Research Article

Effect of Breed and Age on Internal and External Egg Quality Traits of Indigenous and Commercial Chickens: A Systematic Review

Prudence Shibe Mokgapa, Thobela Louis Tyasi*, Joseph Thinawanga Mugwabana

School of Agricultural and Environmental Sciences, Department of Agricultural Economics and Animal Production, University of Limpopo, Private Bag X1106, Sovenga 0727, Limpopo, South Africa.

Abstract | The objective of this study was to systematically review articles that studied the influence of breed and age on egg quality characteristics of chickens. Articles were searched on databases such as ScienceDirect, PubMed, Google Scholar, and Web of Science using breed, genotype, strain, age, 'egg quality traits', 'egg quality characteristics', 'egg quality parameters', chickens, hens, and '*Gallus gallus domesticus*' as keywords. Twenty-six articles included in the systematic review were published from the year 2000 to 2023. The results showed that 19 out of 26 articles studied the effect of breed on egg quality characteristics and found that breed had an effect on internal and external egg quality traits. Commercial and indigenous chicken breeds such as the Isa Brown, Hisex Brown, Hy-line Brown, Isa White, Hy-line white, Kuroiler, Moravia BSL, Tetra SL, Abor Acre, Dominant Brown, Rhode Island Red, Oravka, Amarela, Pedres, Preta, Ermellinata of Rovigo, and Robusta maculata chickens showed better performance in egg quality traits such as the egg weight, albumen height, egg length, haugh unit, egg width, yolk weight, eggshell weight, egg shape index and eggshell colour. The results further indicated that 19 other articles studied the influence of age on egg quality characteristics and found that most of the egg quality traits improved with an increase in age and were optimum above 40 weeks of age. However, eggshell quality decreased as age increased. This systematic review concludes that breed and age significantly influence egg quality characteristics and may be effectively utilised to improve overall egg production and quality.

Keywords | Chicken breed, Hen age, Egg quality, Egg weight, Eggshell thickness, Systematic review

Received | May 19, 2025; **Accepted** | August 13, 2025; **Published** | October 24, 2025
***Correspondence** | Thobela Louis Tyasi, School of Agricultural and Environmental Sciences, Department of Agricultural Economics and Animal Production, University of Limpopo, Private Bag X1106, Sovenga 0727, Limpopo, South Africa; **Email:** louis.tyasi@ul.ac.za
Citation |Mokgapa PS, Tyasi TL, Mugwabana JT (2025). Effect of breed and age on internal and external egg quality traits of indigenous and commercial chickens: A systematic review. J. Anim. Health Prod. 13(4): 1081-1094.
DOI | https://dx.doi.org/10.17582/journal.jahp/2025/13.4.1081.1094
ISSN (Online) | 2308-2801

INTRODUCTION

The poultry sector is a key source of animal protein, providing meat and eggs that contribute to national food security. Poultry eggs are regarded as the most affordable and widely accepted animal products (Dudusola *et al*., 2020; Kurniawan *et al*., 2025). Egg quality characteristics, both internal and external, are important to the global egg industry (Aminami *et al*., 2022). Breed and age are one of the key factors affecting shell colour and other egg quality characteristics (Kraus and Zita, 2019). Poor egg quality characteristics have a major economic impact on commercial egg farmers (Petričević *et al*., 2017). Therefore, understanding these traits and the factors that influence them is important (Guni *et al*., 2021). Consumers prefer better quality eggs, so evaluating internal and external egg quality traits is essential (Rajkumar *et al*., 2009; Sudrajat *et al*., 2024). Indigenous chicken breeds and their products have received little research attention (Lordelo *et al*., 2020). While some work has been done, there is a shortage of comprehensive research on the egg quality characteristics of these indigenous chicken breeds, limiting the ability to fully

understand and improve their production potential. To the best of the authors' knowledge, there is no systematic review on the effect of breed and age on egg quality characteristics of chickens. A search was conducted using breed, age, egg quality traits and also chickens as keywords, and there was no systematic review found on this topic. Therefore, the objective of this study was to conduct a systematic review of articles that investigated the effect of breed and age on egg quality characteristics of chickens. The findings of this systematic review will provide valuable insights about how breed and age influence egg quality traits of chickens. This information may be utilised to improve egg quality traits in chickens through selective breeding, thus improving egg production.

MATERIALS AND METHODS

Eligibility criteria

For this systematic review, the Population, Intervention, Comparison, as well as Outcomes (PICO) components of the research question were identified, as explained by Vriezen *et al.* (2019). The "Chickens" were described as the population, with "breed and age" as the intervention, "different chicken breeds and age groups" as the comparison, and "egg quality traits" as outcomes. An initial search of the PICO components was conducted on databases including Web of Science, ScienceDirect, PubMed, and Google Scholar before planning to conduct the study.

Search strategy

The findings of this systematic review were reported following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher *et al.*, 2009). The search of published articles was conducted by two authors using Web of Science, ScienceDirect, Google Scholar, and PubMed databases from the 25th of September to the 12th of October 2024. The combination of the following keywords: breed OR genotype OR strain, AND age, AND 'egg quality traits' OR 'egg quality characteristics' OR 'egg quality parameters', AND chickens OR hens OR '*Gallus gallus domesticus*' was used when performing publication search.

Inclusion criteria

This systematic review included articles that studied the influence of breed and/or age on egg quality characteristics of chickens, were published in English, and investigated the egg quality parameters of chickens.

Exclusion criteria

Articles that were duplicates, had missing keywords, used a different species, not written in English since the majority of articles are published in English, titled a review, and had no data on the effect of breed and/ or age on egg quality characteristics were excluded.

Data extraction

The two authors independently extracted data and content before reaching an agreement on all materials. The information that was retrieved from the included studies had the name of the first author, publication year, chicken breed and/or age, and studied egg quality traits.

RESULTS

Searched results

The flowchart for identifying and selecting articles for the systematic review is shown in Figure 1. One hundred and fifty-seven articles (n= 157) were extracted where thirty-five articles (n= 35) were removed as duplicates and one hundred and twenty-two articles (n= 122) remained. The remaining articles were analysed for exclusion and inclusion criteria. After screening the articles for title, thirty-five articles (n= 35) were eliminated. Eighty-seven articles (n= 87) were screened for abstract, and thirty-four articles (n= 34) were removed. Fifty-three articles (n= 53) were screened for eligibility and twenty-six articles (n= 26) were included in this systematic review.

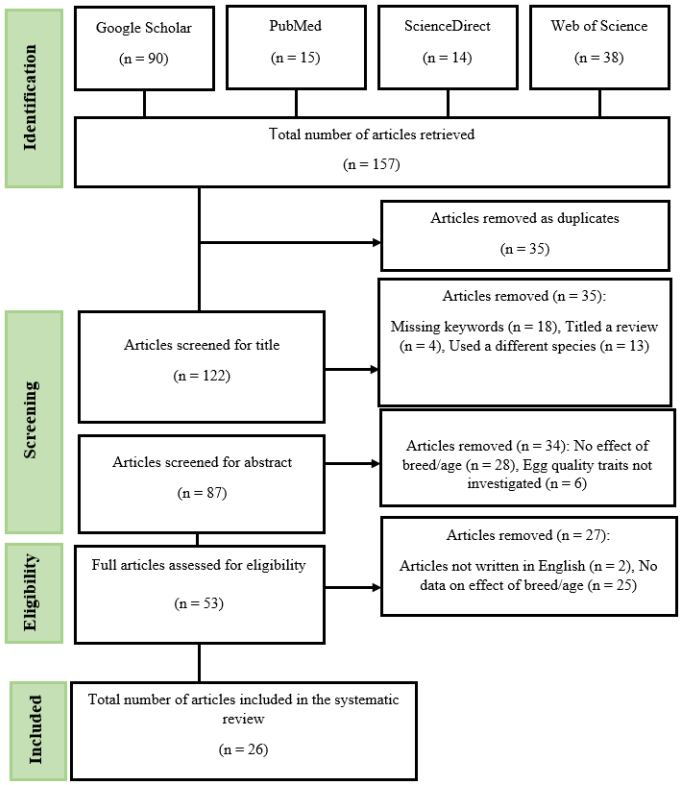

Figure 1: Flow chart of identification and selection of studies used in the systematic review.

