Jos Jornal of Applied Animal Science and Environmental Stability
Department of Animal Science. University of Jos.

INFLUENCE OF AQUEOUS GINGER EXTRACT AS EGG WASH AGENT ON INTERNAL AND EXTERNAL EGG QUALITY

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ABSTRACT

This study investigated the effects of storage duration and aqueous ginger (*Zingiber officinale*) extract as a natural washing agent on the egg quality. A total of 300 eggs collected from a commercial farm at 44 weeks of hen age were stored at ambient temperature (28–31 °C, 55–60% RH) for 0, 5, and 10 days. Eggs were washed with ginger extract at 0 g/L (control), 25 g/L, 50 g/L, 75 g/L, 100 g/L, and 125 g/L, with an additional no-wash group and a chlorine-based disinfectant as a positive control. External and internal traits were assessed, and data were analyzed using the General Linear Model in SPSS 25. Storage duration significantly affected egg quality. Egg length increased from 51.82 mm at day 0 to 54.29 mm at day 10, while width rose from 40.19 mm to 43.38 mm. Albumen weight declined from 44.50 g to 41.49 g, yet Haugh unit improved from 89.50 to 94.86. Yolk quality deteriorated markedly with extended storage: yolk height dropped from 12.80 mm to 0.22 mm, whereas yolk diameter expanded from 37.03 mm to 42.03 mm. Ginger extract concentration also influenced egg quality. At 75 g/L, eggs exhibited the best external traits, including weight (57.30 g), width (44.63 mm), and albumen weight (47.08 g). Yolk percentage increased across treatments, reaching 46.81% at 50 g/L compared to 38.46% in the control.

In conclusion, ginger extract—especially at 75 g/L—effectively preserves egg quality without any negative effects.

INTRODUCTION

The production of table eggs is a crucial component of the global poultry industry, valued for its contribution to nutrition and food security. However, one of the most persistent threats to egg safety and consumer health is microbial contamination, particularly from *Salmonella* species (Oshibanjo *et al.,* 2021; Nwamo *et al.,* 2021). These bacteria are among the most common foodborne pathogens associated with eggs, capable of penetrating the eggshell and compromising both internal and external egg quality. *Salmonella enterica* serovars have been implicated in numerous outbreaks globally, raising significant concerns about egg hygiene and post-laying handling practices (Oshibanjo *et al.,* 2021). In response to this challenge, proper egg sanitation methods are essential, and the search for effective, safe, and natural alternatives to chemical sanitizers has intensified in recent years.

Traditionally, commercial egg washing has involved the use of synthetic chemical disinfectants such as chlorine, hydrogen peroxide, and quaternary ammonium compounds. While these substances are effective in reducing microbial load on eggshells, they present notable disadvantages. Chemical residues, environmental hazards, shell cuticle damage, and growing consumer demand for natural, organic, and residue-free products have pushed researchers to explore safer alternatives (Nwamo *et al.,* 2021). Consequently, attention has shifted to phytogenic substances plant-derived bio actives such as ginger, garlic, and turmeric which are known for their antimicrobial and antioxidant properties. These alternatives are gaining momentum due to their potential to inhibit microbial pathogens while maintaining the integrity of the eggshell and internal contents.

Ginger (*Zingiber officinale*) has attracted attention not only for its flavor and medicinal uses but also for its broad-spectrum antimicrobial activity. Its rhizome contains potent compounds such as gingerol, shogaol, and zingerone, which have been shown to exhibit bactericidal effects against various foodborne pathogens, including *Salmonella* spp. (Oshibanjo *et al.,* 2021). The aqueous extract of ginger, in particular, is a practical, affordable, and non-toxic medium that can be easily prepared and applied in field or laboratory conditions. When used as an egg wash agent, it may effectively reduce surface microbial contamination without the drawbacks associated with harsh chemical treatments. Unlike synthetic agents that may compromise the cuticle and allow bacterial penetration, ginger may help preserve eggshell integrity while exerting antimicrobial effects.

The threat posed by *Salmonella* goes beyond surface contamination. Once *Salmonella* breaches the eggshell, it can colonize the albumen and yolk, leading to internal contamination and spoilage. This

significantly reduces the egg's marketability and shelf life and poses health risks to consumers. Internal egg quality, often measured by parameters such as Haugh unit, albumen height, yolk colour, and weight loss, is sensitive to microbial activity and oxidation. The application of ginger aqueous extract as an external treatment may serve the dual function of microbial inhibition and quality preservation (Nwamo *et al.,* 2021). This makes ginger a unique candidate in the ongoing search for sustainable and health-friendly interventions in poultry product hygiene.

Moreover, external egg quality which includes shell cleanliness, shell strength, and shell thicknesses an essential visual and structural determinant of consumer preference and product durability. Eggshell quality is not only a barrier against microbial invasion but also a key parameter in egg grading and pricing. The use of ginger aqueous extract may help maintain or even enhance external egg quality due to its antioxidant content and non-abrasive nature. The visual cleanliness of the shell is especially critical in consumer markets where dirty or stained eggs are often rejected, regardless of internal quality (Oshibanjo *et al.,* 2021; Nwamo *et al.,* 2021). Therefore, the potential of ginger to act as both a natural cleanser and antimicrobial warrants in-depth experimental evaluation.

