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Effects of Feed Forms on Functional Attributes and Shelf Quality of Stored Eggs in Ibadan, Nigeria

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Abstract
The form in which feed is presented to laying chickens may have considerable impact on the quality of eggs, particularly, the functional attributes which may vary as the egg ages. This study was focused on effect of feed forms on the functional qualities of eggs in Days of Storage (DoS). Lohmann Brown layers (n=270), aged 59-weeks, were allotted to three feed forms: mash, pellet and crumble which were replicated ten times (r=9) in a completely randomised design for 12 weeks. At week-74 hen-age, eggs (n=300) were sampled from hens on feed forms, respectively stored between 24.1 and 28.9oC; relative humidity of 73.0 and 84.0%. Foam Capacity (FC), Foam Stability (FS), Emulsion Capacity (EC), Emulsion Stability (ES), and Least Gelation Capacity (LGC) were measured using standard procedures at 0, 7, 14, 21, and 28 DoS. Data were analysed using descriptive statistics and repeated measures ANOVA at α0.05. The EC (20.72), ES (57.80) and FS (66.04) of eggs of hens on crumble were significantly higher than those on pellet and mash. The FC of mash, pellet and crumbles reduced (R^2 = 0.96 - 0.98) with increasing DoS. During storage, hens on mash, pellet and crumble produced eggs with FC ranging from 80.23 to 73.48, 76.60 to 70.35 and 77.73 to 73.22, respectively. The DoS had no effect on LGC of those fed mash. In conclusion, functional qualities of eggs of hens fed different feed forms all deteriorated drastically in DoS, with those on crumble of relatively enhanced functional attributes.

Keywords: Functional attributes, Egg quality, Shelf-life, Duration of storage, Feed forms.

Introduction

Feed form is an essential determinant of nutrient utilisation, growth performance, and egg attributes in laying chickens (Abdollahi et al., 2014). Feed manufacturers in Nigeria commonly produce mash for laying chickens; however, alternative feed forms such as pellet and crumble have gained attention due to their potential to improve laying performance and egg quality (Agah & Norollahi, 2008).

Pelleting involves the agglomeration of ingredients through mechanical action, when combined with moisture, temperature and pressure to form larger structures called pellets (Massuquetto et al., 2020) which is further broken down to produce crumble. This process induces heat-related transformations such as partial protein denaturation and starch gelatinization (Zimonja & Svihus, 2009), which commonly improve enzymatic access and nutrient digestibility (Rueda et al., 2024; Amoozmehr et al., 2025), particularly through the proteolytic enzymes and the cellulosic cellwalls during heating (Dandago, 2009). It also affects ingestion rate, selection behaviour of the birds, and the extent of feed conditioning (heat and moisture), with effects on digestibility and metabolic utilisation of nutrients by laying hens (Wan et al., 2021; Rueda et al., 2024; Yenice et al., 2025).

In mash, there is ingredient segregation during feed transportation could lead to the inability of the birds to maximise the nutrients in such feeds. It is however, of utmost importance for feeds to be supplied with the needed nutrients to meet the requirements for egg quality (Junqueira et al., 2006). The shelf quality of eggs, reflected by internal indices such as albumen height, yolk index, and Haugh unit, deteriorates rapidly if nutritional and storage factors are suboptimal.

Storage and ambient environment greatly impact the rate at which egg quality attribute declines. In tropical climates, CO_2 and moisture pass through the shell, thereby increasing albumen pH leading to the fast thinning of the albumen when stored, producing rapid decreases in Haugh unit and foaming/emulsifying capacity (Zhang et al., 2022; Ikusika et al., 2025). Initial egg composition including protein conformation and yolk lipid composition, could be diet-dependent which could influence both the fresh functional attributes of eggs and their stability due to biochemical and microbial changes (Ogunwole et al., 2018) during storage. Functional attributes of eggs include the emulsifying capacity and stability, foaming capacity and stability, least gelation capacity.

Ogunwole (2018) opined that the diet of layers could affect the functional properties of eggs during storage. Previous studies (Hafeez et al., 2015; Koçer et al., 2016; Oludoyi et al., 2018, Ege et al., 2019, Wan et al., 2021) have demonstrated that dietary manipulation through feed form modification can influence both external such as shell thickness, egg weight and length, and internal (albumen quality, yolk colour) egg characteristics of laying chickens.