Characteristics of included articles

The characteristics of twenty-six included articles (n= 26) in the systematic review are shown in Table 1. The included articles were published from the year 2000 to 2023 and they used chickens that were from the age of 20 weeks up to 65 weeks.

Table 1: Characteristics of included articles.

Author	Year	Country	Breed	Age (weeks)	Egg quality traits
Aminami *et al*	2022	Nigeria	Marshall, Abor Acre	26 - 52	Egg length, shape index, egg weight, egg width
Calik and Obrzut	2023	Poland	Rhode Island Red, Rhode Island White	33, 53	Egg weight, eggshell strength, egg shape index, shell colour, albumen height, eggshell thickness, yolk content, shell density, yolk weight and colour, haugh units, blood stains, meat stains
Dinesh *et al*	2022	India	Dahlem Red	21, 28, 40, 52, 64	Egg length, shell thickness, egg weight, yolk width, shape index, albumen length, yolk index, albumen width, egg width, albumen height, yolk height, haugh unit index
Dudusola *et al*	2020	Nigeria	Noiler	26, 46	Egg length, egg weight, shell surface area, yolk width, haugh unit, egg shape index, egg width, yolk index, albumen height, eggshell thickness, yolk height, yolk and albumen weight
Guni *et al*	2021	Tanzania	Sasso, Kuroiler	-	Egg length, albumen height, egg weight, shell weight, albumen ratio, egg width, shell ratio, shell thickness, yolk ratio, haugh unit, albumen weight, yolk weight, egg shape index
Hanusová *et al*	2015	Slovakia	Rhode Island Red, Oravka	44	Yolk height, egg shape index, yolk colour, yolk percentage, egg length, albumen width, shell weight, albumen height, egg weight, yolk index, shell percentage, egg width, shell thickness, yolk width, albumen weight, albumen percentage, yolk weight, albumen index, haugh unit
Hanusová *et al*	2021	Slovakia	Oravka	28, 32, 52	Egg weight, shell weight, albumen width, egg length, shell percentage, albumen weight, yolk colour, haugh unit, albumen height, egg shape index, yolk percentage, albumen index, yolk weight, albumen percentage, yolk height, egg width, yolk index, shell thickness, yolk width
Ibrahim *et al*	2020	Nigeria	Amberlin Dekalb, Isa Brown, Bovan Nera black	-	Egg shape index, egg length, yolk pH, albumen height, egg width, yolk height, eggshell percentage, albumen pH, eggshell thickness, albumen width, eggshell weight, albumen length, haugh unit, egg weight, yolk width, albumen index, yolk width, albumen width, albumen-yolk pH, yolk index
Kabir *et al*	2014	Nigeria	Nera Black, Isa Brown	26, 32, 38	Egg length, haugh unit, egg width, eggshell weight, albumen height, eggshell thickness, yolk weight, albumen weight, egg weight, yolk height
Kraus and Zita	2019	Czechia	ISA Brown, Hy-Line Brown	36, 40, 44, 48, 52, 56, 60, 64	Egg shape index, haugh units, egg weight, eggshell proportion, eggshell colour, shell thickness, yolk proportion, albumen index, shell strength, albumen proportion, yolk index and colour
Kraus *et al*	2020	Czechia	Dominant Brown, Dominant Leghorn	28, 35, 59	Egg shape index, albumen index, shell strength, shell weight, egg weight, haugh units, eggshell thickness, yolk weight, shell colour, albumen weight, yolk index
Ledvinka *et al*	2012	Czechia	Moravia BSL, Hisex Brown, ISA Brown	20 - 60	Egg shape index, albumen weight, eggshell weight, egg surface, yolk weight, shell colour, egg yolk index, shell index, egg yolk colour, albumen index, eggshell thickness, eggshell strength, haugh units, egg weight, yolk: albumen ratio
Lordelo *et al*	2020	Portugal	Hybrid, Amarela, Branca, Pedres and Preta	-	Albumen percentage, egg weight, yolk percentage, egg shape index, shell colour, albumen pH, shell percentage, yolk colour and pH, haugh units
Manyeula *et al*	2021	Botswana	Ross broiler breeder	30, 45, 60	Egg length, shell thickness, egg weight, shell weight, egg width
Ogunshola *et al*	2018	Nigeria	Fulani ecotype	20, 22, 24	Shell weight, yolk width, egg weight, albumen height, shell thickness, egg length, albumen weight, haugh unit, albumen width, yolk weight, egg width, albumen index, albumen index, yolk index, albumen length, yolk height
Oleforuh Okoleh *et al*	2018	Nigeria	Normal feather, Naked neck	22, 26, 30, 34	Egg weight, yolk height, egg length, albumen length, egg breadth, yolk weight, egg shape index, albumen height, yolk breadth, haugh unit, yolk pH, albumen breadth, yolk length, albumen pH, yolk index, shell weight, albumen index, shell strength, yolk index, albumen weight

Table continues on next page.....

Author	Year	Country	Breed	Age (weeks)	Egg quality traits
Petricevic *et al*	2017	Serbia	Tetra SL, Bowans Brown	35, 45, 55, 65	Egg weight, shell breaking force, haugh units, shell deformation, albumen height, egg shape index, eggshell mass, and eggshell thickness
Rajkumar *et al*	2009	India	Naked Neck	28, 32, 36, 40	Egg weight, yolk width, egg length, yolk height, egg width, haugh unit, yolk weight, egg shape index, albumen width, yolk colour, shell thickness, yolk index, albumen weight, shell weight, albumen height
Rakonjac *et al*	2021	Serbia	New Hampshire, Isa Brown	-	Shell deformation, egg shape index, albumen height, albumen proportion, eggshell thickness, yolk proportion, egg weight, shell strength, haugh unit, shell proportion
Rizzi	2020	Italy	Robusta maculata, Ermellinata of Rovigo	36, 50	Yolk weight, eggshell thickness, albumen weight, haugh unit, yolk percentage, egg shape index, eggshell weight, yolk : albumen ratio, egg weight, albumen percentage, eggshell length and width
Rizzi and Chiericato	2005	Italy	Hy-Line White, Ermellinata of Rovigo, Robusta maculata, Hy-Line Brown	30, 34, 38, 42	Egg weight, haugh unit, albumen pH, albumen height
Rizzi and Chiericato	2005	Italy	Hy-Line White, Ermellinata of Rovigo, Robusta maculata, Hy-Line Brown	30, 40	Egg weight, yolk percentage, eggshell percentage, albumen percentage, yolk : albumen ratio, eggshell thickness
Scott and Silversides	2000	Canada	ISA-White, ISA-Brown	31	Egghell weight, eggshell percentage, albumen weight, albumen percentage, egg weight, yolk weight, albumen pH, yolk percentage, albumen height
Silversides and Scott	2001	Canada	ISA-White, and ISA-Brown	25, 31, 49, 59	Albumen percentage, egg weight, albumen pH, shell percentage, albumen height, yolk percentage
Sokołowicz *et al*	2018	Poland	Hy-line Brown, Rhode Island Red, Hy-line Brown, Green leg Partridge	56	Shell colour, egg weight, shell thickness, yolk colour, egg shape index, shell density, albumen height, eggshell weight, yolk weight, eggshell strength, haugh units, blood spots, meat spots
Zita *et al*	2009	Czechia	Hisex Brown, Moravia BSL, ISA Brown	20 - 60	Haugh units, albumen percentage, egg shape index, yolk index, egg weight, albumen weight, yolk percentage, eggshell weight, albumen index, eggshell percentage, eggshell thickness, yolk weight, shell deformation, shell strength, eggshell colour