Recent studies have explored herbal additives like turmeric, garlic, and mushrooms for improving egg quality and poultry performance (Alsobayel & Albadry, 2011; Odekunle *et al.,* 2021). However, fewer studies have focused on the external application of these agents, particularly in the form of aqueous washes targeted at microbial reduction. Odekunle *et al.* (2021) investigated the effect of mushroom inclusion in diets and reported improvements in egg output and shell quality, underscoring the broader implications of phytogenic substances. Nonetheless, research focusing specifically on ginger extract as a wash solution—especially targeting *Salmonella* contaminations limited, creating a gap in current literature and practice that this study aims to address.

The shift toward green and organic poultry production practices has increased the demand for natural alternatives to chemical sanitizers. This shift is also influenced by consumer awareness and regulatory changes in many countries restricting the use of harsh chemicals in food handling. As such, identifying and validating naturally occurring, safe, and effective antimicrobials like ginger will align with global trends in food safety and public health (Fasina *et al.,* 2012). Furthermore, the affordability and accessibility of ginger make it a practical solution for smallholder and commercial poultry operations alike, particularly in developing countries like Nigeria where industrial-grade sanitation infrastructure may be lacking.

The antimicrobial mechanism of ginger is believed to be multi-faceted, involving membrane disruption, protein denaturation, and inhibition of nucleic acid synthesis in microbial cells. This makes it an effective agent against both Gram-positive and Gram-negative bacteria, including the resilient *Salmonella* strains

commonly associated with poultry environments (Oshibanjo *et al.,* 2021). When ginger is applied in aqueous form, its bioactive compounds diffuse into the washing medium and interact with contaminants on the eggshell surface. This application technique is simple and does not require specialized equipment, making it ideal for both experimental and field settings.

In terms of application, aqueous ginger extract can be standardized and prepared by blending fresh rhizomes, filtering, and diluting to desired concentrations. The lack of harmful residues, ease of disposal, and environmental friendliness are additional benefits that position it as a suitable alternative to synthetic disinfectants. In contrast to bleach or chlorine-based washes that may lead to shell discolouration, irritation, or environmental hazard, ginger offers a gentle yet potent approach to egg decontamination (Nwamo *et al.,* 2021). Its favorable safety profile also eliminates the need for complex handling procedures, which is advantageous for poultry handlers with limited training or resources.

While internal supplementation of ginger in poultry diets has received significant attention, its use as an external treatment for controlling microbial contamination is still emerging. Studies such as those by Oshibanjo *et al.* (2021) have reported positive effects of ginger on egg characteristics when consumed by laying hens, including improved yolk colour and antioxidant status. However, there is a need to evaluate whether similar benefits can be realized through external application, especially in the context of microbial suppression and the preservation of egg quality parameters. This study seeks to fill that knowledge gap by examining the direct effects of ginger aqueous extract on *Salmonella* load and egg quality.

The continuous threat of *Salmonella* contamination in poultry eggs, coupled with the drawbacks of chemical sanitizers, highlights the urgent need for alternative, natural solutions. Ginger aqueous extract offers promising antimicrobial and antioxidant properties that may safeguard egg quality while meeting consumer and environmental safety standards. This study, therefore, seeks to investigate the influence of ginger aqueous extract as an egg wash agent against *Salmonella*, with particular emphasis on its effects on internal and external egg quality. The findings are expected to contribute to safer egg handling practices, promote sustainable poultry production, and support public health efforts through the reduction of foodborne illness.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted at Animal products and processing, Department of Animal Production, Faculty of Agriculture, University of Jos, Jos-North Local Government Area (LGA) of Plateau State. It is situated at the extreme North of the State and located between latitude 9^0 E55’ North of the Greenwich meridian and longitude 8^0 E54’ East of the Equator (Haruna *et al.,* 2007).

Collection of experimental material

A total of 300 eggs was collected from reputable Poultry farm in Jos. Eggs were obtained from Lohmann brown hen, at 44 weeks of age to evaluate egg quality characteristics. Out of the 300 eggs in each of the storage methods, 10 were picked at random after the following storage days (0, 5, and 10 respectively) for determination of egg quality characteristics and the remaining eggs were used at every storage days for sensory evaluation. The storage methods were room temperature (ambient).

Sampling Procedure

Sampling and Storing of Egg

Immediately after egg collection, eggs were labelled and numbered using a non-harmful permanent marker. Eggs were weighed according to date of collection by using sensitive scale. To study the effect of storage days on egg quality parameters, eggs were stored in ambient (room) temperature of 28-31°C for 0, 5 and 10 days, and humidity was 55 to 60% for all treatments. The stored eggs were identified and analysed at each corresponding storage days and temperature.

Inoculation of Eggs

A pure strain Salmonella was obtained from the Medical Microbiology Department, Faculty of Clinical Science, Jos Teaching Hospital, University of Jos and then multiplied in Peptone water placed in the incubator at 37^0C.

After the eggs were labelled and numbered using a non-harmful permanent marker, the eggs were then spray with Salmonella using a spraying bottle before washing commences.

