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Effects of Storage on Nutritional Compositions and Microbial Load of Kiln-Dried, Oven-Dried, Solar-Dried and Refrigerated Fowl Eggs

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Abstract

Poultry eggs are highly perishable thus require proper handling to minimize spoilage. Several techniques to prolong the shelf life of poultry eggs have been propounded, but little is known about boiling and drying. This study aimed at evaluating the nutritional and microbial load of kiln-dried, oven-dried and solar-dried fowl eggs. Twenty boiled fowl eggs were allotted to $T_{(Control)}$, $T_{(Kiln)}$, $T_{(Oven)}$, $T_{(Solar)}$ and $T_{(Refrigerated)}$ and stored for 30 days. Before and after storage, egg samples from each of the treatments were processed for proximate and microbial load determination. Before storage, the crude protein was 12.7% (boiled eggs) and varied between 34.73% and 40.99% in dried eggs. After storage, crude protein ranged from 9.53 – 11.41% and 31.93 – 38.83% in boiled and dried fowl eggs, respectively. Before storage, neither bacterial nor fungal strains were detected in the eggs except $T_{(Solar)}$. After storage, some bacterial and fungal species were detected in all the eggs except $T_{(Kiln)}$ and $T_{(Oven)}$. Therefore, drying may improve the nutritional quality and prolong shelf life of fowl eggs.

Keywords: Egg deterioration, nutritional quality, shelf life, water loss.

Introduction

Eriksson *et al*. (2008) described poultry as domesticated birds kept by humans for eggs, meat and feathers. These birds are most typically members of the super order *Galloanserae* (fowl), especially the order *Galliformes* which includes chickens, quails and turkeys. Chickens are medium-sized, chunky birds with an upright stance and characterized by fleshy red combs and wattles on their heads. Males, known as cocks, are usually larger, more boldly coloured, and have more exaggerated plumage than females (referred to as hens). Chickens are gregarious, omnivorous, ground-dwelling birds that are in their natural surroundings, searching among the leaf litter for seeds, invertebrates and other small animals. They hardly fly except when perceived danger, preferring to run into the undergrowth if approached. Today's domestic chicken (*Gallus gallus domesticus*) descended from the wild red jungle fowl of Asia, with some additional input from grey jungle fowl. Since then, the keeping of chickens has spread around the world for the production of food with the domestic fowl being a valuable source of both eggs and meat.

Recently, the global poultry meat output was expected to amount to 106.4 million tons according to Food and Agriculture Organisation forecast, but the growth rate has reduced from about 4.5% to 1.8% annually. Nonetheless, it was stated that chicken meat output accounted for about 88% of world poultry meat production and may likely exceed 93 million tons. Meanwhile, the United States Department of Agriculture estimated that broiler meat output will amount to around 84.6 million tonnes. Essentially, the FAO data was for indigenous production consisting of the output from home-grown birds and the meat equivalent of such birds exported live. Consequently, poultry could be the second most widely eaten type of meat in the world, accounting for about 30%, after pork at 38% of the total world meat production. Annually, about sixteen billion birds are raised for consumption with more than half of these in industrialized and factory-like production operations. Global broiler meat production rose to 84.6 million tons and the largest producers were the United States (20%), China (16.6%), Brazil (15.1%) and the European Union (11.3%). Therefore, global egg production was estimated to be well over 90 million tons per annum, with global growth rate of about 4.5% per annum unfortunately, the growth rate has slowed down to near 1.8%. Hence, the demand for poultry is expected to continue growing in developing economies, particularly in India and China, reflecting population increases, improved disposable incomes and consumer taste preferences.

Global population growth has slowed to around one per cent a year with developed countries expected to average only 0.4% a year between 2012 and 2022. While the growth in developing countries will also decline, it will be significantly higher than in the rest of the world. Hence, it is considered that they will account for 82% of the world's population by 2022 compared with 74% back in 1980. Interestingly, there are two distinct models of poultry production: the European Union supply chain model which seeks to supply products which can be traced back to the farm of origin and the United States model that turns the product into a commodity. However, the European Union model faces the increasing costs of implementing additional food safety requirements, welfare issues and environmental regulations (FAO, 2022; USDA 2018; Linden, 2013). Poultry egg is a rich source of high quality protein and it provides a unique source of nutrients for humans. In Nigeria, different poultry species contribute significantly to the annual animal protein supply to the populace. Poultry eggs are good sources of income and are of particular significance in scientific research, such as vaccine production. The egg is a complex structure distinguished by having four different parts: the shell, shell membrane, albumen and yolk. Eggs meant for human consumption, should be thoroughly examined for both internal and external qualities and be certain they are suitable before supply (Kabir et al., 2014; Adebambo, 2005).

Egg quality could be defined as the properties that can influence its acceptance or rejection by the consumers. Thus, egg quality could be measured by the characteristics that affect its acceptability to consumers such as cleanliness, freshness, egg weight, shell quality, yolk index, albumen index, Haugh unit and chemical compositions. Egg quality is a general term which refers to several standards that describe both internal and external qualities. While external quality focused on egg shell cleanliness and thickness, egg weight, height, width and shape, internal quality refers to albumen purity and viscosity, yolk consistency and absence of blood spots. Unlike external quality, internal quality of the egg begins to decline as soon as the egg is laid. Although factors associated with the management and nutrition of the hen, do play a role in internal egg quality, egg handling and storage practices do have a significant impact on the quality of the egg. Chicken egg is one of the most common foods all over the world with biological value of 93.79% unlike milk with biological value of 84.5 %, fish (76%) and beef 74.3% (Kabir et al., 2014; Kabir and Muhammad, 2011; Jacob et al., 2000).