Laying age not indicated

Publication by year

Figure 2 present the publications by year. The findings indicated that the articles included were published between the year 2000 and 2023. Most of the articles were published in 2020 with five articles (n = 5) out of 26 included articles (Dudusola *et al*., 2020; Ibrahim *et al*., 2020; Kraus *et al*., 2020; Lordelo *et al*., 2020; Rizzi, 2020), followed by 2021 (Guni *et al*., 2021; Hanusova *et al*., 2021; Manyeula *et al*., 2021; Rakonjac *et al*., 2021) that had four published articles (n = 4) out of 26 included articles.

Publication by country

The publications by country are shown in Figure 3. The findings showed that twenty-six (n=26) articles were published in different countries all over the world. These articles were from eleven (n = 11) different countries and

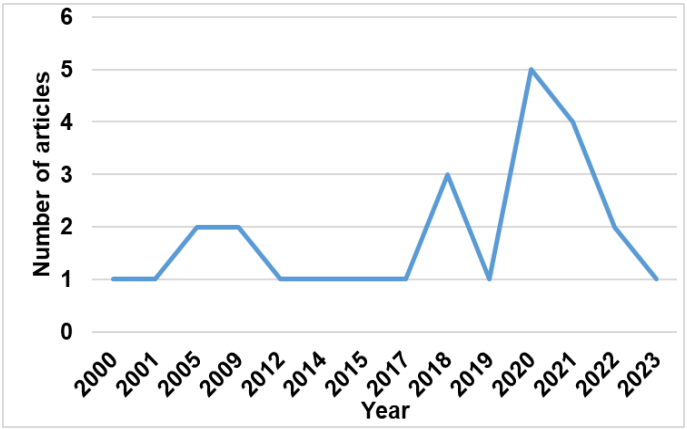

Figure 2: Publication by year.

Nigeria had the highest number of articles, with six articles (n= 6), followed by Czech Republic (Zita *et al.*, 2009; Ledvinka *et al.*, 2012; Kraus and Zita, 2019), Italy (Rizzi and Chiericato, 2005, a; Rizzi, 2020) and Serbia (Rajkumar *et al.*, 2009; Petricevic *et al.*, 2017; Rakonjac *et al.*, 2021), with three articles each (n=3). The other three countries, including Portugal (Lordelo *et al.*, 2020), Tanzania (Guni *et al.*, 2021) and Botswana (Manyeula *et al.*, 2021) had one article each (n=1) out of 26 included articles.

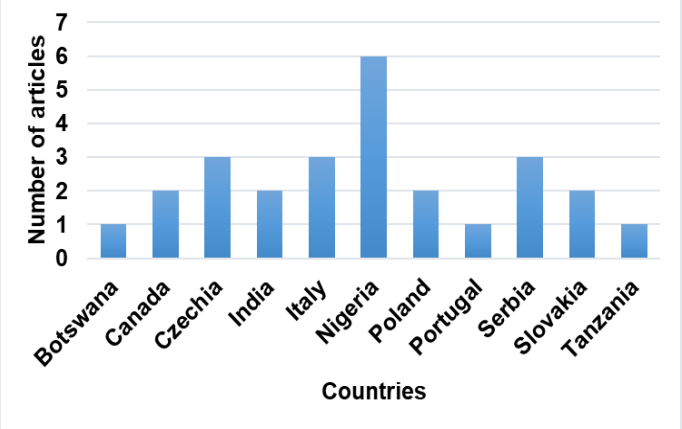

Figure 3: Publication by country.

Publication by subject

Publications by subject for the articles utilised in the review are shown in Figure 4. The findings showed that out of 26 articles included, seven articles (n=7) studied the effect of breed, and seven articles (n=7) studied the effect of age, while twelve articles (n=12) studied the effect of both breed and age on egg quality characteristics.

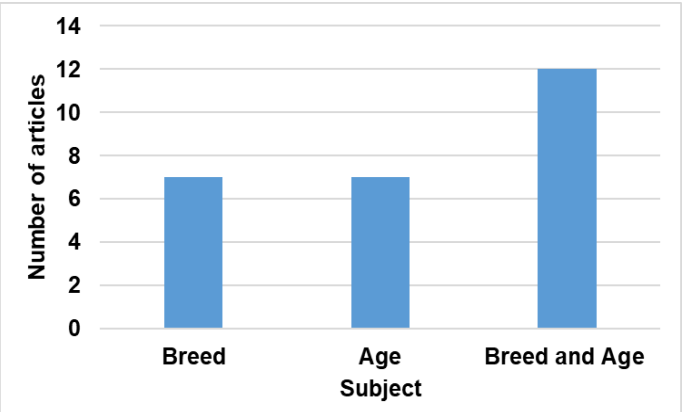

Figure 4: Publication by subject.

Publication by breed

The findings showed that out of 26 articles included, the majority used ISA Brown chicken breed (n=8), followed by Hy-line Brown (Rizzi and Chiericato, 2005, a; Sokolowicz *et al.*, 2018; Kraus and Zita, 2019) which was used in four of the articles (n = 4; Figure 5). Rhode Island Red breed (Hanusova *et al.*, 2015; Sokolowicz *et al.*, 2018; Calik and Obrzut, 2023), Ermellinata of Rovigo (Rizzi and Chiericato, 2005, a; Rizzi, 2020), and Robusta maculata (Rizzi and Chiericato, 2005, a; Rizzi, 2020) were used in three of the included articles (n = 3).

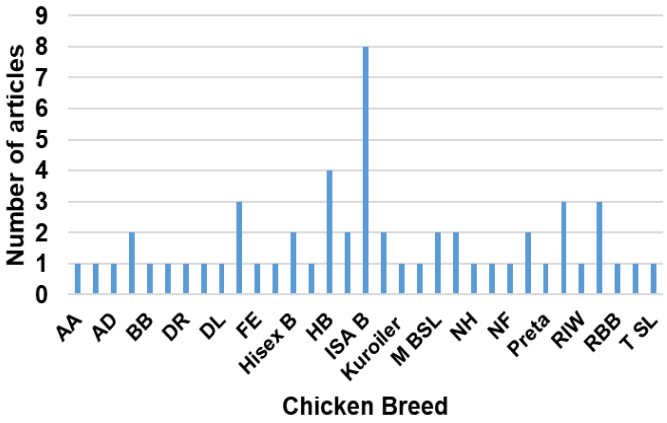

Figure 5: Publication by breed.
AA, Abor Acre; AD, Amberlin Dekalb; BNB, Bovan Nera Black; BB, Bowans Brown; DR, Dahlem Red; DB, Dominant Brown; DL, Dominant Leghorn; ER, Ermellinata of Rovigo; FE, Fulani ecotype, GLP, Green leg Patridge; Hisex B, Hisex Brown; HB, Hy-line Brown; HW, Hy-line White; ISA B, ISA Brown; ISA W, ISA White; M BSL, Moravia BSL; NN, Naked Neck; NH, New Hampshire; NF, Normal feather; RIR, Rhode Island Red; RIW, Rhode Island White; RM, Robusta maculata; RBB, Ross Broiler breeder; TSL, Tetra SL.