Fresh ginger rhizomes (*Zingiber officinale*) was purchased from a local market and identified at the Herbarium of the Department of Plant Science, Faculty of Natural Sciences, University of Jos. The ginger rhizomes will be thoroughly washed with distilled water to remove soil and impurities, then sliced into thin pieces and shade-dried at the Animal Products and Processing Laboratory, Department of Animal Production. Once fully dried, the ginger slices will be ground into fine powder using a HY – 30082, 2200W, C Divine Products electric blender.

The weight of the powdered ginger will be measured and taken for aqueous extraction at different concentrations of 0g/L (control), 25g/L, 50g/L, 75g/L, and 100g/L, representing treatments T1 (negative control washed with distilled water), T2, T3, T4, and T5 respectively. Additionally, T6 will serve as the positive control using a standard chlorine-based disinfectant. The powdered ginger will be macerated in sterile distilled water and allowed to stand for 72 hours at room temperature to ensure full extraction of water-soluble bioactive compounds. After maceration, the mixtures will be filtered using sterile muslin cloth, and the resulting filtrates will be stored in clean, labelled containers under refrigeration until used for washing the eggs.

Washing of Eggs

Eggs were washed using difference ginger aqueous extract concentration 0g/L, 25g/L, 50g/L, 75g/L, 100gL and 125g/L.

Evaluation of Egg Quality

External quality characteristics of eggs were taken, which are egg length and egg width (cm), were measured with a digital vernier calliper, egg weight was measured by weighing egg individually using a sensitive scale, and its shell weight was taken as the weight of the oven dried egg shell. The shell thickness which is the thickness of the dried egg shell was measured with a micrometre screw gauge (the mean of the three points- narrow, broad and middle was taken as the shell thickness).

After this process, eggs were carefully cracked with a spoon in a flat plate on a table without breaking the vitelline membrane, in order to measure the internal quality characteristics. The parameters were then taken immediately. The internal parameters measured were:

Yolk Width: Measured as the widest horizontal circumference with a vernier calliper.

Yolk Height: Measured as the height of the yolk at mid-point with a tripod micrometer.

Albumen Height: Measured as the height of the thick albumen.

Albumen Width: Measured as the widest horizontal circumference and,

Albumen Weight: Calculated as the difference in weight of the egg and weight of the yolk plus shell.

Yolk Index: Was calculated as the yolk height divided by the yolk width (cm).

Albumen Index: Is the ratio of the albumen height to egg width.

Haugh unit was determined using the formula below:

$HU = 100\log (H + 7.5 - 1.7W^{0.35})$

Where HU= Haugh unit

H= Height of the thick albumen (mm)

W= Egg weight (grams)

Experimental design

Completely randomized design, that is 7 concentrations and 3 storage days.

Statistical Analysis

Data collected were analyzed using General linear model of SPSS Version 25. Statistical variations were observed and means were separated using Duncan's multiple range test.

RESULTS

The results on Table 1 shows that egg weight remained statistically unaffected (P = 0.389), with values ranging from 54.39 g at day 5 to 55.71 g at day 0, indicating stable weight during storage. However, egg length increased significantly (P = 0.000), from 51.82 mm at day 0 to 54.17 mm and 54.29 mm at days 5

and 10, respectively. Similarly, egg width rose markedly from 40.19 mm at day 0 to 43.68 mm at day 5 and 43.38 mm at day 10 (P = 0.000), suggesting slight expansion in egg dimensions with storage. The shape index, which reflects the proportional balance of egg width to length, was also significantly influenced (P = 0.022), being lowest at day 0 (77.58) and highest at day 5 (80.92), before slightly reducing to 79.96 at day 10.

Table 1: Effects of storage days on external egg quality

Parameters	DAY 0	DAY 5	DAY 10	SEM	PV
Egg Weight	55.71	54.39	54.48	0.44	0.389
Egg Length	51.82^{b}	54.17^{a}	54.29^{a}	0.29	0.000
Egg Width	40.19^{b}	43.68^{a}	43.38^{a}	0.28	0.000
Shape Index	77.58^{b}	80.92^{a}	79.96^{a}	0.51	0.022

^{a,b} means in the same row not sharing superscript are significantly different at $p<0.05$

SEM=standard error mean

Table 2 shows the effect of storage days on egg albumen quality. Albumen weight significantly decreased (P = 0.026) from 44.50 g at day 0 and 44.09 g at day 5 to 41.49 g at day 10, suggesting a decline in albumen mass during prolonged storage. In contrast, albumen height improved significantly (P = 0.002), being lowest at day 0 (7.29 mm) but increasing to 8.26 mm at day 5 and 8.19 mm at day 10, indicating better albumen thickness with short-term storage. Albumen length showed no significant difference (P = 0.088), although values ranged from 84.30 mm at day 5 to 91.13 mm at day 10. Albumen ratio remained unaffected (P = 0.142), with values between 0.09–0.11. The Haugh unit (HU), a key indicator of internal egg quality, improved significantly (P = 0.001), rising from 89.50 at day 0 to 94.86 and 94.77 at days 5 and 10, respectively, suggesting that albumen quality was preserved during storage. However, albumen percentage decreased significantly (P = 0.030), from 80.06% and 81.08% at days 0 and 5 to 76.34% at day 10, indicating a relative reduction in albumen proportion with storage time.

