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Effect of Eggshell Sealing Methods on Embryonic Mortality And Hatchability In Cracked Broiler Eggs

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ABSTRACT
Eggshell cracking remains a major challenge in broiler hatchery operations due to its adverse effects on embryonic mortality and hatchability. This study evaluated the effectiveness of different eggshell sealing methods on embryonic mortality and hatchability of cracked broiler eggs. A total of 480 fertile broiler breeder eggs obtained from the National Animal Production Research Institute were used. The eggs were sourced from breeder hens aged 32 weeks and randomly assigned to four treatment groups: uncracked eggs (control), cracked eggs sealed with masking tape, nail cortex, and cellophane tape. Each treatment consisted of 120 eggs with five replicates of 24 eggs each in a completely randomized design. Eggs were incubated under standard conditions, and embryonic mortality and hatchability were determined. The results revealed significant differences ($P < 0.05$) among treatments. Embryonic mortality was lowest in the uncracked control and eggs sealed with cellophane tape, while masking tape recorded the highest mortality. Eggs sealed with nail cortex showed intermediate mortality. Similarly, hatchability was highest in the control and cellophane treated groups, moderate in nail cortex, and lowest in masking tape treated eggs. The superior performance of cellophane tape suggests its effectiveness in restoring eggshell integrity, maintaining moisture balance, and allowing adequate gaseous exchange necessary for embryonic development. In contrast, masking tape negatively affected embryo mortality, likely due to restriction of shell pore function and increased susceptibility to contamination. These findings suggest that cellophane tape is a practical and effective method for salvaging cracked broiler eggs, minimizing losses, and improving hatchery efficiency.

Keywords: Cracked Eggs, Embryonic Mortality, Hatchability, Eggshell Sealing, Broiler Chickens

INTRODUCTION

In recent years, the global demand for poultry products, particularly broiler chickens, has increased obviously due to population growth, rising incomes, and changing dietary preferences. This trend is especially evident in African countries, including Nigeria, where poultry production has expanded rapidly and contributes significantly to food security and economic development (FAO, 2015; 2018; 2021). Despite this growth, the broiler breeding industry continues to face several production constraints, among which eggshell damage, particularly cracked eggs, remains a major challenge. Cracked eggshells present serious concerns in broiler production systems, as they adversely affect hatchability, embryonic survival, chick quality, and overall hatchery efficiency. Such eggs are highly susceptible to excessive moisture loss and microbial contamination, which increase the risk of embryonic mortality and reduce hatchery success (Tullett 2009). Consequently, most commercial hatcheries discard cracked eggs to minimize losses, resulting in significant economic waste. Eggshell damage can occur at multiple stages, including oviposition, egg collection, storage, transportation, and handling within hatcheries (Nazareno et al., 2013; Pilotto et al., 2015). It has been reported that up to 2% of hatching eggs are rejected due to shell cracks or breakages (Butcher and Nilipour, 2005).

The eggshell plays a critical role in protecting the developing embryo against microbial invasion, dehydration, and physical injury. When the shell is compromised, these protective functions are reduced, exposing the embryo to environmental stress and infection. This often results in increased embryonic mortality in cracked eggs (Jassim et al., 1996; Solomon, 2010; Yamak et al., 2015). Embryonic mortality, defined as the death of the embryo before hatching, is therefore a key limitation in the successful utilization of cracked eggs.

Hatchability, which represents the proportion of eggs that successfully hatch into viable chicks, is directly influenced by embryonic survival. Increased embryonic mortality in cracked eggs leads to a significant decline in hatchability. In addition, hatchability is affected by factors such as egg quality, incubation conditions, breeder flock management, and handling practices (Wilson, 1991; Arora and Sandhu, 2021). Physical defects, particularly hairline cracks that are often difficult to detect, can further impair hatchability by disrupting gas exchange and increasing the risk of dehydration and contamination (Reijrink et al., 2008). The increasing prevalence of cracked eggs in broiler breeder operations has prompted research into sealing techniques for their salvage. Materials such as adhesive resins, paraffin wax, and nail varnish have been used with varying degrees of success. These methods have been reported to reduce moisture loss, limit microbial contamination, and improve hatchability of cracked eggs (Narahari et al., 2000; Simsek and Gurses, 2009; Gholami et al., 2018). However, most of these studies have been conducted under controlled experimental conditions, with limited attention to locally available materials and practical applications in developing poultry production systems.