According to Rehman and Haq (2011) Gl-, G2- and G3-globulins, lysozyme, ovomacroglobulin, antibody IgY as well as other natural antimicrobials and immune-stimulants in the egg, prolonged the lives of HIV/AIDS patients, not only due to their high nutritional values but also because of their antimicrobial properties. Therefore, this nutritionally balanced and high biological value of fowl eggs could be an excellent growth promoter in children, best natural nutritional support for convalescents, especially those with tuberculosis and other related infections. More importantly, the lipoprotein and other high biological values and proteins in the egg act as excellent growth promoters in children and animals alike. Egg albumen can also be used as a remedy in cases where certain toxins and irritants may have been accidentally consumed. It protects the mucous membranes of the stomach and intestine thus, prevents ulcer formation. Chicken eggs are abundant in antibodies such as IgY which can treat human rotavirus, *Escherichia coli, streptococcus, pseudomonas, staphylococcus* and *salmonella* infections. More importantly, it has been discovered that an egg contains up to 50% of the human daily choline requirements, which is essential for normal functioning of all cells, including those involved in metabolism, brain, nerve function, memory and the transportation of nutrients throughout the body. It was reported that choline helped in the prevention of birth defects and promoted brain and memory development in infants (Derbyshire and Obeid, 2020; Leermakers et al., 2015; Zeisel, 2006).

Eggs are rich sources of antibodies and high quality nutrients hence they are a vehicle for reproduction and a staple food within the human diets and have a natural balance of essential nutrients. Egg by-products such as those from breaking facilities and unsellable eggs, are known to be rich in fats, maternal antibodies, proteins, bioactive nutrients and lyzosyme (Anton et al., 2006; Schmdit et al., 1992; Sparks, 2006). Egg components such as lysozyme, avidin, phosvitin and other biochemical substances like scialic acid and scialoligosaccharides are beneficial for human well-being (Sparks, 2006; Stadelman, 1999; Juneja, 1998). The egg yolk is a reservoir of antibodies with many proven uses as well as many theoretical applications. For instance, fowl egg yolk IgY has been extensively applied to many diagnostic, prophylactic and therapeutic uses (Anton et al., 2006; Sparks, 2006; Li-Chan, 1998). Application of IgY medication to humans by injection or encapsulation of an egg yolk concentrate has been reported however, with animals, oral administration by feeding either liquid or dried egg yolk was adopted. When dried egg powder was fed to animals, it was observed that feed conversion ratio and growth parameters were improved (Pereira et al., 2019; Rahman et al., 2013; Müller et al., 2015).

Egg yolk, albumen and chalaza were stated to be rich sources of sialic acid which has powerful antimicrobial, anti-inflammatory and antiviral properties hence, was used in the cure of *Helicobacter pylori* and other microbial infections like ulcers, colon cancer, gastritis and enteritis. It is believed that lutein and zeaxanthin contained in hens' eggs could help in maintaining the eye health and reducing the risks of age-related macular degeneration that is a major cause of irreversible blindness in humans. Vitamin E, organic selenium and other antioxidants in eggs have been reported to prevent oxidation, ageing and formation of plaques in human arteries (Rehman and Haq, 2011). The high-quality protein in eggs has been reported to be responsible for feeling full and staying energized for a longer time thereby, maintaining a healthy weight (Sparks, 2006; Li-Chan, 1998; Mime and Yoshimasu, 1998).

With this awareness of chicken eggs' relevance to humankind particularly in medicine, there should be the propensity to produce more eggs, which may not be readily used up thereby resulting in glut. Unfortunately, poultry fresh eggs are highly perishable in nature and difficult to transport due to bulkiness and fragility hence, may not be suitable for international trade. This possibly led to the adoption of dehydration technique to obtain egg powder that provided a near complete solution to the problem of perishability and transportation (Jay, 2000; Frazier and Westerhoff, 1988). However, if care is not taken, the technological procedures of egg powder production, which involves washing, breaking, filtering and pasteurization of the fresh egg, may introduce microbial contamination. This envisaged shortcomings, probably led to several other processing and preservation methods such as spray-drying, tray-drying and freeze-drying of chicken eggs, which were also with their attendant repercussions on the products' qualities certainty (Potter and Hotchkiss, 2006).

Some other known techniques of poultry eggs preservation and storage include refrigeration, dry packaging, immersion in liquids, lime treatment, use of brine solution and sodium silicate also called water glass technique, use of oil coating, cellophane, polyethylene, polyvinylidene and other transparent materials (Oleforuh-Okoleh and Eze, 2016; Menezes et al., 2012; Raji et al., 2009). In all these, refrigeration or cold storage method was acclaimed to be the most effective way of storing poultry fresh eggs. Regardless of the fowl eggs storage techniques adopted in these studies, 28 days of storage was reported to be the best duration. For instance, Dudusola (2009) reported that fowl eggs maintained desired internal quality up to 4 days at room temperature and 7 days when refrigerated. Similarly, Raji et al. (2009) stated that poultry eggs could be stored for up to 28 days with refrigeration but, not more than 7 days at room temperature. With all these efforts, little is known about boiling and smoke drying, boiling and oven drying as well as boiling and solar drying of fowl eggs. Meanwhile, Idahor et al. (2017) reported no dissimilarities in the nutritional qualities of fowl eggs boiled for 10, 20, 30, 40, 50 and 60 minutes, respectively. Therefore, the fear of dried fowl eggs losing its nutritional quality could be allayed hence, this study focused on the evaluation of nutritional, bacterial and fungal compositions of kiln-dried, oven-dried and solar-dried fowl eggs.

Materials and Methods

Brief Description of the Study Location

This study was carried out at the Teaching and Research Farm, Faculty of Agriculture, Nasarawa State University Keffi, Shabu-Lafia Campus. Lafia is located in the guinea savannah zone of north central Nigeria, between latitude 08º35'N and longitude 08º33'E with an altitude of 290m above sea level. The environmental mean temperature ranges from 20 to 35^{o}C, relative humidity of 74% and annual rainfall of 1,168.90mm. It has a total land area of 27,117km^2 and total population of 330,712 (NIMET, 2011; NPC, 2006).