Effect of breed on internal egg quality traits

Table 2 presents the findings of the included articles on the influence of breed on internal egg quality parameters. Out of 26 articles included articles, eighteen of them (n = 18) investigated the influence of breed on internal egg quality parameters. The internal egg quality parameters that were investigated in most of the included articles were haugh units (n = 17), albumen height (n = 12), yolk weight (n = 12), and albumen weight (n = 10). Haugh units was investigated in seventeen articles (n = 17), where twelve articles (n = 12) indicated that breed had a significant effect on haugh units, and five articles (n = 5) showed that breed had no significant influence on haugh units. Out of eighteen included articles (n = 18), twelve of them (n = 12) investigated yolk weight and albumen height where nine articles (n = 9) indicated that breed had a significant effect on yolk weight and albumen height while three articles (n = 3) indicated that breed had no significant influence on yolk weight and albumen height. Albumen weight was investigated in ten articles (n = 10), where eight articles (n = 8) indicated that breed had a significant effect on albumen weight, and two articles (n = 2) indicated that breed had no significant effect on albumen weight.

Table 2: Effect of breed on internal egg quality traits.

Author	Breed	Egg quality traits	Significance
Calik and Obrzut (2023)	Rhode Island Red, Rhode Island White	Yolk weight	*
		Haugh unit	*
		Yolk colour	*
		Albumen height	*
		Yolk content	*
Guni *et al.* (2021)	Sasso and Kuroiler	Albumen weight	ns
		Yolk ratio	ns
		Haugh unit	*
		Albumen height	*
		Yolk weight	*
		Albumen ratio	ns
Hanusová *et al.* (2015)	Rhode Island Red and Oravka	Haugh unit	*
		Albumen height	ns
		Yolk colour	*
		Albumen width	ns
		Yolk index	*
		Albumen index	ns
		Yolk weight	*
		Albumen percentage	ns
		Yolk width	ns
		Albumen weight	*
		Yolk percentage	ns
		Yolk height	ns
Ibrahim *et al.* (2020)	Amberlin Dekalb, Isa Brown and Bovan Nera black	Yolk height	*
		Yolk index	*
		Yolk width	*
		Albumen height	*
		Albumen index	*
		Yolk length	*
		Albumen width	ns
		Haugh unit	*
		Albumen length	*
Kabir *et al.* (2014)	Nera Black and Isa Brown	Albumen height	ns
		Yolk weight	*
		Haugh unit	ns
		Yolk height	*
		Albumen weight	*
Kraus and Zita (2019)	Dominant Brown and Dominant Leghorn	Yolk proportion	*
		Albumen proportion	*
		Yolk index	ns
		Albumen index	*
		Yolk colour	*
		Haugh unit	*
Kraus *et al.* (2020)	ISA Brown and Hy-Line Brown	Yolk weight	*
		Albumen index	ns
		Haugh unit	ns
		Yolk index	*
		Albumen weight	*
Ledvinka *et al.* (2012)	Hisex Brown, Moravia BSL, ISA Brown	Yolk : albumen ratio	*
		Haugh unit	*
		Albumen index	*
		Yolk index	*
		Yolk weight	*
		Albumen weight	*
		Yolk colour	*
Lordelo *et al.* (2020)	Hybrid, Amarela, Branca, Pedres and Preta	Yolk percentage	*
		Haugh unit	*
		Albumen percentage	*
		Yolk colour	*
		Albumen pH	*
		Yolk pH	*
Oleforuh Okoleh *et al.* (2018)	Normal feather and Naked neck	Albumen weight	*
		Albumen length	ns
		Albumen height	*
		Haugh unit	ns
		Albumen index	*
		Albumen pH	ns
		Yolk breadth	ns
		Yolk index	*
		Yolk pH	ns
		Yolk height	*
		Yolk length	ns
		Albumen breadth	ns
		Yolk weight	ns
Petricevic *et al.* (2017)	Tetra SL and Bowans Brown	Albumen height	*
		Haugh unit	*
Rajkumar *et al.* (2009)	Naked Neck	Albumen weight	ns
		Albumen height	ns
		Yolk colour	*
		Yolk weight	ns
		Yolk height	*
		Albumen width	ns
		Yolk index	*
		Haugh unit	ns
		Yolk width	ns
Rakonjac *et al.* (2021)	New Hampshire and Isa Brown	Haugh unit	*
		Yolk proportion	*
		Albumen proportion	*
		Albumen height	*

Table continues on next column.....

Table continues on next page.....

Author	Breed	Egg quality traits	Significance
Rizzi (2020)	Isa Brown and New Hampshire	Yolk percentage	ns
		Haugh unit	ns
		Yolk weight	*
		Albumen percentage	*
		Yolk : albumen ratio	ns
		Albumen weight	*
Rizzi and Chiericato (2005)	Robusta maculata, Hy-Line White, Ermellinata of Rovigo, Hy-Line Brown	Albumen height	*
		Albumen pH	*
		Haugh unit	*
Scott and Silversides (2000)	ISA-Brown, ISA-White	Albumen weight	*
		Yolk percentage	*
		Albumen pH	ns
		Yolk weight	*
		Albumen percentage	*
		Albumen height	*
Sokołowicz *et al.* (2018)	Rhode Island Red, Hy-line Brown, Green leg Partridge	Yolk weight	ns
		Yolk colour	ns
		Blood spots	ns
		Meat spots	*
		Albumen height	*
		Haugh unit	*
Zita *et al.* (2009)	Hisex Brown, ISA Brown, Moravia BSL	Yolk weight	*
		Yolk percentage	*
		Albumen weight	*
		Haugh unit	*
		Yolk index	*
		Albumen percentage	*
		Albumen index	ns

*, Significant at p≤ 0.10; ns, non-significant.

Effect of breed on external egg quality traits

Table 3 indicates the findings of the included articles on the influence of breed on external egg quality characteristics. Out of 26 articles included articles, nineteen of them (n = 19) investigated the influence of breed on external egg quality parameters. The external egg quality parameters that were investigated in most of the included articles were egg weight (n = 18), egg shape index (n = 16), eggshell thickness (n = 15), and eggshell weight (n = 14). Out of 19 included articles, eighteen of them (n = 18) investigated egg weight and it was found that sixteen of the articles (n = 16) indicated that breed had a significant effect on egg weight while two of the articles (n = 2) indicated that breed had no significant effect on egg weight. Egg shape index was investigated in sixteen articles (n = 16), where ten articles (n = 10) showed that breed had a significant effect on egg shape index, and six articles (n = 6) indicated that breed had no significant effect on egg shape index. Eggshell thickness was investigated in fifteen articles (n = 15), where thirteen articles (n = 13) indicated that breed had a significant effect on eggshell thickness, and two articles (n = 2) indicated that breed had no significant effect on eggshell thickness. Out of nineteen included articles (n = 19), fourteen of them (n = 14) investigated eggshell weight and it was found that eight articles (n = 8) indicated that breed had a significant effect on eggshell weight while six articles (n = 6) indicated that breed had no significant effect on eggshell weight.