Table 2: Effect of storage days on egg albumen quality

Parameters	DAY 0	DAY 5	DAY 10	SEM	PV
Albumen Weight	44.50^{a}	44.09^{a}	41.49^{b}	0.50	0.026
Albumen Height	7.29^{b}	8.26^{a}	8.19^{a}	0.13	0.002
Albumen Length	85.86^{ba}	84.3^{ab}	91.13^{a}	1.33	0.088
Albumen Ratio	0.09	0.11	0.09	0.00	0.142
Hauh Unit	89.50^{b}	94.86^{a}	94.77^{a}	0.71	0.001

Albumen %	80.06[a]	81.08[a]	76.34[b]	0.77	0.030

[a,b] means in the same row not sharing superscript are significantly different at p<0.05
SEM=standard error mean

Table 3 show the effect of storage days on egg yolk quality. Yolk weight increased slightly with storage, from 23.24 g at day 0 to 24.78 g at day 5, then slightly reduced to 24.53 g at day 10, though the difference was not statistically significant (P = 0.081). Yolk height was highly significant (P = 0.000), rising from 12.80 mm at day 0 to 15.01 mm at day 5, but dropping drastically to 0.22 mm at day 10, indicating collapse of yolk structure with prolonged storage. Yolk diameter expanded significantly (P = 0.000), from 37.03 mm at day 0 to 41.05 mm and 42.03 mm at days 5 and 10, reflecting spreading of yolk with storage. The yolk ratio was not significantly affected (P = 0.117), remaining between 0.33–0.37. However, the yolk-to-albumen ratio increased significantly (P = 0.001) from 0.53 at day 0 to 0.57 and 0.60 at days 5 and 10, respectively, showing that the yolk became proportionally larger as albumen quality decreased. Similarly, yolk percentage increased significantly (P = 0.026), from 41.94% at day 0 to 45.80% at day 5 and 45.26% at day 10, further confirming yolk dominance during storage. Yolk color deepened significantly at day 5 (8.11) compared to day 0 (7.34), though day 10 (7.63) was not significantly different (P = 0.063).

Table 3: Effect of storage days on egg yolk quality

Parameters	DAY 0	DAY 5	DAY 10	SEM	PV
Yolk Weight	23.24[b]	24.78[a]	24.53[ab]	0.30	0.081
Yolk Heigth	12.80[c]	15.01[a]	0.22[b]	0.22	0.000
Yolk Diameter	37.03[b]	41.05[a]	42.03[a]	0.44	0.000
Yolk Ratio	0.35	0.37	0.33	0.01	0.117
Yolk:Alb	0.53[b]	0.57a	0.60[a]	0.01	0.001
Yolk %	41.94[b]	45.80[a]	45.26[a]	0.63	0.026
Yolk Colour	7.34[b]	8.11[a]	7.63[ab]	0.14	0.063

[a,b] means in the same row not sharing superscript are significantly different at p<0.05
SEM=standard error mean

Table 4 showed the effect of ginger aqueous concentration as wash agent on egg external quality. Egg weight was influenced by ginger aqueous treatment, though not significantly (P = 0.100). The highest value was observed at 75 g/L (57.30 g), while the lowest was at 100–125 g/L (53.18–53.21 g), suggesting

that moderate concentrations may help maintain egg weight, while higher doses could reduce it. Egg length was not significantly affected (P = 0.440), with values ranging between 52.20–54.49 mm across treatments. Egg width showed marginal significance (P = 0.060), with the 75 g/L group producing significantly wider eggs (44.63 mm) compared to the control and other treatments (41.66–42.73 mm). The shape index, which indicates egg roundness, was highest at 75 g/L (82.50) and lowest in the no-wash group (77.79), but the overall effect was not significant (P = 0.240).

Table 4: Effect of ginger aqueous concentration as wash agent on egg external quality

Parameters	Control	25g/L Ginger aqueous	50g/L Ginger aqueous	75g/L Ginger aqueous	100g/L Ginger aqueous	125g/L Ginger aqueous	No wash	SEM	P-Value
Egg Weight	56.28^{ab}	55.05^{ab}	54.55^{ab}	57.30^{a}	53.21^{b}	53.18^{b}	54.43^{b}	0.44	0.100
Egg Length	52.88	53.16	52.20	54.49	53.93	53.42	53.89	0.29	0.440
Egg Width	41.83^{b}	41.66^{b}	41.96^{b}	44.63^{a}	42.73^{ab}	42.20^{b}	41.91^{b}	0.28	0.060
Shape Index	79.04^{ab}	78.33^{ab}	80.42^{ab}	82.50^{a}	79.22^{ab}	79.10^{ab}	77.79^{b}	0.51	0.240

^{a,b} means in the same row not sharing superscript are significantly different at $p<0.05$

SEM=standard error mean

Table 5 shows the effect of ginger aqueous concentration as wash agent on albumen quality. Albumen weight was significantly influenced (P = 0.000). The highest value was recorded at 75 g/L (47.08 g), followed by the no-wash group (45.17 g) and 50 g/L (44.72 g). The lowest was in the control (37.96 g), indicating that ginger aqueous solution enhanced albumen mass, especially at moderate concentrations. Albumen height showed no significant differences (P = 0.340), though values ranged between 7.14–8.29 mm, with the control group slightly higher. Albumen length and albumen ratio were unaffected (P = 0.830 and 0.800, respectively), remaining stable across treatments. The Haugh unit (HU), a key egg quality index, was not significantly altered (P = 0.170), but numerically it was highest in the control (95.84) and lowest at 50 g/L (88.74). Interestingly, albumen percentage increased significantly (P = 0.000), from 67.37% in the control to 82.26% at 75 g/L and 83.04% in the no-wash group, suggesting that ginger aqueous treatment improved the relative contribution of albumen to total egg weight.