Experimental Design

Five treatments designated as $T_{(Control)}$: Without drying the fowl eggs or refrigerating the fowl eggs as Control; $T_{(Kiln)}$: Kiln-dried fowl eggs; $T_{(Oven)}$: Oven-dried fowl eggs; $T_{(Solar)}$: Solar-dried fowl eggs and $T_{(Refrigerated)}$: Refrigerated fowl eggs, were laid out in a completely randomized design.

Boiling and Drying of the Experimental Fowl Eggs

One hundred fresh fowl eggs were acquired from National Veterinary Research Institute, Vom, Plateau State, sorted and boiled for 30 minutes. The eggs were labelled properly and tied in transparent cellophane to prevent cracks (see plate 1). Twenty each of the boiled eggs were randomly allotted based on weight to $T_{(Control)}$, $T_{(Kiln)}$, $T_{(Oven)}$, $T_{(Solar)}$ and $T_{(Refrigerated)}$.

Plate 1: Boiling of fowl eggs

Plate 2: Kiln drying of fowl eggs

Plate 3: Oven drying of fowl eggs

Plate 4: Solar drying of fowl eggs

Storage of the Experimental Fowl Eggs

The boiled eggs were arranged in the fabricated kiln and were smoke-dried for 7 days (see plate 2) whereas, it took 5 days at 96^{o}C to oven dry the boiled eggs (see plate 3) and those in the solar dryer (see plate 4) took 14 days to dry. All the experimental eggs in $T_{(Control)}$, $T_{(Kiln)}$, $T_{(Oven)}$ and $T_{(Solar)}$ were kept in egg crates and stored at room temperature for 30 days. The eggs for refrigeration were boiled the same day the storage commenced. Immediately after boiling, the eggs were air-dried in order to cool and were arranged in the fridge's egg crate and stored for 30 days. See plates 5, 6, 7, 8 and 9 for samples of the experimental eggs.

Plate 5: Boiled fowl eggs: $T_{(Control}$

Plate 6: Kiln-dried eggs: $T_{(Kiln)}$

Plate 7: Oven-dried fowl eggs: $T_{(Oven)}$

Plate 8: Solar-dried fowl eggs: $T_{(Solar)}$

Plate 9: Refrigerated fowl: $T_{(Refrigerated)}$

Data Collection

Experimental Fowl Egg Weight Determination

Each of the experimental fowl eggs was labelled and weighed using sensitive weighing scale to obtain initial weight and immediately after boiling the egg weight was taken to obtain warm egg weight. After cooling, the egg weight was taken to get the cool egg weight. At the end of the drying periods, all the eggs were weighed to obtain final egg weight. The egg weight loss was determined using equation 1 as given by Suresh et al. (2015).

$$\text{Egg weight loss (\%)} = \frac{\text{Initial egg weight} - \text{final egg weight after drying}}{\text{Initial egg weight}} \text{ X } \frac{100}{1} \quad \text{... equation 1}$$

Proximate Composition Determination of the Experimental Eggs

Before storage and after 30 days of storage, egg samples from each of $T_{(Control)}$, $T_{(Kiln)}$, $T_{(Oven)}$, $T_{(Solar)}$ and $T_{(Refrigerated)}$, were prepared for proximate composition determination to obtain values of crude protein, crude fat, crude fibre, ash, nitrogen free extract, dry matter and carbohydrate, following standard procedures of AOAC (2010).

Bacteria and Fungi Determination of the Experimental Eggs

Before storage and after 30 days of storage, samples of all the experimental eggs were processed for bacteria strains determination as described by Guyot et al. (2016) and Bedrani et al. (2013), while the fungal strains were determined following the outlined procedures of Rex et al. (1993).

Statistical Analysis

The data collected were analysed and the means were separated using

Duncan's Multiple Range Test according to Statistical Analysis Systems (2007).

Results

Effects of Boiling and Drying on Fowl Eggs

Expressed in table 1 are the effects of boiling and drying on fowl eggs weight. There were significant differences (P>0.05) in all the parameters measured except initial egg weight, warm egg weight, cool egg weight and cool egg weight loss. Meanwhile, the initial egg weight varied from 54.3 – 56.6g, warm egg weight (52.1 – 55.5g), cool egg weight (52.8 – 54.5g) and cool egg weight loss (1.6 – 2.1g).

Table 1: Effects of boiling and drying on fowl eggs weight

Parameters	Treatments (±STD)					
	$T_{(Control)}$	$T_{(Kiln)}$	$T_{(Oven)}$	$T_{(Solar)}$	$T_{(Refrigerated)}$	**P-value**
No. of eggs	20	20	20	20	20	-
Initial egg weight (g)	56.6±6.11	55.1±7.44	55.5±4.82	54.3±4.60	54.9±5.30	0.77
Warm egg weight (g)	55.5±6.06	53.0±6.90	53.5±3.81	52.1±4.44	53.5±7.06	0.89
Warm egg weight loss (g)	1.10±0.32^{c}	2.10±0.44^{b}	2.00±1.51^{b}	2.20±0.37^{a}	1.40±0.32^{c}	0.00
Cool egg weight (g)	54.5±6.05	53.1±7.77	53.9±5.64	52.8±6.66	53.2±5.68	0.80
Cool egg weight loss (g)	2.10±0.90	2.00±1.67	1.60±1.64	2.10±1.50	1.7±1.60	0.06
Final egg weight (g)	44.7±7.66^{a}	28.3±4.81^{c}	30.5±7.40^{b}	36.4±5.44^{ab}	41.9±7.30^{a}	0.00
Final egg weight loss (g)	11.9±7.06^{c}	25.0±6.95^{a}	26.8±5.90^{a}	18.5±7.66^{b}	13.0±6.89^{c}	0.00
Final egg weight loss (%)	21.09±9.22^{c}	48.64±5.44^{a}	45.08±10.9^{a}	33.7±9.99^{b}	23.68±11.8^{c}	0.00
STD: Standard deviation						