In many poultry production systems, particularly in Nigeria, cracked eggs are routinely discarded due to concerns about poor hatchability and increased embryonic mortality. Although some poultry farmers attempt to salvage such eggs using locally available sealing materials, there is limited empirical evidence on the effectiveness of these techniques under local conditions. Therefore, this study aims to evaluate the effect of different eggshell sealing methods on embryonic mortality and hatchability in cracked broiler eggs.

MATERIALS AND METHODS

Experimental Site

The study was conducted at the Teaching and Research Farm, College of Animal Science, Joseph Sarwuan Tarka University (JOSTUM), Makurdi, Benue State, Nigeria (approximately 7°44′ N, 8°32′ E). The area experiences a tropical wet and dry climate, characterized by a distinct rainy season from April to October and a dry season from November to March. Mean ambient temperatures generally range from the high 20s to upper 30s °C throughout the year, with cooler conditions during the rainy season and peak heat in March. Relative humidity increases noticeably during the rainy months, often exceeding 80%, while lower values are recorded in the dry season. Annual rainfall is concentrated in the wet season, particularly between May and September, consistent with the Guinea Savannah climatic zone. These climatic conditions are typical of the region and provide a suitable environment for broiler egg incubation studies (Weather Atlas, 2026).

Egg Collection and Experimental Design

A total of 480 fertile broiler breeder eggs were obtained from the National Animal Production Research Institute (NAPRI), Zaria. The eggs were sourced from breeder hens aged 32 weeks. The eggs were initially sorted into uncracked (n = 120) and cracked (n = 360) categories. Hairline cracks were artificially induced on selected eggs to simulate natural cracking conditions (Perić et al., 2023). The experiment was arranged in a Completely Randomized Design (CRD). Eggs were randomly assigned to four treatment groups: uncracked eggs (control), cracked eggs sealed with masking tape, cracked eggs sealed with nail cortex, and cracked eggs sealed with cellophane tape. Each treatment consisted of 120 eggs and was replicated five times, with 24 eggs per replicate. Randomization was carried out to ensure uniform distribution of experimental units and to minimize potential bias across treatments.

Egg Sealing and Handling Procedure

Prior to sealing, cracked eggs were disinfected using 70% ethanol to reduce microbial contamination. Masking tape was cut to appropriate size and applied to completely cover the cracked area. Nail cortex was carefully applied directly to the crack and allowed to air-dry before incubation, while cellophane tape was used to provide an airtight seal over the damaged region. All eggs were properly labelled according to treatment and replicate, and were randomly arranged in incubator trays to eliminate positional effects within the incubator. Masking tape, nail cortex, and cellophane tape were applied to seal the cracked regions as described above (Figure 1).

Figure 1: Eggshell Sealing Techniques Applied to Cracked Broiler Eggs (a) Masking Tape (b) Nail Cortex, and (c) Cellophane Tape

Incubation Procedure

Incubation was carried out in a single forced-draft automatic incubator and hatcher with capacity of 1000 eggs maintained at a temperature of 37.5°C and relative humidity of 55–60% for the first 18 days. Eggs were automatically turned at regular intervals throughout this period to ensure proper embryonic development. On day 18 of incubation, egg turning was discontinued and the eggs were transferred to the hatching compartment. Relative humidity was subsequently increased to 65–70% until hatching on day 21.