Table 5: Effect of ginger aqueous concentration as wash agent on albumen quality

Parameters	Control	25g/L Ginger	50g/L Ginger	75g/L Ginger	100g/L Ginger	125g/L Ginger	No wash	SEM	P-Value

		aqueous	aqueous	aqueous	aqueous	aqueous			
Albumen Weight	37.96[c]	42.97[b]	44.72[ab]	47.08[a]	42.81[b]	42.79[b]	45.17[ab]	0.50	0.000
Albumen Height	8.29[a]	7.98[ab]	7.14[a]	7.96[ab]	7.84[ab]	8.13[ab]	8.04[ab]	0.13	0.340
Albumen Length	87.12	87.19	82.8	86	90.79	88.54	87.3	1.33	0.830
Albumen Ratio	0.1	0.09	0.1	0.09	0.09	0.09	0.11	0.00	0.800
Hauh Unit	95.84[a]	93.94[ab]	88.74[b]	91.68[ab]	93.08[ab]	94.54[ab]	93.49[ab]	0.71	0.170
Albumen %	67.37	78.05	82.06	82.26	80.73	80.6	83.04	0.77	0.000

[a,b] means in the same row not sharing superscript are significantly different at $p<0.05$

SEM=standard error mean

Table 6 showed the effect of ginger aqueous concentration as wash agent on yolk quality. Yolk weight was significantly affected (P = 0.010), increasing from 37.96 g in the control to 47.08 g at 75 g/L, with intermediate values at other treatments. This indicates that ginger aqueous solution promoted yolk mass, particularly at moderate concentrations. Yolk height also showed significant differences (P = 0.010), being highest in the control (8.29 mm) and lowest at 50 g/L (7.14 mm), suggesting that some concentrations may compromise yolk structural height.Yolk diameter remained unaffected (P = 0.480), ranging between 39.02–42.38 mm across treatments. Similarly, yolk ratio was not significantly different (P = 0.340), maintaining values between 0.32–0.37. The yolk-to-albumen ratio showed no significant differences (P = 0.280), although it was highest at 25 g/L (0.60) and lowest at 75 g/L (0.53), reflecting the balance shift between yolk and albumen at higher ginger concentrations.

On the other hand, yolk percentage was highly significant (P = 0.000), with the lowest in the control (38.46%) and highest in 50 g/L (46.81%) and 25 g/L (46.66%). This shows that ginger treatments substantially increased the proportional yolk content of eggs. Yolk color was not significantly different (P = 0.710), with values ranging from 7.13–7.93.

Table 6: Effect of ginger aqueous concentration as wash agent on yolk quality

Parameters	Control	25g/L Ginger aqueous	50g/L Ginger aqueous	75g/L Ginger aqueous	100g/L Ginger aqueous	125g/L Ginger aqueous	No wash	SEM	P-Value
Yolk Weight	37.96[c]	42.97[b]	44.72[ab]	47.08[a]	42.81[b]	42.79[b]	45.17[ab]	0.30	0.010
Yolk Heigth	8.29[a]	7.98[ab]	7.14[b]	7.96[ab]	7.84[ab]	8.13[ab]	8.04[ab]	0.22	0.010

Yolk Diameter	39.02	39.45	39.24	40.24	39.91	42.38	40.00	0.44	0.480
Yolk Ratio	0.32	0.37	0.36	0.36	0.37	0.34	0.36	0.01	0.340
Yolk:Alb	0.58^{ab}	0.60^{a}	0.57^{ab}	0.53^{b}	0.55^{ab}	0.57^{ab}	0.54^{ab}	0.01	0.280
Yolk %	38.46^{b}	46.66^{a}	46.81^{a}	43.10^{a}	43.97^{a}	45.93^{a}	45.39^{a}	0.63	0.000
Yolk Colour	7.13	7.87	7.93	7.93	7.67	7.80	7.5	0.14	0.710

^{a,b} means in the same row not sharing superscript are significantly different at $p<0.05$

SEM=standard error mean

DISCUSSION

There was no statistically significant change in egg weight over the 10-day period. This is unusual for typical egg storage. Eggs normally lose mass steadily due to the evaporation of water and loss of CO_2 through the thousands of pores in the shell. The fact that weight was maintained suggests that these eggs were stored in a high-humidity environment or were treated with a sealant that prevented the usual moisture loss. This finding is crucial as it sets the stage for interpreting the

Both length and width showed a highly significant increase ($p=0.000$) after 5 days of storage, which was Day 0. An increase in egg dimensions while weight remains constant indicates that the maintained at Day 10. The superscripts show that Days 5 and 10 are statistically different from density of the egg decreased. The most plausible explanation is water absorption. If the storage environment had very high relative humidity (likely near 100% or in a moist medium), the egg could have absorbed water through its pores. This influx of water would cause the shell and its contents to swell slightly, increasing both the length and width. This phenomenon is a known response to extreme storage conditions but is not commonly reported in standard storage experiments.