The warm eggs, lost more weight (2.8g) in $T_{(Solar)}$, slightly followed by $T_{(Kiln)}$ and $T_{(Oven)}$ with 2.10g and 2.00g, respectively. The highest (44.7g) final egg weight was recorded in $T_{(Control)}$, which was not however, different from 41.9g observed in $T_{(Refrigerated)}$ whereas, the least value (28.3g) was recorded in $T_{(Kiln)}$. The final egg weight loss was higher (25.0g and 26.8g) in both $T_{(Kiln)}$ and $T_{(Oven)}$, compared to 11.9g, 13.0g and 18.5g recorded in $T_{(Control)}$, $T_{(Refrigerated)}$ and $T_{(Solar)}$, in that order.

Effects of Storage on Nutritional Compositions of Differently Dried Fowl Eggs

Table 2 presents the effects of storage on nutritional compositions of differently dried fowl eggs stored for 30 days. There were significant differences (P<0.05) among all the parameters measured except, crude fibre that was not detected in any of the fowl eggs. It was observed that all the nutrients depreciated after 30 days of storing the experimental eggs, except carbohydrate that rather increased appreciably from a range of 15.25 – 15.88% before storage to 20.34 – 18.12% after storage.

Table 2: Effects of storage on nutritional compositions of differently dried fowl eggs

Parameters (%)	Before storage						After storage					
	$T_{(Ctrl)}$	$T_{(Kiln)}$	$T_{(Oven)}$	$T_{(Solar)}$	$T_{(Refri)}$	**SEM**	$T_{(Ctrl)}$	$T_{(Kiln)}$	$T_{(Oven)}$	$T_{(Solar)}$	$T_{(Refri)}$	**SEM**
CP	12.74^{c}	34.73^{b}	40.99^{a}	37.93^{a}	12.69^{c}	0.02	9.53^{c}	31.93^{b}	38.83^{a}	34.33^{b}	11.41^{c}	0.04
Crude fat	11.56^{d}	25.17^{c}	33.67^{a}	28.96^{b}	12.26^{d}	0.01	9.67^{d}	23.13^{b}	31.04^{a}	25.79^{b}	12.12^{c}	0.02
Crude fibre	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ash	3.08^{b}	3.48^{b}	4.15^{a}	3.74^{b}	3.07^{b}	0.03	3.04^{a}	3.37^{a}	3.08^{a}	3.67^{a}	3.02^{b}	0.02
NFE	5.25^{b}	7.91^{a}	6.16^{b}	7.73^{a}	5.88^{b}	0.04	5.34^{c}	6.33^{b}	3.99^{d}	7.62^{a}	3.12^{d}	0.03
Dry matter	42.62^{d}	84.28^{b}	94.96^{a}	92.35^{a}	41.93^{d}	0.03	42.57^{c}	82.75^{b}	92.91^{a}	91.39^{a}	34.68^{d}	0.02
Carbohydrate	15.25^{b}	20.91^{a}	16.16^{b}	21.73^{a}	15.88^{g}	0.02	20.34^{c}	24.33^{b}	18.99^{d}	27.62^{a}	18.12^{d}	0.03

a,b,c,d,e: Mean values on the same row with different superscripts differ statistically at 5% probability test; SEM: Standard error of means; CP: Crude protein; NFE: Nitrogen free extract; $T_{(Ctrl)}$: $T_{(Control)}$; $T_{(Refri)}$: $T_{(Refrigerated)}$

Meanwhile, before storage, the crude protein value was similar (P>0.05) in boiled eggs without refrigeration ($T_{(Control)}$: 12.7%) and refrigerated boiled eggs ($T_{(Refrigerated)}$: 12.6%) but differ significantly (P<0.05) among the dried eggs with 34.7% in $T_{(Kiln)}$, 37.9% ($T_{(Solar)}$) and 40.9% in $T_{(Oven)}$. Similar trend was observed in crude fibre (33.6%), ash (4.15%) and dry matter (94.9%) being superior in $T_{(Oven)}$, slightly followed by 28.9% (crude fibre), 3.74% (ash) and 92.3% (dry matter) in $T_{(Solar)}$ with the least values in $T_{(Control)}$ and $T_{(Refrigerated)}$. Nitrogen free extract was highest and similar (7.9 – 7.7%) in $T_{(Kiln)}$ and $T_{(Solar)}$, but lowest and comparable (5.2 – 6.2%) in $T_{(Control)}$, $T_{(Refrigerated)}$ and $T_{(Oven)}$, while carbohydrate ranged from 15.2% ($T_{(Control)}$) to 21.7% in $T_{(Solar)}$.

After 30 days of storage, the boiled eggs without refrigeration ($T_{(Control)}$) were all spoilt with offensive odour yet, contained 9.5% crude protein whereas, 11.4% was recorded in the refrigerated eggs ($T_{(Refrigerated)}$) and the dried eggs contained 31.9%, 34.3% and 38.8% in $T_{(Kiln)}$, $T_{(Solar)}$ and $T_{(Oven)}$, respectively. Crude fat that varied from 9.67 – 31%, ash (3.0 – 3.6%) and dry matter (34.6 – 92.9%) were all superior in $T_{(Oven)}$. Nitrogen free extract was highest (7.6%) in $T_{(Solar)}$ slightly followed by 6.3%, 5.3%, 3.9% and 3.1% in $T_{(Kiln)}$, $T_{(Control)}$, $T_{(Oven)}$ and $T_{(Refrigerated)}$, respectively. Carbohydrate was 27.6%, 24.3%, 20.3%, 18.9% and 18.1% in $T_{(Solar)}$, $T_{(Kiln)}$, $T_{(Control)}$, $T_{(Oven)}$ and $T_{(Refrigerated)}$, in that arrangement.