Oludoyi et al. (2024) surmised the influence of different feed brands on the functional attributes of chicken eggs. However, the impact of feed form on egg functional properties is less documented, particularly under tropical storage conditions. Hence, there is need to ascertain how different feed forms influence the functional properties of eggs during storage. This study was therefore conducted to evaluate the effects of different feed forms on the functional attributes and shelf quality of stored eggs in Ibadan, Nigeria.

Materials and Methods

Experimental Location

This experiment was conducted at the Poultry Unit, Teaching and Research Farm, University of Ibadan which is situated in the derived savanna vegetation belt of Nigeria and lies between longitude 7°27.05 north and 3°53.74 of the Greenwich Meridian east at an altitude 200m above sea level (Ogunwole, 2018).

Experimental Animals

Lohmann Brown layers (n=270), aged 59-weeks, were allotted to three feed forms: mash, pellet and crumble which were replicated ten times (r=9) in a completely randomised design for 12 weeks. The laying chickens were reared in a 3-tier battery cage system with each cubicle measuring 50 x 45 x 40cm3 according to the animal welfare requirements of the Poultry Unit, Teaching and Research Farm, University of Ibadan, Ibadan, Nigeria. Early report on proprietary feed brands ancillary to this research have been documented (Oludoyi et al., 2024).

Experimental Design

The experimental design was a completely randomised design where the three feed forms represented the treatments in the study.

Parameters Measured

The 300 freshly laid eggs were sampled from layers fed different feed forms at week-74 hen age and stored between temperatures 24.1-28.9^{o}C and relative humidity of 73-84%. Functional properties such as least gelation capacity, foam capacity and stability, emulsion capacity and stability were determined on days 0, 7, 14, 21 and 28 of eggs storage. The proximate composition of the three forms of feed used in this study was carried out according to the methods described in (AOAC, 2005).

Functional Properties of Chicken Eggs

To measure foam capacity and stability, the methods outlined by Coffman and Garcia (1997), with slight adjustments were used. We whipped 50 mL of each egg pool with 100 mL of distilled water using a Kenwood blender set to speed 1-inch for 5 minutes. The foam capacity and stability of the resulting mixture were determined by pouring it into a 250 mL graduated cylinder. Volume Increase (%) was calculated using the following equation:

$$\frac{\text{Volume after whipping (mL)} - \text{Volume before whipping (mL)}}{\text{Volume before whipping (mL)}} \times 100$$

Foam stability (%) = Vs/ V_t x 100 On Days 0, 7, 14, 21, and 28, the volume of liquid albumen separated (V_s) and the total volume of albumen that originated the foam transferred into the conical vessel (V_t) were measured.

Suspensions ranging from 2% to 20% were prepared using distilled water (Coffman & Garcia, 1997). Each dispersion was transferred to a test tube, with 10 ml in each. The test tubes were then heated in a boiling water bath for one hour and rapidly cooled in a bath of cold water. Afterwards, the samples were cooled at 4°C for 2 hours. The least gelation concentration was determined by observing when the egg sample from the inverted test tube did not fall or slip.

Emulsion capacity and stability were determined according to Beuchat (1997) with modifications. A Philips blender was used to blend 50 ml of egg sample and 100 ml of distilled water at 1600 rpm for 30 seconds. During the blending process, vegetable oil was added gradually in 5ml increments from a burette. The blending continued until the emulsion breakpoint was observed which was indicated by the separation of the mixture into two layers. The assessment of emulsification was conducted at room temperature. The emulsion capacity was determined by calculating the amount of oil emulsified and held per gram of sample.

$$EC\ (mL/g) = \frac{V_0}{W_s}$$

V_0 = Volume of oil emulsified (mL)
W_s = Weight of sample (g)

To determine emulsion stability, an egg sample was prepared as per the emulsion capacity measurement. The mixture was heated for 15 minutes at 85°C, then cooled and uniformly distributed into 50ml centrifuge tubes. The tubes were centrifuged at 1100 rpm for 5 minutes. Emulsion stability was expressed as the percentage of emulsifying activity remaining after heating.

$$ES\,(\%) = \frac{V_s}{V_i} \times 100$$

V_s = Volume of stable emulsion after heating
V_i = Initial volume of emulsion formed

Statistical Analysis

Data were analysed using descriptive statistics and repeated measures ANOVA and means separated at α0.05 of SPSS version 28.0. Means were separated using Duncan's multiple range test of the same software.