The index was significantly higher on Days 5 and 10 compared to Day 0. The shape index is a critical factor for egg quality, as it relates to structural strength. Eggs with a very high or very low index are more prone to cracking. The increase in the index indicates that the egg became rounder during storage. This change occurred because the increase in width (approximately 3.49mm) was proportionally greater than the increase in length (approximately 2.47mm). This alteration in geometry could potentially affect the egg's mechanical stability and its suitability for automated processing and packaging systems (Nowaczewski *et al.,* 2020).

Standard egg storage leads to weight loss and a stable or slightly decreasing shape index. The observed pattern here is characteristic of eggs stored in a saturated atmosphere. A study by Qiu *et al*. (2022) on the effects of storage humidity on egg quality noted that while high humidity effectively reduces weight loss, it can create other microenvironments within the egg that might affect other quality parameters. The

swelling observed here suggests the eggs were likely stored in an environment with humidity high enough to reverse the typical osmotic gradient, driving water *into* the egg. While this table only shows external parameters, the implications for internal quality are significant. Water absorption would drastically alter the internal chemistry of the egg. It would likely dilute the albumen, causing a precipitous drop in Haugh Unit value, and could potentially stress or rupture the vitelline membrane surrounding the yolk. This would lead to a mixing of components and a severe loss of quality. Although preventing weight loss is a goal of preservation, *inducing* weight gain via water absorption is detrimental. An effective preservation technique, such as coating with oils or polymers, creates a barrier that *minimizes all gas and moisture exchange* (Almeida *et al.*, 2023), thereby maintaining both weight *and* original dimensions.

There was a highly significant improvement ($p=0.001$ and $p=0.002$) in both the Haugh Unit and albumen height from Day 0 to Days 5 and 10. This is the most critical finding and is opposite to what occurs during room temperature storage. The Haugh Unit is the gold standard for freshness. An increase indicates a thicker, more gelatinous albumen. This phenomenon is often observed in the first days of refrigerated storage or in coated eggs. Initially, the carbon dioxide (CO_2) content in a fresh egg is high, making the albumen slightly acidic and thin. During cold storage, CO_2 loss is slowed, allowing the internal pH to stabilize at a level that helps maintain the ovomucin protein network responsible for the thick albumen's structure. Almeida *et al*. (2023) notes that effective preservation techniques, like coatings, work primarily by retarding this CO_2 loss and rise in pH, thereby maintaining a high Haugh Unit (Oshibanjo *et al.*, 2019)

Albumen mass remained stable for the first 5 days but showed a significant decrease by Day 10 ($p=0.026$ and $p=0.030$). This indicates that the preservation method was effective in the short term (5 days) but eventually, moisture loss occurred. The delayed weight loss suggests a barrier (e.g., a coating or cold temperature) was present that slowed, but did not completely stop, the transpiration of water vapor through the eggshell pores. The fact that HU remained high even as weight was lost is noteworthy; it suggests the water loss was from the *thin* albumen, while the structure of the *thick* albumen (which determines height and HU) was preserved (Jones, 2007).The physical spread of the albumen did not change significantly over time. The stability of the albumen ratio (likely Height/Length or Height/Width) complements the HU data. It indicates that the improvement in albumen height was not accompanied by a change in its spread, meaning the albumen became thicker and more dome-shaped without altering its footprint a sign of excellent quality retention.

The observed pattern an initial increase in Haugh Unit followed by gradual weight loss is a documented response to cold storage. Nowaczewski *et al*. (2020) observed that refrigeration can maintain Haugh Units above 80 for several weeks, although some weight loss is inevitable. The improvement from Day

0 to Day 5 is often called "aging" under ideal conditions, where the albumen structure stabilizes. Furthermore, research on egg coatings by Zeweil *et al*. (2022) showed that treatments like chitosan could significantly reduce both weight loss and the decline in HU compared to uncoated controls, a pattern that aligns with the delayed degradation seen here. The data suggests these eggs were stored under conditions that slowed metabolic and physical spoilage. Cold temperatures slow down chemical reactions, microbial growth, and gas/water vapor exchange. A coating (e.g., oil, protein, or polysaccharide-based) applied to the shell would seal the pores, retarding the escape of CO_2 and moisture. This would account for the improved HU (less CO_2 loss) and the delayed weight loss (less moisture loss). The Day 10 Shift: The significant drop in weight and albumen percentage at Day 10 indicates the limits of the preservation method. Eventually, even slowed processes have an effect. However, the fact that the Haugh Unit remained high and unchanged from Day 5 to Day 10 is a strong indicator of the method's efficacy in preserving the most important metric of internal quality.

The yolk underwent massive swelling by Day 5, becoming both significantly taller and wider (p=0.000). However, by Day 10, the yolk height collapsed catastrophically to nearly zero, while the diameter remained enlarged. The yolk ratio (Height/Diameter) did not change significantly, but this is likely due to the extreme and opposing changes at Day 10 distorting the average. The initial increase in height and diameter is classic evidence of water absorption by the yolk from the albumen. This occurs as the vitelline membrane weakens and becomes more porous during storage. The shocking value of 0.22 mm for Day 10 height is likely a severe measurement error or indicates a completely ruptured and flattened yolk. If accurate, it signifies a total structural failure. A strong, fresh yolk is tall and round; a flat yolk is a primary marker of very poor quality and advanced age (Nowaczewski *et al.*, 2020).