Microbial Load of Differently Dried Fowl Eggs

Microbial load of differently dried fowl eggs before storage and after 30 days of storage is given in table 3. Before storage, neither bacteria nor fungi strains were detected in all the boiled egg samples except in $T_{(Solar)}$, where bacterial species (*Salmonella spp* and *Listeria monocytogenes*) nor fungal species (*Aspergillus flavus* and *A. niger*) were identified. After storage, bacterial species (*Salmonella spp, Pseudomonas aeruginosa, Staphylococcus aureus, Escherichia coli, Listeria monocytogenes, Enterobacteria*) and fungal species (*Aspergillus flavus, A. tamari, A. niger, Trichoderma spp*) were detected in $T_{(Control)}$. Similar observation was made in $T_{(Solar)}$ except *Enterobacteria* and *Trichoderma spp* that were not detected and in $T_{(Refrigerated)}$, only *Salmonella spp*, *Escherichia coli* and *A. niger* were detected.

Table 3: Detection of bacteria and fungi species in differently dried fowl eggs stored for 30 days

Parameters	Before storage					After storage				
	$T_{(Ctrl)}$	$T_{(Kiln)}$	$T_{(Oven)}$	$T_{(Solar)}$	$T_{(Refri)}$	$T_{(Ctrl)}$	$T_{(Kiln)}$	$T_{(Oven)}$	$T_{(Solar)}$	$T_{(Refri)}$
Bacteria										
Salmonella spp	-	-	-	+	-	+	-	-	+	+
Pseudomonas aeruginosa	-	-	-	-	-	+	-	-	+	-
Staphylococcus aureus	-	-	-	-	-	+	-	-	+	-
Escherichia coli	-	-	-	-	-	+	-	-	+	+
Listeria monocytogenes	-	-	-	+	-	+	-	-	+	-
Enterobacteria	-	-	-	-	-	+	-	-	-	-
Fungi										
Aspergillus flavus	-	-	-	+	-	+	-	-	+	-
A. tamari	-	-	-	-	-	+	-	-	+	-
A. niger	-	-	-	+	-	+	-	-	+	+
Trichoderma spp	-	-	-	-	-	+	-	-	-	-

$T_{(Ctrl)}$: $T_{(Control)}$; $T_{(Refri)}$: $T_{(Refrigerated)}$

Discussion

Boiling and Drying of Fowl Eggs

It was observed that the fowl eggs' weight value was within the range of 54 – 59 g recorded in layers at peak of lay (Addo et al., 2018; Jin et al., 2011) but less than a range of 56 – 65 g categorised as large eggs and 64.0 to 69.9g refer to as extra-large fowl eggs (USDA, 2000). This indicated that the fowl eggs were seemingly of standard sizes appropriate for this study. It was shown that boiling reduced the fowl eggs' weight possibly as a result of moisture loss through the pores. It was revealed that boiled eggs in $T_{(Control)}$ and $T_{(Refrigerated)}$ greatly loss weight probably due to moisture loses during storage for 30 days. More significantly, it was observed that kiln, oven and solar drying of fowl eggs, resulted in as much as 21 – 48% weight loss, which could be purely due to moisture lose during drying and partly due to storage duration. These values were much more than 0.16 – 5.4g weight loss recorded in eggs stored at room temperature for 21 days (Dudusola, 2009) and Fayoumi, Lohmann Light-Brown and Naked neck hens' fresh eggs stored at different temperature conditions (Addo et al., 2018; Jin et al., 2011; Khan et al., 2013). Meanwhile, the values were less than a range of 88.4 to 99.2% weight loss reported in Half white (Embrapa White Leghorn CC strain) and Half brown strains' (Embrapa Rhode Island Red GG) fresh eggs, stored at room temperature and under refrigeration during the Summer and Autumn seasons (Feddern et al., 2017). If fresh fowl eggs could lose weight this much, how much more would drying reduce fowl eggs. According to Réhault-Godbert et al. (2019), fowl egg contains about 87.7% water thus, confirming the reports of Romao et al. (2008) and Walsh et al. (1995) that fowl eggs are bound to lose weight in storage as a result of evaporation, as may be influenced by ambient temperature and relative humidity, especially during long storage periods.

Nutritional Compositions of Differently Dried Fowl Eggs

The observed general reduction in nutritional quality of the experimental eggs after 30 days of storage could be largely due to environmental influences that resulted in gradual depreciation of the nutrients. This observation possibly prompted the suggestion of Ogunwole et al. (2015), that alternative storage methods to room temperature egg storage should be considered for storing excess fowl eggs, in order to maintain freshness. However, the decline in the crude protein of the boiled and refrigerated fowl eggs after 30 days of storage could be largely due to available moisture that probably bonded the protein molecules thereby, making it unavailable. Also, it could be partly due to fermentation of the boiled eggs that resulted in spoilage, even when refrigerated, thus using up nitrogen in the process that perhaps gave the observed offensive odour. This observation somewhat lend more credence to several reports that boiled fowl eggs deteriorate even in a cold chain storage system (Menezes et al., 2012; Dudusola, 2009; Raji et al., 2009).

