completely Randomized Design (CRD).

Model: $\gamma_{ij} = \mu + S_i + \varepsilon_{ij}$; γ_{ij} - observation of the i^{th} Egg in j^{th} duration, μ - population mean, S_i - effect of the i^{th} duration and ε_{ij} = experimental error committed during experiment. Correlations within external and internal parameters were carried out using Pearson's correlation statistical software (SAS) version 9.2.

Results

Table 1 reveals the summary statistics of the quality characteristics of egg. The weight of egg, length of egg, width of egg, shell index, shell weight, shell ratio and shell thickness were 56.82 g, 5.69 mm, 4.43mm, 78.02 %, 7.45 g, 13.11 %, 0.28 mm respectively for external traits, while height of yolk, height of albumen, weight of yolk, weight of albumen, albumen ratio, yolk ratio and Haugh unit were 13.55 mm, 4.97 mm, 16.32 g, 33.06 g, 58.11 %, 28.82 % and 67.50 respectively, for internal traits. In external traits, highest coefficient of variance (59.40) was observed in shell thickness while lowest (6.12) was observed in egg width. Albumen height shows highest coefficient of variance (30.76) while albumen ratio gives the lowest value (6.02).

Table 2 reveals the effect of duration of storage on the external traits of table eggs. Significant difference (P<0.05) was observed in all the traits considered except for shape index. In egg weight, there was no significant variation observed from week 0 to week 2, however there was significant difference between week 3 and other earlier weeks. Egg weight reduced as the egg aged. The values for the egg length across the weeks were 5.72, 5.87, 5.63 and 5.49. No statistical significance was observed through week 0 to week 2. Similar trend was observed in values for egg width and shell ratio but significant difference was observed between week 0 and week 3. The values for shell weight were 7.72, 7.38, 7.19 and 7.43 for the weeks respectively.

Table 1: Summary statistics for egg quality characteristics

Variables	Means	N	Minimum	Maximum	CV
Egg weight (g)	56.82 ± 0.40	109	47.3	67.96	7.37
Egg length (mm)	5.69 ± 0.03	109	5.06	6.62	6.39
Egg width (mm)	4.43 ± 0.02	109	4.06	5.28	6.12
Shape index	78.02 ± 0.50	109	64.23	92.63	6.70
Shell weight (g)	7.45 ± 0.07	109	5.60	9.14	9.39
Shell %	13.11 ± 0.10	109	10.91	15.52	7.58
Shell thickness (mm)	0.28 ± 0.02	109	0.01	0.49	59.40
Yolk height (mm)	13.55 ± 0.23	85	7.09	16.90	15.84
Albumen height (mm)	4.97 ± 0.15	107	2.36	10.23	30.76
Yolk weight (mm)	16.32 ± 0.19	89	12.50	22.90	10.92
Albumen weight (g)	33.06 ± 0.40	89	24.10	41.87	11.41
Albumen %	58.11 ± 0.37	89	46.35	65.20	6.02
Yolk %	28.82 ± 0.34	89	21.22	40.00	10.98
Haugh unit	67.50 ± 1.21	107	40.15	100.00	18.58

Table 2: Storage duration effect on external quality of egg

Variable	0-week	1-week	2-week	3-week	SEM
Egg weight (g)	58.48^{a}	57.38^{a}	56.29^{a}	53.94^{b}	0.40
Egg length (mm)	5.72^{ab}	5.87^{a}	5.63^{bc}	5.49^{c}	0.03
Egg width (mm)	4.48^{ab}	4.54^{a}	4.36^{bc}	4.27^{c}	0.03
Shape index	78.52^{a}	77.61^{a}	78.06^{a}	77.84^{a}	0.50
Shell weight (g)	7.72^{a}	7.38^{ab}	7.19^{b}	7.43^{ab}	0.07
Shell %	13.22^{b}	12.87^{b}	12.78^{b}	13.44^{a}	0.10
Shell thickness (mm)	0.24^{a}	0.30^{a}	0.26^{a}	0.33^{a}	0.02

Means with different superscript in a row are significantly different (p<0.05).

Table 3 reveals the effect of storage duration on the internal quality characteristics of the egg. Significant difference (P<0.05) was observed in all the traits considered. In yolk height, significant difference was observed from 0 week through to week 3. Hence, yolk height reduces as the egg aged. The values for albumen height were 6.80, 4.32, 4.30 and 3.86 through the weeks. Significant differences were noted in week 0 and the other weeks, however, no statistical significance was observed among week 1 through to week 3. Similar trend was observed in albumen ratio and Haugh unit as well. Albumen ratio reduces as the egg aged, while yolk ratio increased as the egg aged. The values for albumen weight were 35.09, 33.36, 32.61, and 28.96. This reduced as the egg aged.