Table 3: Effect of breed on external egg quality traits.

Author	Breed	Egg quality traits	Significance
Aminami *et al.* (2022)	Marshall and Abor Acre	Egg weight	*
		Egg shape index	ns
		Egg length	ns
		Egg width	ns
Calik and Obrzut (2023)	Rhode Island Red, Rhode Island White	Egg weight	*
		Eggshell colour	*
		Eggshell density	*
		Eggshell thickness	*
		Egg shape index	*
		Eggshell weight	*
Guni *et al.* (2021)	Sasso and Kuroiler	Egg length	*
		Eggshell thickness	ns
		Eggshell weight	ns
		Egg shape index	ns
		Egg width	ns
		Eggshell ratio	ns
		Egg weight	*
Hanusová *et al.* (2015)	Rhode Island Red and Oravka	Egg width	*
		Eggshell thickness	*
		Egg length	*
		Egg shape index	ns
		Eggshell weight	*
		Shell percentage	*
		Egg weight	*
Ibrahim *et al.* (2020)	Amberlin Dekalb, Isa Brown and Bovan Nera black	Eggshell thickness	*
		Egg shape index	*
		Egg width	ns
		Eggshell weight	*
		Shell percentage	*
		Egg weight	*
		Egg length	*

Table continues on next page.....

Author	Breed	Egg quality traits	Significance
Kabir *et al.* (2014)	Nera Black and Isa Brown	Eggshell weight	*
		Egg width	ns
		Eggshell thickness	*
		Egg weight	*
		Egg length	ns
Kraus and Zita (2019)	Dominant Brown and Dominant Leghorn	Egg weight	*
		Shell colour	*
		Egg shape index	*
		Eggshell thickness	*
		Eggshell strength	*
		Eggshell proportion	*
Kraus *et al.* (2020)	ISA Brown and Hy-Line Brown	Eggshell thickness	*
		Shell colour	*
		Shell weight	ns
		Egg weight	*
		Shell strength	*
		Egg shape index	*
Ledvinka *et al.* (2012)	Hisex Brown, Moravia BSL, ISA Brown	Eggshell thickness	*
		Shell index	*
		Egg surface	*
		Eggshell colour	*
		Shell strength	*
		Egg shape index	*
		Egg weight	*
		Eggshell weight	*
Lordelo *et al.* (2020)	Hybrid, Amarela, Branca, Pedres and Preta	Egg weight	*
		Eggshell colour	*
		Shell percentage	*
		Egg shape index	*
Oleforuh Okoleh *et al.* (2018)	Normal feather and Naked neck	Eggshell thickness	*
		Egg shape index	ns
		Egg length	*
		Shell weight	ns
		Egg weight	*
		Egg breadth	*
Petricevic *et al.* (2017)	Tetra SL and Bowans Brown	Eggshell thickness	*
		Egg shape index	ns
		Shell deformation	ns
		Breaking force	ns
		Eggshell weight	ns
		Egg weight	ns
Rajkumar *et al.* (2009)	Naked Neck	Eggshell thickness	ns
		Egg length	ns
		Egg shape index	ns
		Egg width	ns
		Eggshell weight	ns
		Egg weight	ns
Rakonjac *et al.* (2021)	New Hampshire and Isa Brown	Shell strength	*
		Shell deformation	*
		Eggshell thickness	*
		Egg shape index	*
		Egg weight	*
Rizzi (2020)	Isa Brown and New Hampshire	Shell weight	ns
		Egg shape index	*
		Shell thickness	*
		Eggshell length	*
		Eggshell width	*
Rizzi and Chiericato (2005)	Hy-Line White, Ermellinata of Rovigo, Hy-Line Brown, Robusta maculata	Egg weight	*
Scott and Silversides (2000)	ISA-White and ISA-Brown	Shell percentage	*
		Eggshell weight	*
		Egg weight	*
Sokołowicz *et al.* (2018)	Rhode Island Red, Hy-line Brown, Green leg Partridge	Shell weight	*
		Egg shape index	*
		Shell density	*
		Shell thickness	*
		Egg weight	*
		Shell strength	ns
		Eggshell colour	*
Zita *et al.* (2009)	Hisex Brown, Moravia BSL and ISA Brown	Eggshell thickness	*
		Shell weight	*
		Shell percentage	*
		Eggshell strength	*
		Eggshell colour	*
		Eggshell deformation	*
		Egg weight	*
		Egg shape index	*

*, Significant at p≤ 0.10; ns, non-significant.

Effect of age on internal egg quality traits

Table 4 indicates the findings of the included articles on the effect of age on internal egg quality characteristics. Out of 26 included articles, eighteen of them (n = 18) investigated the effect of age on internal egg quality characteristics. The egg quality parameters that were investigated in most of the included articles were haugh units (n = 15), albumen height (n = 11), yolk weight (n = 11), yolk index (n = 11), and albumen weight (n = 10). Haugh units was investigated in sixteen articles (n = 16)

, where thirteen articles (n = 13) showed that age had a significant effect on haugh units, and two of them (n = 3) indicated that age had no significant effect on haugh units. Out of eighteen included articles (n = 18), eleven of them (n = 11) investigated albumen height where nine articles (n = 9) indicated that age had a significant effect on albumen height while two articles (n = 2) showed that breed had no significant effect on albumen height. Eleven articles (n = 11) investigated yolk weight where ten articles (n = 10) indicated that age had a significant effect on yolk weight while one article (n = 1) showed that age had no significant effect on yolk weight. Yolk index was also investigated in eleven articles (n = 11), where nine articles (n = 9) showed that age had a significant effect on yolk index, and two articles (n = 2) indicated that breed had no significant influence on yolk index. Albumen weight was investigated in ten articles (n = 10), where nine articles (n = 9) showed that age had a significant effect on albumen weight, and one article (n = 1) indicated that age had no significant effect on albumen weight.

Table 4: Effect of age on internal egg quality traits.