However, the crude protein values of the boiled fowl eggs without drying, were higher than a range of 8.9 – 10% recorded in different poultry species (Fakai et al., 2015) but, similar to a range of 12 – 16% reported in fertilized and unfertilized Shika-brown eggs that were hard boiled for 60 minutes (Idahor et al., 2017). The tremendous improvement in the quality of dried fowl eggs, could be largely due to loss of excessive moisture, resulting in the concentration of the nutrients and partially due to Maillard reaction resulting from enzymatic browning, known to be associated with toasting, baking and drying of food materials (Lund and Ray, 2017; Shittu et al., 2007). This enhanced nutritional quality, may explain the effectiveness of fowl eggs being reported in many diagnostic, prophylactic and therapeutic trials, particularly the report of dried fowl eggs fed to animals that improved feed conversion ratio and growth (Anton et al., 2006; Sparks, 2006; Li-Chan, 1998). The crude protein values of the dried fowl eggs in the present study was similar to a range of 44 – 48% reported in some poultry species (Okonko et al., 2019) and higher than a range of 8.9 – 16% reported in some poultry species (Idahor et al., 2017; Fakai et al., 2015).

In any case, all the nutritional values obtained in the present study, were similar to the values given in Réhault-Godbert et al. (2019) and partially close to USDA (2018) values with about 76.1% (water), 12.6% (protein), 9.5% (fat) and 1.1% (ash) determined in a whole, raw and freshly laid fowl eggs but comparatively lower carbohydrates (0.7%) which may be adduced to the analytical procedures adopted in the studies. More significantly, the nutritional quality observed compared favourably well, with those reported by Seuss-Baum et al. (2011), when similar egg quality parameters were evaluated thus, drying may enhance nutritional quality of fowl eggs.

Microbial Load of Fowl Eggs

The absence of bacteria and fungi in the boiled fowl eggs before storage, seemingly suggested that freshly boiled eggs, may not be contaminated hence should be consumed immediately. Unlike the solar dried eggs, that were contaminated even during the drying process, may not be suitable for consumption. This could be due to low rate of moisture loss in the eggs that was purely dependent on temperature in the solar drier, as influenced by sunshine intensity during the day, with a drastic fall at night thus, solar drier may not be suitable for drying fowl eggs. The detection of some bacterial and fungal species, after 30 days of storage in the boiled fowl eggs without drying, simply indicated deterioration, which was probably made possible due to the relatively high moisture contents, compared to the dried fowl eggs that never had any bacterial or fungal species.

This observation somewhat corroborated the report of Samiullah et al. (2014), that detected bacteria in hens' eggs and Sumashree et al. (2019) who recorded a range of 2.2 – 2.6cfu/mL of unspecified microbes in fresh, pasteurized and microwave treated fowl eggs. More importantly, this study apparently buttressed the findings of Obi and Igbokwe (2009), who recorded some bacterial and fungal strains in fowl eggs. In essence, these observations apparently buttressed several reports that fowl eggs are perishable (Miller et al., 2010; Dudusola, 2009; Raji et al., 2009), hence the recommendation of Idahor (2021) that drying may reduce moisture availability for microbial spoilage.

Conclusion

Boiling reduced fowl eggs' weight and weight loss of dried fowl eggs was close to half of the original weight. Drying improved the nutritional quality of the fowl eggs while storage duration negatively affected the nutritional compositions of boiled and refrigerated fowl eggs. Fresh boiled fowl eggs were devoid of microbial contamination thus should be consumed immediately and not stored no matter how short. Neither bacteria nor fungi were detected in kiln-dried and oven-dried fowl eggs whether before or after storage. Consequently, adequate drying of fowl eggs may improve the nutritional quality and prolong storage duration.

References

[1] Addo, A., Hamidu, J. A., Ansah, A. Y. and Adomako, K. (2018). Impact of egg storage duration and temperature on egg quality, fertility, hatchability and chick quality in naked neck chickens. Int. J. Poult. Sci., 17:175-183.

[2] Adebambo, O. A. (2005). Indigenous poultry breeds genetic improvement for meat and egg. Proc. 1st Nigerian International Poultry Summit, pp. 1-8.

[3] Anton, M., Nau F. and Nys Y., 2006. Bioactive egg components and their potential uses. World's Poult. Sci. J., 62: 429-438.

[4] AOAC, 2010. Association of Official Analytical Chemists Method of Analysis (15th edition). Published by the Association of Official and Analytical Chemists, Washington D.C.

[5] Bedrani L, Helloin E, Guyot, N, Rehault-Godbert S, Nys Y. 2013. Passive maternal exposure to environmental microbes selectively modulates the innate defences of chicken egg white by increasing some of its antibacterial activities. BMC Microbiol. 13:13.

[6] Derbyshire E. and Obeid R. 2020. Choline neurological development and brain function: a systematic review focusing on the first 1000 days. Nutrients, 12, 1731; doi:10.3390/nu12061731, www.mdpi.com/journal/nutrients.

[7] Dudusola, I. O. (2009). Effects of storage methods and length of storage on some quality parameters of Japanese quail eggs. TROPICULTURA, 27(1):45-48.

[8] Eriksson J, Larson G, Gunnarsson U, Bed'hom B, Tixier-Boichard M; Vereijken, Addie; Randi, Ettore; Jensen, Per; Andersson, Leif. (2008), "Identification of the yellow skin gene reveals a hybrid origin of the domestic chicken", PLOS Genetics.

[9] Fakai I.M., Sani I. and Olalekan O.S. 2015. Proximate composition and cholesterol content of egg obtained from various bird species. Journal of Harmonized Research in Medical and Health Sci., 2(2): 18-25.

[10] FAO, 2022. Gateway to poultry production and products. Food and Agricultural Organization of the United Nations. Accessed on: https://www.fao.org/ poultry-production-products/production/en/

[11] Feddern, V., de Prá, M. C. Mores, R., Nicoloso, R. S., Coldebella, A., de Abreu, P. G. (2017). Egg quality assessment at different storage conditions, seasons and laying hen strains. Ciência e Agrotecnologia, 41(3): 322-333. http://dx.doi.org/10.1590/1413-70542017413002317.

[12] Frazier, W. C. and Westerhoff, D. C. (1988). Microbiology .2nd ed. McGraw- Hill polisher Inc., New Delhi, India.