Results and Discussion

The proximate composition of different feed forms can be seen in Table 1. Crumble was found to contain 16.80% crude protein, 3.98% ether extract, 3.37% ash while 16.30% crude protein, 3.65% ether extract and 6.02% ash in mash.

Table 1: Proximate Composition of Different Forms of feed fed to Laying Chickens

Parameters	EC	ES	FC	FS	LGC
Mash	20.06±1.22^{b}	57.39±1.67^{b}	76.58±2.31^{a}	63.05±1.91^{b}	73.33±9.54^{a}
Pellet	20.16±1.05^{b}	56.85±1.63^{c}	72.89±2.18^{c}	63.04±2.59^{b}	71.56±9.99^{a}
Crumble	20.72±1.06^{a}	57.80±1.89^{a}	75.45±1.59^{b}	66.04±1.83^{a}	66.22±15.85^{b}
SEM	0.05	0.06	0.05	0.05	1.26

^{abc}Means with different superscripts along the column differed significantly (P<0.05), CP: Crude Protein, EE: Ether Extract, NFE: Nitrogen Free Extract, SEM: Standard Error of Mean.

The higher compositions of crude protein and ether extract found in crumble and pellet feed forms compared to mash could be due to the homogeneity of particles bulk density and reduced fines which can alter the relative proportion of ingredients in the analysed subsample (Svihus et al., 2025). The steam-conditioning and mechanical action during processing of pellet and crumble could also improve incorporation and stabilisation of added fats, which sometimes produces a higher ether extract compositions in the finished feed form (Massuquetto et al., 2020).

Mash contained NFE of 59.96% while 59.72% and 59.26% were observed in pellet and crumble, respectively. Pelleting alters physical characteristics such as particle agglomeration, porosity and improves starch gelatinisation through steam conditioning, thereby reducing anti-nutrients which then, changes the apparent nutrient availability (Abdollahi et al., 2020).

Mash contained higher crude fibre (4.40%) than crumbles (4.27%) and pellet (4.20%). During pelleting, the steam and heat can partially break down complex fibre fractions like cellulose and hemicellulose, thereby, reducing the crude fibre content. This process alters the fibre structure, thereby, making some components more soluble or digestible during crude fibre analysis in pellet and crumble. Relatively high temperature required for pelleting could invariably cause partial degradation of fibre polysaccharides in Maillard reaction. This could reduce the neutral detergent and acid detergent fibre fractions resulting to reduced crude fibre composition in pellet and crumble. Similar observations in the processing procedures have been documented (Ege et al., 2019; Rasool et al., 2025).

Effect of feed forms on functional quality of eggs is shown in Table 2. Higher EC of eggs of hens fed crumble was 20.72 which was significantly higher (p<0.05) than 20.16 in pellet and 20.06 in mash. Layers fed crumble produced eggs with better ES of 57.80 than was observed in pellet (56.85) and mash (57.39). The behaviour of protein affects the functional attributes of eggs during the processing stage of feed. The observed increase in EC and ES of eggs in those fed crumbles could be due to the denaturation of protein which occurs during feed processing and makes it easily digestible by the laying chickens via proteolytic enzymes and cellulosic cell walls degradation when heated (Dandago, 2009). The eggs of hens on mash (76.58) had more FC than in pellet (72.89) and crumbles (75.45). This could be due to the high temperature and pressure used during the production of pellet leading to reduced enzyme activity, then, biosynthesis of high-quality albumen proteins in treated hens. These, could subsequently, result in less quality egg white and lower FC. The FS of eggs from layers fed crumble was 66.04 and was observed to be higher than 63.04 in pellet and 63.05 in mash. These findings indicated that the protein content of the feed had a significant impact on foaming stability of eggs of hens fed crumble. Wan et al. (2021), similarly, observed improved egg albumen quality from layers fed pellet than hens on mash which is an important indicator of a good functional egg attribute.