Determination of Embryonic Mortality and Hatchability

Embryonic development was monitored through candling on days 7, 14, and 18 of incubation. Eggs showing no evidence of development or containing dead embryos were identified and recorded accordingly. At the end of incubation (day 21), all unhatched eggs were carefully broken out to determine embryonic mortality. Although embryonic mortality was initially categorized into early (0 –7 days), mid (8 – 14 days), and late (15 – 21 days) stages based on the period of embryonic death, only total embryonic mortality was used for analysis due to incomplete stage specific records.

Hatchability was determined at the end of the incubation period as the proportion of hatched chicks relative to the total number of fertile eggs. Both embryonic mortality and hatchability were expressed as percentages and calculated using standard formulae (Equations 1 and 2). Embryonic mortality rate was computed as the proportion of dead embryos relative to the total number of fertile eggs set (McDaniel et al., 1979; Fathi et al., 2022), while hatchability was calculated as the proportion of hatched chicks relative to the total number of fertile eggs (King'ori, 2011).

i. $Embryonic\ mortality\ rate\ (\%) = \frac{\text{Number of dead embryos at each stage}}{Total\ number\ of\ fertile\ eggs} \times 100$

ii. $Hatchability\ (\%) = \frac{\text{Number of chicks hatched}}{Number\ of\ fertile\ eggs} \times 100$

Statistical Analysis

All data were analysed using R statistical software (R Core Team, 2015). Prior to analysis, the assumptions of normality and homogeneity of variance were evaluated using the Shapiro–Wilk test and Levene's test, respectively. A one-way analysis of variance (ANOVA) was employed to assess the effect of treatment on the measured variables. Where

significant differences were detected, means were separated using Tukey's honest significant difference test. Statistical significance was declared at $P < 0.05$.

The statistical model used for the analysis was:

$Y_{ij} = \mu + A_i + e_{ij}$

where Y_{ij} is the observation on the j^{th} replicate under the i^{th} treatment; μ is the overall mean; A_i is the fixed effect of the i^{th} treatment (uncracked eggs, masking tape, nail cortex, and cellophane tape); e_{ij} is the random error term associated with each observation, assumed to be independently and normally distributed with mean zero and constant variance $(0, \sigma^2)$.

RESULTS AND DISCUSSION

Total Embryonic Mortality of Broiler Eggs Subjected to Different Sealing Techniques

The effect of eggshell sealing methods on total embryonic mortality of cracked broiler eggs is shown in Table 1. Significant differences ($P < 0.05$) were observed among treatment groups, indicating that sealing technique influenced embryo mortality during incubation. The uncracked control eggs recorded the lowest embryonic mortality, consistent with expected values in well-managed incubation systems (Al Nasser et al., 2020).

Table 1: Effect of Eggshell Sealing Methods on Total Embryonic Mortality of Broiler Eggs

Treatment	Embryonic Mortality (%)	SD
Uncracked eggs	7.85^{a}	1.12
Masking tape	14.87^{c}	2.03
Nail cortex	11.25^{b}	1.54
Cellophane tape	8.11^{a}	1.31

(Means with Different Superscripts Differ Significantly at $P < 0.05$)

Among the sealed treatments, eggs sealed with cellophane tape exhibited the lowest embryonic mortality, statistically comparable to the uncracked control. This indicates that cellophane tape effectively maintained eggshell integrity following cracking, supporting an optimal balance between moisture retention and gas exchange. Recent studies highlight that thin, flexible sealing materials reduce excessive water loss and microbial penetration while maintaining shell conductance (Neto et al., 2024; Li et al., 2021; Masia et al., 2025). Eggs sealed with nail cortex showed intermediate embryonic mortality, significantly higher than cellophane tape but lower than masking tape. This suggests partial effectiveness, likely due to non-uniform coverage that can disrupt moisture regulation and gaseous exchange. Similar observations have been reported for natural sealing materials, where inconsistent application increases embryo susceptibility to dehydration (Afolayan and Abiola, 2010; Kumar et al., 2023). The highest embryonic mortality was observed in eggs sealed with masking tape, indicating that this method is unsuitable for sealing cracked eggs. Masking tape may restrict shell pores, reduce oxygen availability and increase carbon dioxide accumulation, critical factors for embryonic respiration (Deeming, 2001). Additionally, its adhesive properties may deteriorate under high humidity, facilitating microbial invasion at the crack site (Li et al., 2021).