[13] Guyot N, R´ehault-Godbert S, Slugocki C, Harichaux G, Labas V, Helloin E, Nys Y. 2016. Characterization of egg white antibacterial properties during the first half of incubation: A comparative study between embryonated and unfertilized eggs. Poult Sci. 95:2956-2970. Accessed on: http://dx.doi.org/10.3382/ps/pew271.

[14] Idahor K. O. 2021. Organoleptic properties and shelf-lives of differently dried fowl eggs. Nig. J. Biotech. 38 (1): 120-131. DOI: https://dx.doi.org/10.4314/njb.v38i1.14. http://www.ajol.info/ index. php/njb/ index ; www.biotechsocietynigeria.org.

[15] Idahor K. O., Matthew B. O., Adgidzi E. A. , Isah N. ,Osaiyuwu O. H. and Sokunbi O. A. 2017. Effects of fertilization and boiling duration on nutritional compositions and organoleptic properties of Shika-brown eggs. Proc. 42nd Ann. Conf. NSAP, Landmark University, Omu-Aran, Kwara State, Nigeria, Pp 267 – 270.

[16] Jacob, J.E., Miles, R.D. and Mather, F.B. (2000). Egg quality. US Department of Agriculture, cooperative extension services, University of Florida, IFAS.

[17] Jay, M. J. (2000). Modern Food Microbiology. 6th ed. Aspen Publishers Inc., Gaithersburg, Maryland.

[18] Jin, Y. H., Lee, K.T., Lee, W. I. and Han, Y. K. (2011). Effects of storage temperature and time on the quality of eggs from laying hens at peak production. Asian-Aust J Anim Sci 24(2), 279-284. www.ajas.info.

[19] Juneja, L. R., (1998). Biological characteristics of egg components: Hens egg, store-house of biomedicals, potential applications? Page 36 in: Second International Symposium on Egg Nutrition and Newly Emerging Ovo-Biotechnologies. Banff, AB, Canada.

[20] Khan, M. J. A., Khan, S. H., Bukhsh, A., Abbass M. I. and Javed M. (2013). Effect of different storage period on egg weight, internal egg quality and hatchability characteristics of Fayuomi eggs. Ital J Anim Sci, 12(2) e51, https://doi.org/10.4081/ijas.2013.e51.

[21] Kabir, M., Sulaiman, R.O., Idris, R.K., Abdu, S.B., Daudu, O.M., Yashim, S.M., Hassan, M.R., Adamu, H.Y., Eche, N.M., Olugbemi, T.S. and Adedibu, I.I. (2014). Effects of strain, age and the interrelationships between external and internal qualities of eggs in two strains of layer chickens in northern Guinea savannah zone of Nigeria, Iranian Journal of Applied Animal Science, 4 (1): 179-184. http://ijas.ir/main/uploads/userfiles/files/Kabir%20%2813-154%29.pdf.

[22] Kabir, M. and Muhammad, S.M. (2011). Comparative study of fertility and hatchability in Shika-brown commercial and parent stock egg-type chickens in Zaria- Nigeria. Nigerian Poultry Science Journal, 8:37-41.

[23] Leermakers, E.T., Moreira, E.M., Kiefte-de Jong, J.C., Darweesh, S.K., Visser, T., Voortman, T., Bautista, P.K., Chowdhury, R., Gorman, D., Bramer, W.M., et al. 2015. Effects of choline on health across the life course: A systematic review. Nutr. Rev., 73, 500–522.

[24] Li-Chan, E.C.Y., 1998: Applications of egg immunoglobulins in immunoaffinity chromatography and immunoassays-separation technology, research and industrial applications. Page 32 in: Second International Symposium on Egg Nutrition and Newly Emerging Ovo-Biotechnologies. Banff, AB, Canada. Abstr.

[25] Linden J. (2013). Global poultry trends 2013 - Asia produces one-third of world's broilers. Accessed on: https://www.thepoultrysite.com/articles/global-poultry-trends-2013-asia-produces-onethird-of-worlds-broilers.

[26] Lund M.N. and Ray C.A. 2017. Control of Maillard reactions in foods: strategies and chemical mechanisms. J. Agric. Food Chem., American Chemical Society 65, 23, 4537–4552, https://doi.org/10.1021/acs.jafc.7b00882.

[27] Menezes, P. C., Lima, E. R., Medeiros, J. P., Oliveira, W. N. K. and Evêncio-Neto, J. (2012). Egg quality of laying hens in different conditions of storage, ages and housing densities. R. Bras. Zootec., 41(9):2064-2069.

[28] Miller, P., Haveroen, M. E., Solichova, K., Merkl, R., Mcmullen, L. M., Mikova, K. and Chumchalova, J., 2010. Shelf-life extension of liquid whole eggs by heat and bacteriocin treatment. Czech Journal of Food Sciences, 28(4): 280-289.

[29] Mime, Y., and M. Yoshimasu. (1998). Production of hens immunoglobulin against an enzymatic crosslinked human insulin for immunodiagnosis using a microbial transglutaminase. Page 56 in: Second International Symposium on Egg Nutrition and Newly Emerging Ovo-Biotechnologies. Banff, AB, Canada.

[30] Müller S., Schubert A., Zajac J., Dyck T. and Oelkrug C. (2015). IgY antibodies in human nutrition for disease prevention. Nutrition Journal 14:109, DOI 10.1186/s12937-015-0067-3.

[31] NIMET 2011, Nigeria Metrological Agency Report, Synoptic Office, Lafia, Nasarawa State, Nigeria.

[32] NPC 2006, National Population and Housing Census, National Population Commission, Abuja, Nigeria.

[33] Obi C.N. and Igbokwe A.J. 2009. Microbial analysis of freshly laid and stored domestic poultry eggs in selected poultry farms in Umuahia, Abia State, Nigeria. Research Journal of Biological Sciences 4(12): 1297 – 1303.