Table 2: Effects of feed forms on egg functional properties of laying chickens

Form	%CP	%EE	%CF	%Ash	%DM	%NFE
Mash	16.30±0.44^{c}	3.65±0.11^{c}	4.40±0.13^{a}	6.02±0.15^{c}	90.33±0.19^{c}	59.96±0.64^{a}
Pellet	16.66±0.33^{b}	3.80±0.12^{b}	4.20±0.15^{c}	6.19±0.14^{b}	90.57±0.15^{b}	59.72±0.60^{b}
Crumble	16.80±0.37^{a}	3.98±0.13^{a}	4.27±0.13^{b}	3.37±0.12^{a}	90.66±0.14^{a}	59.26±0.60^{c}
SEM	0.01	0.00	0.00	0.00	0.00	0.02

^{abc}Means with different superscripts differed significantly (p<0.05), EC: Emulsion capacity, ES: Emulsion stability, FC: Foam Capacity, FS: Foam Stability, LGC: Least Gelation Concentration

Effect of feed forms on functional properties of eggs in DoS is shown in Table 3. The EC of mash varied from 21.82 to 18.64, 21.41 to 18.65 in pellet and 22.08 to 19.23 in crumble while ES significantly deteriorated ($p<0.05$) from 59.84 to 55.26 in mash, 59.16 to 54.60 in pellet, and 59.87 to 55.01 in crumble in DoS. The FC [mash (80.23 to 73.48), pellet (76.60 to 70.35), crumble (77.73 to 73.22)] and FS [mash (66.16 to 60.70), pellet (67.81 to 60.53) and crumble (68.80 to 63.50)] of eggs, reduced in storage. Eggs LGC of hens fed mash remained unchanged significantly ($p>0.05$) throughout DoS. This conformed to the report of Oludoyi et al. (2018), of declined internal attributes of eggs as a result of feeding different feed forms to hens. Ogunwole (2018) surmised that the feeding of diets supplemented with different vitamin-mineral premixes resulted in significant variations in functional attributes of chicken eggs during storage. The changes observed could be because of the variance in microbial contamination in DOS (Jones et al., 2004) that might invariably be implied on the functional attributes as egg ages.

Table 3: Effect of feed forms on the rheological properties of eggs in days of storage

Parameters	Days of storage	Mash	Pellet	Crumble
EC	0	21.82±0.29[a]	21.41±0.16[a]	22.08±0.22[a]
	7	20.94±0.40[b]	20.97±0.25[b]	21.34±0.18[b]
	14	19.80±0.32[c]	20.31±0.34[c]	20.78±0.11[c]
	21	19.08±0.21[d]	19.42±0.25[d]	20.15±0.16[d]
	28	18.64±0.19[e]	18.65±0.26[e]	19.23±0.17[e]
	SEM	0.14	0.15	0.15
ES	0	59.84±0.28[a]	59.16±0.20[a]	59.87±0.07[a]
	7	58.27±0.17[b]	57.55±0.26[b]	58.85±0.12[b]
	14	57.60±0.18[c]	57.22±0.13[c]	58.84±0.16[b]
	21	55.95±0.17[d]	55.68±0.23[d]	56.41±0.28[c]
	28	55.26±0.20[e]	54.60±0.21[e]	55.01±0.13[d]
	SEM	0.19	0.24	0.28
FC	0	80.23±0.30[a]	76.60±0.13[a]	77.73±0.30[a]
	7	77.35±0.20[b]	73.43±0.32[b]	76.33±0.23[b]
	14	76.76±0.25[c]	72.55±0.23[c]	75.55±0.17[c]
	21	75.06±0.25[d]	71.51±0.12[d]	74.40±0.19[d]
	28	73.48±0.25[e]	70.35±0.20[e]	73.22±0.18[e]
	SEM	0.27	0.32	0.23
FS	0	66.16±0.25[a]	67.81±0.16[a]	68.80±0.22[a]
	7	63.68±0.38[b]	63.32±0.20[b]	66.86±0.11[b]
	14	62.97±0.37[c]	61.95±0.18[c]	66.03±0.15[c]
	21	61.74±0.27[d]	61.57±0.27[d]	64.97±0.13[d]
	28	60.70±0.26[e]	60.53±0.22[e]	63.50±0.08[e]
	SEM	0.22	0.38	0.27
LGC	0	71.11±0.51	62.22±2.22[b]	44.44±2.93[c]
	7	68.88±0.54	64.44±2.93[b]	55.55±2.93[b]
	14	75.55±0.81	75.55±2.93[a]	75.55±2.93[a]
	21	75.55±0.81	77.77±2.22[a]	77.77±2.22[a]
	28	75.55±0.43	77.77±2.22[a]	77.77±2.22[a]
	SEM	1.07	1.48	2.36

[a, b, c]Means with different superscripts differed significantly ($p<0.05$), EC: Emulsion capacity, ES: Emulsion stability, FC: Foaming Capacity, FS: Foaming Stability, LGC: Least Gelation Concentration.