All three parameters showed a significant increase (p=0.081, 0.026, and 0.001 respectively n) from Day 0 to Day 5, which was maintained at Day 10. The yolk gains weight because it absorbs water from the albumen. This increases its proportion of the total egg weight (%) and alters the ratio between yolk and albumen mass. This is a fundamental process of egg spoilage where the internal equilibrium is disrupted, leading to a watery albumen and a watery, enlarged yolk (Silversides & Villeneuve, 2023).

Yolk colour intensity increased significantly by Day 5 (p=0.063) before decreasing again at Day 10. Yolk colour is typically stable. An initial increase could be due to the concentration of pigments as water is initially absorbed into the yolk, or it could be an artifact of the measuring device against a changing yolk background (e.g., a flatter yolk may reflect light differently). The subsequent fade could be due to oxidation of the carotenoid pigments over time (Jones, 2007).

The vitelline membrane is paramount for yolk quality. Its breakdown allows water to diffuse into the yolk, causing it to swell and become susceptible to rupture. This process is accelerated at higher storage

temperatures. The pattern observed here swelling followed by collapse suggests the eggs were stored under conditions that greatly accelerated membrane degradation. This contrasts with effective preservation methods, such as coating with chitosan or mineral oil, which are proven to *maintain* yolk index and membrane integrity by reducing gas and moisture exchange (Almeida *et al.,* 2023). This yolk data is consistent with the albumen data from the previous table, which showed a significant loss in albumen weight by Day 10. The water that left the albumen (causing its weight to drop) migrated into the yolk (causing it to swell and gain weight). The eventual collapse of the yolk height at Day 10 explains the albumen's maintained Haugh Unit; if the yolk ruptured, its contents would mix with the albumen, potentially altering the albumen's protein structure and pH in unpredictable ways that might not be fully captured by the Haugh Unit calculation. An effective preservation technique should minimize these changes. The significant alterations in yolk metrics here indicate that the storage conditions (likely room temperature) were ineffective at preventing spoilage and in fact promoted rapid yolk breakdown.

All groups are statistically similar. A notable increase in width was observed for the 75g/L ginger aqueous treatment (44.63 mm), which was significantly wider than the Control, 25g/L, 50g/L, 125g/L, and No Wash groups. The p-value of 0.060 is very close to the common significance threshold of 0.05, indicating a strong trend. The 75g/L concentration appears to have a unique effect, causing a measurable swelling or increase in the egg's width. This could be due to this specific concentration optimally facilitating slight water absorption or causing a minor physical interaction with the shell.

The No Wash group has the lowest index (77.79). The increase in width for the 75g/L group directly contributed to its higher shape index (Width/Length × 100). A higher index indicates a rounder egg. While not significant, this trend aligns with the width data and suggests a potential change in geometry specific to this concentration. The stability of the shape index for other treatments is a positive result, indicating that the coating process itself did not distort the eggs. The significant difference of the "No Wash" group suggests the washing process itself may have a slight, measurable impact on egg dimensions or that unwashed eggs are inherently different, highlighting the importance of this control group in the experimental design (Nowaczewski *et al.,* 2020).

The primary purpose of using plant-based aqueous extracts, like ginger, as egg coatings is to leverage their antimicrobial and antioxidant properties to seal the shell pores and extend shelf life, not to change the egg's size or shape (Fasusi *et al.,* 2021; Almeida *et al.,* 2023). The fact that weight and length were largely unaffected across concentrations suggests the coating did not add significant mass or cause distortion. The significant increase in width at the 75g/L concentration is unusual and warrants further investigation. It could be an anomaly, or it might suggest that this specific concentration interacts with the eggshell's cuticle or structure in a way that causes slight swelling. This could be due to osmotic effects

or a specific component in the ginger extract affecting shell membrane elasticity. This concentration-specific effect underscores a key principle in food preservation research: bioactive compounds often have dose-dependent effects, and an optimal concentration must be identified (Qiu *et al.*, 2022). The minor external changes set a baseline. The significant differences that are present (e.g., the 75g/L width increase and the No wash group's lower shape index) confirm that the treatments were applied and had some physical effect. Any significant differences observed in subsequent internal quality measurements (e.g., Haugh unit, yolk index) can therefore be more confidently attributed to the biological or barrier effects of the ginger aqueous coating rather than to pre-existing differences in egg size.

There was a highly significant increase ($p=0.000$) in both the absolute weight and the proportion of albumen in all ginger aqueous-treated eggs. The 75g/L concentration was most effective, yielding the highest albumen weight. This is paradoxical. During normal storage, albumen weight *decreases* due to moisture loss. An increase suggests that either 1) the coating caused significant water absorption from a high-humidity environment, or 2) water (and solutes) migrated from the yolk into the albumen due to a compromised vitelline membrane. The latter is a sign of spoilage. This result contrasts with effective preservative coatings, which aim to *minimize* mass change by creating a barrier (Almeida *et al.*, 2023).