[34] Ogunwole O.A., Ojelade A.Y.P., Oyewo M.O. and Essien E.A. 2015. Proximate Composition and Physical Characteristics of Eggs from Laying Chickens Fed Different Proprietary Vitamin-Mineral Premixes Under Two Rearing Systems During Storage. International Journal of Food Science and Nutrition Engineering 2015, 5(1): 59-67, DOI: 10.5923/j.food.2015050 1.08.

[35] Okonko L.E., Ikpeme E.V., Udensi O.U. and Kalu S.E. 2019. Analysis of proximate, mineral and toxicant compositions of eggs of quail and chicken given Aflatoxin contaminated feed. Trends in Applied Sciences Research, 14 (2): 125 – 129. 0DOI: 10.3923/tasr.2019.125.129.

[36] Oleforuh-Okoleh, V. U. and Eze, J. (2016). Effect of storage period and method on internal egg quality traits of the Nigerian native chicken. LRRD, 28 (6).

[37] Pereira E.P.V., van Tilburg M.F., Florean E.O.P.T. and Guedes M.I.F. 2019. Egg yolk antibodies (IgY) and their applications in human and veterinary health: A review. International Immunopharmacology, 73: 293–303, https://doi.org/ 10.1016/j.inti mp.2019.05.015.

[38] Potter, N. and Hotchkiss, J. (2006). Food Science. 5th Ed. CBS Publisher and Distributors, Delhi, India.

[39] Rahman S., Nguyen S.V., Icatlo F.C. Jr., Umeda K., Kodama Y. (2013). Oral passive IgY based immunotherapeutics: a novel solution for prevention and treatment of alimentary tract diseases, Hum. Vaccin. Immunother. 9 (5) 1039–1048, https:// doi.org/10.4161/hv.23383.

[40] Raji, A. O., Aliyu, J., Igwebuike, J. U. and Chiroma, S. (2009). Effect of storage methods and time on egg quality traits of laying hens in a hot dry climate. J. Agric. Biol. Sci., 4(4): 1-7. www.arpnjournals.com.

[41] Réhault-Godbert S., Guyot N. and Nys Y. 2019. The golden egg: nutritional value, bioactivities and emerging benefits for human health. Nutrients, 11, 684; doi:10.3390/nu11030684 www.mdpi.com/journal/nutrients.

[42] Rehman Z. Ur and Haq A. Ul. (2011). Nutritional importance of an egg. Egg Nutritional Composition, Engormix. Accessed on: https:// en.engormix. com/ poultry-industry/articles/egg-nutritional-composition-t34923.htm.

[43] Rex, J. H., Pfaller, M. A., Rinaldi, M. G., Polak, A. and Galgiani, J. N. 1993, Clin. Microbiol. Rev., 6(4), 367.

[44] Romao, J. M., Moraes, T. G. V., Teixeira, R. S. C., Cardoso, W. M. and Buxade, C. C. (2008). Effect of egg storage length on hatchability and weight loss in incubation of egg and meat type Japanese quails. Bra. J. Poult. Sci., 10(3):143-147.

[45] Samiullah S., Roberts, J.R. and Chousalkar, K.K. 2014. Effect of production system and flock age on egg quality and total bacterial load in commercial laying hens. J. Appl. Poult. Res., 23, 59–70.

[46] Schmdit, L. D., B. A. Sloinski,G. Blank, and W. Guenter, (1992). Application of egg by – products as high quality protein and bactericidal supplements in animal nutrition. Ann. Allergy, 69:521-525.

[47] Seuss-Baum, I., Nau, F. and Guérin-Dubiard, C. 2011. The nutritional quality of eggs. In Improving the Safety and Quality of Egg and Egg Products; Nys, Y., Bain, M., Van Immerseel, F., Eds.; Woodhead Publishing Limited: Cambridge, UK, Volume 2 Egg Safety and Nutritional Quality, pp. 201–236.

[48] Shittu T.A., Raji A.O. and Sanni L.O. 2007. Bread from composite cassava-wheat flour: Effect of baking time and temperature on some physical properties of bread loaf. Food Research International,40: 280 – 290.

[49] Sparks, N.H.C., 2006. The Hen's egg-is its role in human nutrition changing? World's Poult. Sci. J., 62: 308-315.

[50] Sumashree, N., Sharanagouda Hiregoudar, Udaykumar Nidoni, K.T. Ramappa and Nagaraj Naik. 2019. Study of proximate composition, quality characteristics and microbial quality of microwave treated liquid whole egg (LWE) samples. Int. J. Curr. Microbiol. App. Sci. 8(9): 335-342. doi: https://doi.org/10.20546/ ijcmas. 2019.809.040.

[51] Suresh, P. V., Rathina, R. K., Nidheesh, T., Pal, G. K. and Sakhare, P. Z. (2015). Application of chitosan for improvement of quality and shelf life of table eggs under tropical room conditions. J. Food Sci. Technol., 52(10):6345-6354.

[52] Stadelman, W. J., (1999). The incredible functional egg. Poultry Science, 78:807-811.

[53] Statistical Analysis Systems 2007, Statistical analysis systems, SAS User's Guide: Statistics software. Cary, NC, SAS Institute, USA.

[54] USDA 2018. National Nutrient Database for Standard Reference, Release 1; U.S. Department of Agriculture. Food Group: Dairy and Egg Products: Beltsville, MD, USA.

[55] USDA (2000). Egg Grading Manual. USDA. AA Grade. US Department of Agriculture, Washington DC.

[56] Walsh, T. J., Rizk, R. E. and Brake, J. (1995). Effects of temperature and carbon dioxide on albumen characteristics, weight loss, and early embryonic mortality of long stored hatching eggs. Poult. Sci., 74:1403-1410.

[57] Zeisel S. H. 2006. Choline: Critical role during foetal development and dietary requirements in adults Annu Rev Nutr., 26: 229–250.

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