Author	Breed	Age	Egg quality traits	Significance
Calik and Obrzut (2023)	Rhode Island Red, Rhode Island White	33, 53 weeks	Yolk weight	ns
			Yolk colour	*
			Yolk content	ns
			Albumen height	ns
			Haugh unit	ns
Dinesh *et al.* (2022)	Dahlem Red	21, 28, 40, 52, 64 weeks	Yolk height	*
			Albumen width	*
			Haugh unit	ns
			Albumen index	ns
			Yolk width	*
			Albumen length	*
			Yolk index	ns
			Albumen height	*
Dudusola *et al.* (2020)	Noiler	26, 46 weeks	Haugh unit	*
			Albumen height	*
			Yolk width	*
			Yolk + albumen weight	*
			Yolk height	*
			Yolk index	*
Hanusová *et al.* (2021)	Oravka	28, 32, 52 weeks	Yolk width	*
			Albumen width	*
			Yolk index	*
			Albumen height	*
			Haugh unit	*
			Albumen weight	*
Kabir *et al.* (2014)	Nera Black, Isa Brown	26, 32, 38 weeks	Yolk height	*
			Yolk percentage	*
			Albumen percentage	*
			Yolk weight	*
			Albumen index	*
			Yolk colour	*
Kraus *et al.* (2020)	ISA Brown, Hy-Line Brown	28, 35, 59 weeks	Yolk weight	*
			Haugh unit	ns
			Albumen height	ns
			Albumen weight	ns
			Yolk height	ns
Kraus and Zita (2019)	Dominant Brown, Dominant Leghorn	36, 40, 44, 48, 52, 56, 60, 64 weeks	Albumen weight	*
			Yolk index	*
			Haugh unit	*
			Yolk weight	*
			Albumen index	*
Ledvinka *et al.* (2012)	Hisex Brown, Moravia BSL, ISA Brown	20-60 weeks	Albumen index	*
			Yolk proportion	*
			Haugh unit	*
			Yolk index	*
			Albumen proportion	*
			Yolk colour	ns
Manyeula *et al.* (2021)	Ross broiler breeder	30, 45, 60 weeks	Yolk weight	*
			Yolk index	*
			Albumen weight	*
			Yolk colour	*
			Yolk weight	*
			Yolk height	*
			Yolk width	*
			Egg content	*
			Egg volume	*
			Haugh unit	*
			Yolk index	ns
			Albumen weight	*
			Thin albumen	*
			Thick albumen	*
Ogunshola *et al.* (2018)	Fulani ecotype	20, 22, 24 weeks	Yolk weight	*
			Albumen height	*
			Yolk index	*
			Albumen width	*
			Haugh unit	*

Table continues on next column.....

Table continues on next page.....

Author	Breed	Age	Egg quality traits	Significance
			Albumen length	*
			Yolk width	ns
			Albumen index	*
			Yolk height	*
			Albumen weight	*
Oleforuh Okoleh *et al.* (2018)	Normal feather, Naked neck	22, 26, 30, 34 weeks	Albumen length	*
			Albumen index	*
			Yolk breadth	*
			Yolk weight	*
			Yolk height	*
			Albumen breadth	*
			Haugh unit	*
			Yolk pH	*
			Yolk index	*
			Albumen pH	*
			Yolk length	*
			Albumen weight	*
			Albumen height	*
Petricevic *et al.* (2017)	Tetra SL, Bowans Brown	35, 45, 55, 65 weeks	Albumen height	*
			Haugh unit	*
Rajkumar *et al.* (2009)	Naked Neck	28, 32, 36, 40 weeks	Albumen width	*
			Yolk colour	*
			Albumen height	*
			Yolk index	*
			Albumen weight	*
			Yolk weight	*
			Haugh unit	*
			Yolk width	*
			Yolk height	*
Rizzi (2020)	Isa Brown, New Hampshire	36, 50 weeks	Haugh unit	*
			Albumen percentage	*
			Albumen weight	*
			Yolk : albumen ratio	*
			Yolk percentage	*
			Yolk weight	*
Rizzi and Chiericato (2005)	Ermellinata of Rovigo, Hy-Line White, Robusta maculata, Hy-Line Brown	30, 34, 38, 42 weeks	Haugh unit	*
			Albumen pH	*
			Albumen height	*
Rizzi and Chiericato (2005)	Ermellinata of Rovigo, Hy-Line White, Robusta maculata, Hy-Line Brown	30, 40 weeks	Albumen percentage	*
			Yolk : albumen ratio	*
			Yolk percentage	*
			Yolk percentage	*
Silversides and Scott (2001)	ISA-White, ISA-Brown	25, 31, 49, 51 weeks	Albumen pH	*
			Albumen percentage	*
			Albumen height	*
			Yolk percentage	*
Zita *et al.* (2009)	ISA Brown, Moravia BSL, Hisex Brown	20-60 weeks	Yolk index	*
			Albumen percentage	*
			Yolk weight	*
			Albumen weight	*
			Yolk percentage	*
			Albumen index	ns
			Haugh unit	*

*, Significant at p≤ 0.10; ns, non-significant.

Effect of age on external egg quality traits

Table 5 shows the findings of the included articles on the effect of age on external egg quality characteristics. Out of 26 included articles, nineteen of them (n = 19) investigated the effect of age on external egg quality characteristics. The external egg quality parameters that were investigated in most of the included articles were egg weight (n = 18), eggshell thickness (n = 16), egg shape index (n = 14), and eggshell weight (n = 11). Egg weight was investigated in eighteen articles (n = 18) , where sixteen articles (n = 16) indicated that age had a significant effect on egg weight while two articles (n = 2) indicated that age had no significant effect on egg weight. Out of nineteen included articles (n = 19), sixteen (n = 16) investigated eggshell thickness and it was found that ten articles (n = 10) indicated that age had a significant effect on eggshell thickness while six articles (n = 6) indicated that age had no significant influence on eggshell thickness. Egg shape index was investigated in fourteen articles (n = 14), where ten articles (n = 10) indicated that age had a significant effect on egg shape index, and four articles (n = 4) indicated that age had no significant effect on egg shape index. Eleven articles (n = 11) investigated eggshell weight where nine articles (n = 9) showed that age had a significant effect on eggshell weight while two articles (n = 2) indicated that breed had no significant influence on eggshell weight.

Table 5: Effect of age on external egg quality traits.

Author	Breed	Age	Egg quality traits	Significance
Aminami *et al.* (2022)	Marshall, Abor Acre	26-52 weeks	Egg length	*
			Egg shape index	*
			Egg weight	*
			Egg width	*
Calik and Obrzut (2023)	Rhode Island Red, Rhode Island White	33, 53 weeks	Shell density	ns
			Shell colour	*
			Shell weight	*
			Egg shape index	*
			Egg weight	*
			Shell thickness	*
			Shell strength	*
Dinesh *et al.* (2022)	Dahlem Red	21, 28, 40, 52, 64 weeks	Egg width	*
			Shell thickness	*
			Egg shape index	ns
			Egg length	*
			Egg weight	*
Dudusola *et al.* (2020)	Noiler	26, 46 weeks	Shell thickness	*
			Egg length	*
			Shell surface area	*
			Egg shape index	ns
			Egg width	*
			Egg weight	*
Hanusová *et al.* (2021)	Oravka	28, 32, 52 weeks	Egg weight	*
			Eggshell percentage	*
			Egg width	*
			Egg shape index	ns
			Eggshell weight	*
			Eggshell thickness	*
			Egg length	*
Kabir *et al.* (2014)	Nera Black, Isa Brown	26, 32, 38 weeks	Egg weight	ns
			Shell thickness	ns
			Egg length	ns
			Shell weight	ns
			Egg width	ns
Kraus *et al.* (2020)	ISA Brown, Hy-Line Brown	28, 35, 59 weeks	Eggshell colour	*
			Shell weight	*
			Egg shape index	*
			Shell thickness	ns
			Shell strength	*
			Egg weight	*
Kraus and Zita (2019)	Dominant Brown, Dominant Leghorn	36, 40, 44, 48, 52, 56, 60, 64 weeks	Eggshell proportion	*
			Shell strength	*
			Egg weight	*
			Eggshell colour	*
			Egg shape index	*
			Eggshell thickness	*
Ledvinka *et al.* (2012)	Hisex Brown, Moravia BSL, ISA Brown	20-60 weeks	Eggshell colour	*
			Egg shape index	*
			Shell thickness	*
			Shell index	*
			Eggshell strength	ns
			Egg weight	*
			Eggshell weight	*
			Egg surface	*
Manyeula *et al.* (2021)	Ross broiler breeder	30, 45, 60 weeks	Shell thickness	ns
			Egg length	*
			Eggshell percentage	*
			Egg weight	*
			Egg surface area	*
			Shell weight	*
			Egg width	*
			Egg shape index	*
Ogunshola *et al.* (2018)	Fulani ecotype	20, 22, 24 weeks	Egg weight	*
			Shell thickness	ns
			Egg width	*
			Shell weight	ns
			Egg length	*
Oleforuh Okoleh *et al.* (2018)	Normal feather, Naked neck	22, 26, 30, 34 weeks	Eggshell thickness	*
			Egg length	*
			Eggshell weight	*
			Egg weight	*
			Egg shape index	*
			Egg breadth	*
Petricevic *et al.* (2017)	Tetra SL, Bowans Brown	35, 45, 55, 65 weeks	Eggshell mass	ns
			Egg shape index	*
			Eggshell thickness	ns
			Breaking force	ns
			Shell deformation	ns
			Egg weight	ns
Rajkumar *et al.* (2009)	Naked Neck	28, 32, 36, 40 weeks	Eggshell weight	*
			Egg length	*
			Eggshell thickness	*
			Egg weight	*
			Shell width	*
			Egg shape index	ns