Hatchability of Broiler Eggs Subjected to Different Sealing Techniques

Hatchability results are presented in Figure 2. The highest hatchability was observed in the uncracked control and in eggs sealed with cellophane tape, whereas eggs treated with masking tape had the lowest hatchability. Nail cortex sealed eggs exhibited intermediate hatchability. The high hatchability in uncracked eggs reflects optimal incubation conditions, confirming the suitability of the experimental environment (Masia et al., 2025). The comparable hatchability between the uncracked control and cellophane treated eggs demonstrates that cellophane tape can effectively restore eggshell functionality post cracking. By minimizing excessive water loss and permitting adequate gas exchange, cellophane supports normal embryonic development (Khabisi et al., 2012; Wesam et al., 2017). Eggshell structures, particularly the cuticle and palisade layers, are essential for regulating permeability and preventing microbial invasion (Onagbesan et al., 2007; Li et al., 2021; Rayan et al., 2023). Cracks compromise these functions, but appropriate sealing can partially restore them. Maintaining balanced gas conductance is critical for oxygen diffusion and carbon dioxide elimination during embryogenesis (Ar and Bettaieb, 2012; Al Nasser et al., 2020).

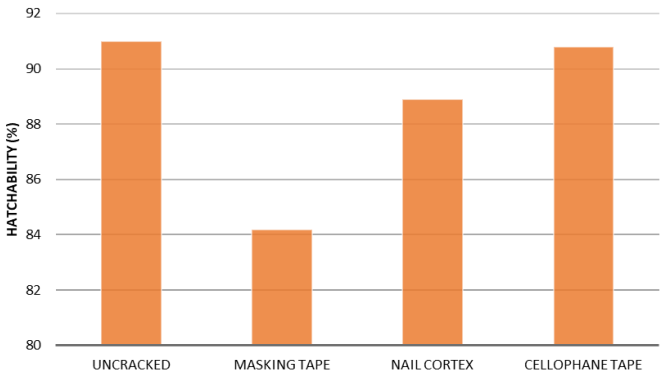

Figure 2: Hatchability of Broiler Eggs Subjected to Different Eggshell Sealing Techniques

The slightly lower hatchability observed in nail cortex sealed eggs may be due to partial restriction of gas exchange or non-uniform coverage across the shell. Recent studies indicate that variations in sealing thickness and material properties can influence hatch outcomes by affecting shell conductivity and embryonic microenvironment (Kumar et al., 2025). Microbial

invasion through cracks further reduces hatchability if not adequately mitigated (Li et al., 2021). The reduced hatchability in masking tape treated eggs aligns with their higher embryonic mortality, emphasizing the importance of selecting sealing materials that maintain moisture balance and shell permeability. These findings corroborate current understanding that hatchability is influenced by eggshell integrity, environmental conditions, and microbial control (Romanoff and Romanoff, 1949; Li et al., 2021).

CONCLUSION

Eggshell sealing materials significantly influence embryonic mortality and hatchability in cracked broiler eggs. Cellophane tape effectively maintained shell integrity, optimized moisture retention and gas exchange, and resulted in embryonic mortality and hatchability comparable to uncracked eggs. Nail cortex offered partial protection, producing intermediate results, while masking tape was unsuitable, leading to higher embryonic mortality and lower hatchability. These results highlight the importance of selecting appropriate sealing materials to salvage cracked eggs. The use of cellophane tape provides a practical, cost-effective solution to reduce losses and enhance hatchery efficiency in broiler production systems.

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