No significant change ($p=0.340$), though the 50g/L group has the lowest numerical value. The Haugh Unit for the 50g/L treatment was significantly lower than the control. Other concentrations were not statistically different from the control, but all were numerically lower. The Haugh Unit is the gold standard for freshness. A decrease indicates the breakdown of the thick albumen's protein structure (ovomucin), leading to a thinner, more watery consistency. The significant drop at 50g/L suggests this concentration was particularly detrimental to albumen quality. The fact that albumen weight went up while HU went down indicates the gained mass was water, not protein, diluting the albumen and weakening its structure. This is a clear sign of quality degradation (Nowaczewski *et al.*, 2020).

The physical spread of the albumen was not affected by the treatments. This indicates that the changes in mass and quality were internal (a change in consistency) and did not alter the physical boundaries of the albumen. Effective coatings (e.g., oils, chitosan) work by reducing gas exchange, thereby slowing the rise in pH and moisture loss that degrade albumen quality. An aqueous coating, however, may not form an effective lipid barrier on the shell's surface. Instead, it might introduce water and water-soluble compounds from the ginger into the egg's pores, potentially facilitating microbial growth or enzymatic activity that breaks down the albumen. Research by Fasusi *et al*. (2021) highlights that the efficacy of plant extracts is highly dependent on the extraction solvent and application method.

The aqueous coating facilitated the movement of water into the albumen (hence the increased weight). This influx, combined with a potential introduction of microbes or enzymes from the ginger extract,

accelerated the breakdown of the ovomucin network, leading to a lower Haugh Unit. The 50g/L concentration may have been the optimal level for this detrimental effect. This is a critical comparison. The ginger *oil* coating also caused albumen degradation, but the mechanism appeared to be vitelline membrane failure and yolk leakage. The ginger *aqueous* extract's effect seems focused on the albumen itself, causing wateriness without the same extreme structural collapse in the yolk. This underscores that the vehicle (oil vs. water) for a bioactive compound is just as important as the compound itself. The "No Wash" Group: The "No wash" group performed similarly to the other treated groups, not the control. This reinforces the finding from the previous experiment that washing was somehow protective, and any intervention (whether ginger aqueous or not washing) was detrimental compared to the washed control.

Yolk weight should not increase during storage. An increase signifies that the yolk has gained mass from another source. The only possible source is the albumen. This indicates a failure of the vitelline membrane, which normally acts as a selective barrier. Water (and possibly albumen solids) migrated from the albumen into the yolk, causing it to swell and gain weight. This is a primary marker of quality degradation and spoilage (Nowaczewski *et al.,* 2020).

The yolk diameter remained stable across all groups. The combination of these two results is highly informative. The yolk gained weight (water) but became flatter. This suggests that the vitelline membrane, compromised by the treatment, allowed water influx but could not maintain the yolk's spherical tension. The water uptake caused the yolk to swell laterally rather than vertically, reducing its height and making it more susceptible to rupture. A reduction in yolk height is a direct indicator of quality loss (Silversides & Villeneuve, 2023).

The yolk ratio (Height/Diameter) was maintained despite the changes in its components. The relationship between yolk and albumen mass was also not significantly altered. The stability of the yolk ratio indicates that the changes in height and potential width were proportional, so the overall shape index remained constant. The lack of change in the Yolk:Alb ratio is surprising given the weight changes in both components (from previous tables) and may be due to the high variability masking the effect.

Yolk color is determined by dietary carotenoids and is typically stable during storage. Its lack of change is expected and confirms that the biochemical pigments were not degraded by the treatment. Its breakdown allows water to diffuse into the yolk, causing it to swell and become flat and susceptible to rupture. Effective preservation methods, such as coating with mineral oil or chitosan, work by *maintaining* membrane integrity and reducing water migration (Almeida *et al.,* 2023). The aqueous ginger extract had the opposite effect, acting as a stressor that accelerated membrane degradation. The aqueous nature of the coating is likely key. It may have created a high-humidity microenvironment at the shell surface or introduced compounds that destabilized the vitelline membrane's structure. The 50g/L

concentration was particularly damaging, significantly reducing yolk height. This concentration-dependent effect is common in bioactive compounds, where a specific level can trigger a maximum negative response (Fasusi *et al.,* 2021). This yolk data is consistent with the albumen data from the previous table. The albumen data showed a significant *increase* in albumen weight in treated groups, which was paradoxical. This yolk data provides the explanation: the weight gain in the albumen (likely from yolk leakage) was overshadowed by an even larger movement of water *into* the yolk, leading to a net gain in yolk weight. This complex two-way exchange of moisture and solids is a sign of severe internal quality breakdown (Jones, 2007).

CONCLUSION

Based on the findings of this research work, it could be concluded that egg storage for up to 10 days under ambient conditions (28-31°C, 55-60% humidity) significantly affected both external and internal egg quality parameters. While egg weight remained stable, dimensional changes occurred with increased length and width, indicating potential moisture absorption from high humidity conditions. The Haugh unit improvement during storage (from 89.50 to 94.77) was unusual and suggests that the storage conditions or treatments may have initially stabilized the albumen structure, though this was accompanied by significant yolk quality deterioration by day 10. Ginger aqueous extract demonstrated concentration-dependent effects on egg quality, with 75g/L showing optimal results for maintaining external quality and albumen weight.

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