Table continues on next column.....

Table continues on next page.....

Author	Breed	Age	Egg quality traits	Significance
			Egg width	*
			Eggshell length	*
Rizzi (2020)	Isa Brown, New Hampshire	36, 50 weeks	Shell width	*
			Eggshell thickness	*
			Egg shape index	ns
			Shell weight	*
			Shell length	*
Rizzi and Chiericato (2005)	Ermellinata of Rovigo, Hy-Line White, Robusta maculata, Hy-Line Brown	30, 34, 38, 42 weeks	Egg weight	*
Rizzi and Chiericato (2005)	Ermellinata of Rovigo, Hy-Line White, Robusta maculata, Hy-Line Brown	30, 40 weeks	Egg weight	*
			Eggshell thickness	ns
			Eggshell percentage	ns
Silversides and Scott (2001)	ISA-White, ISA-Brown	25, 31, 49, 51 weeks	Egg weight	*
			Shell percentage	*
			Albumen pH	*
Zita *et al.* (2009)	Hisex Brown, ISA Brown, Moravia BSL	20-60 weeks	Egg weight	*
			Shell deformation	*
			Eggshell weight	*
			Shell strength	*
			Shell colour	*
			Egg shape index	*
			Shell thickness	*
			Shell percentage	*

*, Significant at p≤ 0.10; ns, non-significant.

DISCUSSION

Breed and age are one of the most essential factors influencing egg quality (Kraus and Zita, 2019). Egg quality parameters (internal and external) are critical for both consumers and the egg production sector (Silversides and Scott, 2001). The systematic review was conducted to provide information on the influence of breed and age on egg quality parameters of chickens using 26 included articles. The findings of this systematic review indicated that 19 out of 26 articles studied the effect of breed on egg quality characteristics, while 19 other articles investigated the effect of age on egg quality parameters. Most of the reviewed articles indicated that breed had an effect on egg shape index, egg weight, eggshell thickness, albumen weight, haugh units, shell weight, yolk weight, eggshell colour, yolk index, albumen percentage, yolk height, eggshell percentage, yolk colour, albumen index, eggshell strength, albumen height, egg length, yolk percentage. However, three included articles (Rajkumar *et al.*, 2009; Hanusová *et al.*, 2015; Ibrahim *et al.*, 2020) that investigated albumen width indicated that breed did not affect albumen width. Commercial chicken breeds such as the Isa Brown, Hisex Brown, Hy-line Brown, Isa White, Hy-line white, Kuroiler, Moravia BSL, Tetra SL, Abor Acre, Dominant Brown, and indigenous chicken breeds, including the Rhode Island Red, Oravka, Amarela, Pedres, Preta, Ermellinata of Rovigo, and Robusta maculata, had better egg quality traits compared to the other breeds included in the systematic review. Sinha *et al.* (2018) conducted a review study on the estimate and effect of breeds on egg quality traits of poultry, and it was found that breed significantly influenced the majority of egg quality traits, except for the Haugh unit and egg shape index. It was found that the improved varieties, such as the Gramapriya and Vanaraja, performed well compared to the other indigenous chicken breeds. The majority of included articles indicated that age affected shell thickness, yolk weight, eggshell weight, albumen height, yolk index, albumen weight, egg shape index, egg length, yolk height, albumen percentage, yolk: Albumen ratio, haugh units, egg width, albumen index, egg weight, shell strength, yolk width, albumen pH, eggshell colour, yolk percentage, albumen width, yolk colour, albumen length, and shell deformation. The results indicated that most of the egg quality traits improved with an increase in age and were optimum above 40 weeks of age. However, eggshell quality decreased as age increased. However, according to the authors' knowledge, this is the first systematic review to report on the effect of breed and age on egg quality characteristics of chickens. This systematic review's findings imply that breed and age may be utilised to improve the egg quality parameters of chickens. This systematic review's strength is that no study similar to this one has been carried out on the influence of breed and age on chickens. The systematic review contributes to the body of knowledge by suggesting that breed and age significantly affect egg quality characteristics in chickens, with certain breeds having superior egg characteristics and age-related changes affecting internal and external egg quality parameters.

CONCLUSION AND RECOMMENDATIONS

In conclusion, breed as well as age affect the egg quality parameters and may be utilised during breeding as a selection criterion to improve the egg quality traits of chickens. The systematic review suggests that there is lack of information on the effect of breed as well as age on egg quality parameters of indigenous chickens. Therefore, it is recommended that more research be conducted to evaluate

egg quality parameters like the eggshell thickness, yolk colour, eggshell strength, egg weight, eggshell colour, and haugh unit in indigenous chickens, including the naked neck. Research should also be carried out to study the effect of other factors such as the environment, genetics, and nutrition on egg quality parameters of chickens.

ACKNOWLEDGEMENT

This systematic review was supported by the Department of Agricultural Economics and Animal Production at the University of Limpopo.

NOVELTY STATEMENT

This study offers valuable information on how both breed and age effect on egg quality traits of chickens. The findings provide important insights for improving breeding strategies and thus egg quality traits of chickens.

AUTHOR'S CONTRIBUTION

All authors contributed to the writing of this manuscript. The first draft of the manuscript was written by Prudence Shibe Mokgapa. The manuscript was then revised by Thobela Louis Tyasi and Joseph Thinawanga Mugwabana. The final manuscript was read and then approved by all the authors.

Generative AI and AI-assisted technology statement

The authors state that no Generative AI was used to prepare this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Aminami M, Aliyu J, Saleh B, Mukaddas J, Mbursa D, Zannah BB, Bulau MM (2022). Effects of genotype, age and season on body weight and some egg quality characteristics of broiler breeding stocks. Niger. J. Anim. Prod., pp. 107-111.