In Figure 1, the polynomial relationship between the duration of storage and foaming capacity of eggs of hens fed different feed forms was negative. The Regression coefficients R^2 for mash (0.98), pellet (0.96), crumble (0.98) showed gradual decline in FC was due to DoS. From the equations shown below, within 0 and 7 days, the changes in FC were more pronounced than were observed for subsequent days.

y = 5E-05x4 - 0.0033x3 + 0.0694x2 - 0.6963x + 66.167……Mash (1)

y = 8E-06x4 - 0.0014x3 + 0.0581x2 - 0.9829x + 67.811….. ..Pellet (2)

y = 2E-05x4 - 0.0015x3 + 0.0352x2 - 0.4578x + 68.8……… Crumble (3)

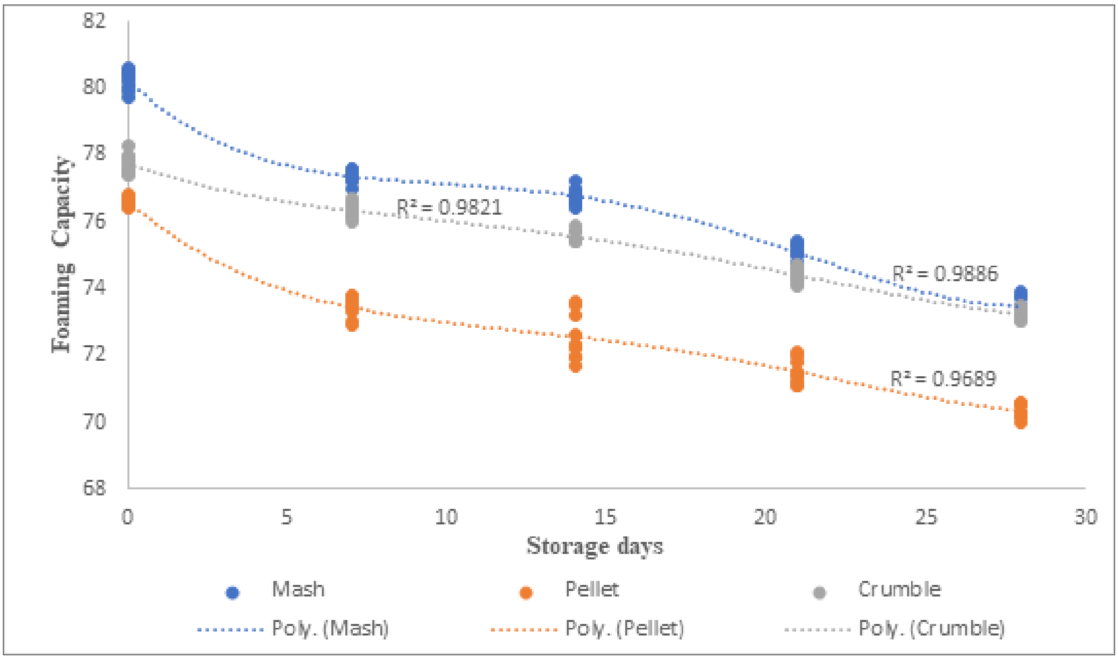

Figure 1: Relationship between the duration of storage and foaming capacity of eggs from laying chickens fed different forms of feed

Conclusion

From this study, hens fed crumble produced eggs with better functional attributes, however, during storage these qualities deteriorated in all the feed forms.

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Data Availability

It will be available on request.

Declarations

Consent to publish is not applicable to this study as it does not include information to require such.

Consent to Participate

This is not applicable for this study because no human participants, interviews or surveys was involved.

Consent for Publication

All authors consented to the publication of this study.

Competing Interests

The authors declared no competing interests with any establishment

Ethics Declarations

The methods/procedures used in this study, "Effects of Feed Forms on Functional Attributes and Shelf Quality of Stored Eggs in Ibadan, Nigeria" carried out at the Poultry Unit, Teaching and Research Farm, University of Ibadan, Ibadan, Nigeria were in concomitant with those outlined in the Animals ARRIVE guidelines and were carried out by the U.K. Animals (Scientific Procedures) Act, 1986 and associated guidelines; EU Directive 2010/63/EU for animal experiments; or the National Institutes of Health guide for the care and use of laboratory animals (NIH Publications No. 8023, revised 1978).

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