Table 4 shows the relationship among the external egg qualities. Egg weight was highly significant (p<0.001) and positively related with the length of the egg, width of the egg, and shell weight while the phenotypic correlation with shell index, ratio and thickness respectively were low and not significant (p>0.05). The correlations between egg length and egg weight, shell index, weight, ratio and thickness were 0.413, -0.562, 0.181, -0.268 and -0.120 respectively. Positive significant effect (p<0.001, p<0.05) were observed between egg width and shell index (0.518) and shell weight (0.270) while negative, non-significant (p>0.05) relationship was

Table 3: Effect of storage duration on internal quality of egg

Variable	0-week	1-week	2-week	3-week	SEM
Yolk height	15.22^{a}	14.37^{b}	11.52^{c}	10.33^{d}	0.23
Albumen height	6.80^{a}	4.32^{b}	4.30^{b}	3.86^{b}	0.15
Yolk weight	15.54^{b}	16.56^{ab}	16.53^{ab}	17.09^{a}	0.19
Albumen weight	35.09^{a}	33.36^{ab}	32.61^{b}	28.96^{c}	0.40
Albumen %	60.10^{a}	58.15^{b}	57.89^{b}	54.29^{b}	0.37
Yolk %	26.71^{c}	28.94^{b}	29.38^{b}	32.04^{a}	0.34
Haugh unit	81.48^{a}	61.68^{b}	63.39^{b}	58.98^{b}	1.21

Means with different superscript in a row are significantly different (p<0.05).

Table 4: Correlation coefficient among external quality of egg

	Egg weight	Egg length	Egg width	Shell index	Shell weight	Shell %	Shell thickness
Egg weight	1.00						
Egg length	0.509***	1.00					
Egg width	0.465***	0.413***	1.00				
Shell index	-0.063	-0.562***	0.518***	1.00			
Shell weight	0.605***	0.181	0.270**	0.071	1.00		
Shell %	-0.207	-0.268***	-0.108	0.155	0.652***	1.00	
Shell thickness	-0.126	-0.120	-0.122	-0.005	-0.210	-0.126	1.00

**p<0.05; **p<0.01; ***p<0.001.*

Table 5: Correlation coefficient among internal quality of egg

	Yolk height	Albumen height	Yolk weight	Albumen weight	Albumen %	Yolk %	Haugh unit
Yolk height	1.00						
Albumen height	0.544^{xxx}	1.00					
Yolk weight	-0.180	-0.265^{x}	1.00				
Albumen weight	0.366^{xx}	0.432^{xxx}	-0.142	1.00			
Albumen %	0.347^{xx}	-0.437^{xxx}	-0.697^{xxx}	0.786^{xxx}	1.00		
Yolk %	-0.364^{xx}	-0.465^{xxx}	0.755^{xxx}	-0.744^{xxx}	-0.963^{xxx}	1.00	
Haugh unit	-0.504^{xxx}	-0.949^{xxx}	-0.301^{xx}	0.254^{x}	0.335^{xx}	-0.361	1.00

**p<0.05; **p<0.01; ***p<0.001.*

Table 6: Effect of duration of storage on nutrients composition of table egg

Variables (%)	Week 0	Week 1	Week 2	Week 3	overall	SEM
Moisture	76.61^{b}	77.14^{a}	76.23^{c}	75.10^{d}	76.27	0.23
Protein	13.18^{b}	13.07^{b}	13.47^{a}	12.11^{c}	12.96	0.16
Ash	3.78^{a}	1.33^{b}	1.16^{bc}	1.06^{c}	1.83	0.34
Fat	4.09^{c}	5.03^{b}	4.09^{c}	5.28^{a}	4.62	0.16
CHO	2.51^{d}	3.44^{c}	5.06^{b}	6.47^{a}	4.37	0.46

Means with different superscript in a row are significantly different (p<0.05).

observed between egg width and shell ratio and shell thickness. The relationship between shell index, weight, ratio and thickness were low and not significant (p>0.05). Shell weight/ratio, shell weight/thickness and shell ratio/thickness were 0.652, -0.210 and -0.126 respectively. Table 5 reveals the relationship among the internal egg qualities which ranged between - 0.963 and 0.786. Table 6 and 7 show the effect of duration of storage on the nutrients and mineral profile of the eggs, respectively. There were significant differences in all the nutrients considered. In moisture content, significant difference was recorded from week 0 through week 3 and there was increase between week 0 and week 1. Crude protein did not differ significantly between week 0 and week 1 but did at weeks 2 and 3. Crude protein reduced as the egg aged likewise ash. Ash differed significantly between week 0 and week 1 but did not show any significant difference between week 1 and week 2. Fat did differ significantly at weeks 0 and 1, and between weeks 0 and 3. Carbohydrate increased as the egg aged.