Calik J, Obrzut J (2023). Influence of genotype on productivity and egg quality of three hen strains included in a biodiversity program. Animals, 13(11): 1848. https://doi.org/10.3390/ani13111848

Dinesh K, Sankhyan V, Thakur D, Verma N, Bhardwaj N (2022). Effect of age on egg quality traits of Dahlem Red chicken under intensive system of management in Himachal Pradesh. Indian J. Anim. Sci., 92(3): 347-352. https://doi.org/10.56093/ijans.v92i3.122268

Dudusola I, Bashiru HA, Adeleke OE (2020). Effect of laying age and plumage colour on internal and external quality characteristics of Noiler chicken eggs. Slovak J. Anim. Sci., 53(4): 192-198.

Guni FS, Mbaga SH, Katule AM , Goromela EH (2021). Effects of breed and management system on egg quality traits of two improved dual-purposes chicken breeds. Livest. Res. Rural Dev., 33(12): 552-555.

Hanusova E, Hanus A, Hrnčár C (2021). Eggs quality of Oravka breed hens depending on hens age. Acta Fytotech. Zoot., 24 https://doi.org/10.15414/afz.2021.24.mi-prap.11-14.

Hanusová E, Hrnčár C, Hanus A, Oravcová M (2015). Effect of breed on some parameters of egg quality in laying hens. Acta Fytotech. Zoot., 18 (1): 20-24. https://doi.org/10.15414/afz.2015.18.01.12-24

Ibrahim AA, Abare MY, Salisu IB, Abdulkarim A (2020). Effects of strain and storage period on some quality characteristics of chicken eggs. Niger. J. Anim. Sci. Technol., 3(2): 52-65.

Kabir M, Sulaiman RO, Idris RK, Abdu SB, Daudu OM, Yashim SM, Hassan MR, Adamu HY, Eche NM, Olugbemi TS, Adedibu II (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.

Kraus A, Zita L (2019). The effect of age and genotype on quality of eggs in brown egg-laying hybrids. Acta Univ. Agric. Silvicult. Mendelianae Brunensis, 67(2). https://doi.org/10.11118/actaun201967020407

Kraus A, Zita L, Krunt O, Volek Z, Tyller M, Anderle V (2020). Comparison of basic internal and external egg quality traits of brown and white egg-laying hens in relationship to their age. Acta Univ. Agric. Silvicult. Mendelianae Brunensis, 68(1). https://doi.org/10.11118/actaun202068010049

Kurniawan T, Firmansyah AM, Setiyawan AI, Rosyidah A, Yusmaman WM, Belgis M, Anggraeny YN, Syahputra AR, Hariadi H, Triyannanto E, Wahyuningsih R (2025). Effects of gamma irradiation on morphological characteristics and nutrient content of Arabic chicken egg powder. J. Anim. Health Prod., 13(2): 307-315. https://doi.org/10.17582/journal.jahp/2025/13.2.307.315

Ledvinka Z, Tůmová E, Englmaierová M, Podsedníček M (2012). Egg quality of three laying hen genotypes kept in conventional cages and on litter. Arch. Geflügelk, 76(1): 38-43. https://doi.org/10.1016/S0003-9098(25)01547-4

Lordelo M, Cid J, Cordovil CM, Alves SP, Bessa RJ, Carolino I (2020). A comparison between the quality of eggs from indigenous chicken breeds and that from commercial layers. Poult. Sci., 99(3): 1768-1776. https://doi.org/10.1016/j.psj.2019.11.023

Manyeula F, Sebolai B, Sempule G, Moreki JC (2021). Effects of broiler breeders' Age on egg quality characteristics and their correlation coefficients. J. World's Poult. Res., 11(3): 368-375. https://doi.org/10.36380/jwpr.2021.44

Moher D, Liberati A, Tetzlaff J, Altman DG (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Br. Med. J., 339. https://doi.org/10.1093/ptj/89.9.873

Ogunshola OJ, Bankole OA, Baki OI, Morenikeji OB, Chineke CA (2018). Effects of age and management system on egg quality traits of Fulani ecotype hens. Niger. J. Anim. Prod., pp. 19-21.

Oleforuh-Okoleh VU, Chukwuemeka UM, Adeoye GO (2018). Influence of strain and production cycle on egg quality traits of two Nigerian indigenous chicken strains. Niger. J. Anim. Prod., 45(2): 29-39. https://doi.org/10.51791/njap.v45i2.475

Petričević V, Škrbić Z, Lukić M, Petričević M, Dosković V, Rakonjac S, Marinković M (2017). Effect of genotype and age of laying hens on the quality of eggs and eggshells. Sci. Pap. Ser. D. Anim. Sci.,

Rajkumar U, Sharma RP, Rajaravindra KS, Niranjan M, Reddy BLN, Bhattacharya TK, Chatterjee RN (2009). Effect of genotype and age on egg quality traits in naked neck chicken under tropical climate from India. Int. J. Poult. Sci., 8(12): 1151-1155. https://doi.org/10.3923/ijps.2009.1151.1155

Rakonjac S, Dosković V, Bošković SB, Škrbić Z, Lukić M, Petričević V, Petrović DM (2021). Production performance and egg quality of laying hens as influenced by genotype and rearing system. Braz. J. Poult. Sci., 23(02). https://doi.org/10.1590/1806-9061-2019-1045

Rizzi C (2020). Laying hen biodiversity: The effect of genotype and age on the yield performance and egg quality of two Italian purebred chickens. https://doi.org/10.15414/afz.2020.23.mi-fpap.296-304

Rizzi C, Chiericato GM (2005). Effect of genotype and storage on some egg quality parameters of laying hens reared according to organic farming production.

Rizzi C, Chiericato GM (2005a). Organic farming production. Effect of age on the productive yield and egg quality of hens of two commercial hybrid lines and two local breeds. Ital. J. Anim. Sci., 4(3): 160-162. https://doi.org/10.4081/ijas.2005.3s.160

Scott TA, Silversides FG (2000). The effect of storage and strain of hen on egg quality. Poult. Sci., 79(12): 1725-1729. https://doi.org/10.1093/ps/79.12.1725

Silversides FG, Scott AT (2001). Effect of storage and layer age on quality of eggs from two lines of hens. Poult. Sci., 80(8): 1240-1245. https://doi.org/10.1093/ps/80.8.1240

Sinha B, Mandal K, Kumari R, Kumari T (2018). Estimate and effect of breeds on egg quality traits of poultry: A review. Int. J. Livest. Res., 8(4): 8-21. https://doi.org/10.5455/ijlr.20170812102444

Sokołowicz Z, Krawczyk J, Dykiel M (2018). Effect of alternative housing system and hen genotype on egg quality characteristics. Emirates J. Food Agric., 30(8): 695-703. https://doi.org/10.9755/ejfa.2018.v30.i8.1753

Sudrajat D, Wahyuni D, Malik B, Kardaya D (2024). Assessment of egg sensory quality in quails fed with a diet containing betel leaf (*Piper betle* L.) meal and extract. J. Anim. Health Prod., 12(3): 343-347. https://doi.org/10.17582/journal.jahp/2024/12.3.343.347

Vriezen R, Sargeant JM, Vriezen E, Reist M, Winder CB, O'Connor AM (2019). Systematic reviews and meta-analyses in animal health, performance, and on-farm food safety: A scoping review. Anim. Health Res. Rev., 20(2): 116-127. https://doi.org/10.1017/S1466252319000197

Zita L, Tůmová E, Štolc L (2009). Effects of genotype, age and their interaction on egg quality in brown-egg laying hens. Acta Vet. Brno, 78(1): 85-91. https://doi.org/10.2754/avb200978010085