Table 7: Effect of duration of storage on the mineral composition of table egg

Variables(ppm)	Week 0	Week 1	Week 2	Week 3	overall	SEM
Ca	120^{c}	415.50^{b}	681.00^{a}	694.00^{a}	477.63	70.99
P	412.06^{c}	453.21^{b}	771.34^{a}	781.96^{a}	604.64	52.31
K	1227.5^{d}	2400.00^{c}	3700.00^{b}	4285.00^{a}	2903.13	361.25
Na	239.00^{c}	271.50^{b}	305.50^{a}	309.00^{a}	281.25	8.72
Fe	28.00^{c}	42.50^{a}	24.50^{c}	36.00^{b}	33.5	2.55
Zn	7.50^{d}	66.50^{a}	42.50^{c}	55.00^{b}	42.88	6.72
Mn	ND	ND	ND	ND		
Cu	ND	ND	ND	ND		

Means with different superscript in a row are significantly different ($p<0.05$).

Significant difference was indicated in all the minerals considered, and all the minerals increase as egg aged. In calcium (Ca), significant difference occurred from week 0 to week 2, however, there was no significant difference between week 2 and week 3. Phosphorus (P) and sodium (Na). Potassium (K) and zinc (Zn) had significant different from week 0 through to week 3. Iron (Fe) as well had significant difference between week 0 and other weeks, except week 2 where there is no significant different. Manganese (Mn) and cupper (Cu) were not determined.

Discussion

The significant effect of duration of storage observed on virtually all egg quality trait characteristics observed in this study, is in line with the works of earlier researchers (Akyurek and Okur, 2009; Silversides and Scott, 2001; Sekeroglu *et al.,* 2008; Sung and Kyung, 2014). The decrease in egg weight reported in this study as egg aged could be as a result of evaporation of water through the shell pores. This is in consonance with the observation of Sung and Kyung (2014). This could also be responsible for decrease in Haugh unit, albumen weight, heights of yolk and albumen with age. However, yolk weight increased as the duration of egg storage increased, Khan *et al*. (2013) reported that movement of water from the content of albumen to yolk content could be responsible for the increased yolk weight with storage duration. This also accounted for decrease in albumen weight. During aging there is carbon dioxide and oxygen exchange and water evaporates through the shell increasing the air chamber and reducing albumen height. The Haugh unit of 61.6 at the seventh day of storage is lower than 66.2 reported by Sung and Kyung, (2014) at room temperature. The discrepancies could be caused by differences in age and breed of the layers used. The non-significant effect of storage duration on shell thickness and index is similar to the observation of Sung and Kyung, 2014 while the significant effect observed in shell weight is contrary to the report of the researchers. The positive relationship between weight and length of an egg, width and shell weight indicates that similar genes are responsible for the phenotypic characteristics of the traits. These observations are in consonance with the report of Yakubu *et al.,* (2008). The negative correlation observed between weight of the egg and shell qualities except shell weight in this study is in consonance with the report of Kul and Seker (2004). The different positive and negative correlations observed among the internal quality of egg in this study could be compared to the reports of earlier researchers (Benoff and Renden 1983; Stadelman, 1986; Asuquo *et al*., 1992; Yakubu *et al.,* 2008 and Olawumi and Ogunlade, 2008). The minerals observed in this study increased as the as the eggs aged in storage. Moisture content decreased as the eggs aged, this could be caused by the evaporation of water from the shell pores (Sung and Kyung 2014). Protein and ash followed similar trend except fat and carbohydrate that increased as the eggs aged.

Conclusion

In conclusion, egg quality, moisture content, protein and ash declined as the eggs aged while carbohydrate, fat and minerals increased. Thus, the period of storage had a statistical significant effect on egg quality, proximate composition and mineral profile. It could be concluded that storage reduces the acceptability of eggs by consumers as quality is grossly affected.

Conflict of interest

Authors declare no conflict of interest

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Author's contribution

The experiment was developed and designed by Adeoye, A.A.. The proximate analysis was carried out by P Akinleye and JB Ojajuni. Measurements of the parameters affecting egg quality were conducted by RA Olorunsola and OO Oyeleye. AA Adeoye contributed in the drafting of the manuscript, whereby all authors critically revised for noteworthy intellectual value and then approved the final manuscript.

Ethical approval

The experiment does not require ethical approval.

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