

**INVESTIGATION OF EGG QUALITY CHARACTERISTICS OF ROSS 308 BROILER
BREEDER CHICKENS**

BY

ACHY NKUNE

A dissertation submitted in conformity with the qualification for the degree of

MASTER OF SCIENCE IN AGRICULTURE (MSc)

in the theme

ANIMAL SCIENCE

at

UNIVERSITY OF SOUTH AFRICA

SUPERVISOR: Prof TL TYASI

CO-SUPERVISOR: Prof JW NG`AMBI

2026

SUPERVISORY COMMITTEE

Prof. T.L. Tyasi: Department of Agricultural Economics and Animal Production
University of Limpopo
Private Bag X 1106 Sovenga
0727
South Africa

Prof. J.W Ng'ambi: Department of Agriculture and Animal Health
University of South Africa
Florida Science Campus
Private Bag X6 Florida
1710
South Africa

DECLARATION

Name and Surname: Achy Nkune

Student ID Number: 21002231

Qualification: Degree in Master of Science in Agriculture, Animal Science.

Dissertation title: Investigation of Egg Quality Traits of Ross 308 Broiler Breeder Chickens.

I proclaim that the above dissertation is the work conducted by myself, and all the sources used or quoted have been revealed and acknowledged by means of references.

I additionally, proclaim that dissertation submitted to checking software and it falls within the accepted requirements for originality.

I further proclaim that, this work has never submitted before, or any-part of it, for assessment at University of South Africa for another qualification or other higher learning institution.

A handwritten signature in black ink, appearing to be 'Achy Nkune', is written over a horizontal dotted line. The signature is stylized and somewhat cursive.

Signature

28 April 2026

Date

DEDICATION

This work is dedicated to my lovely family, for their prayers, caring and love throughout the process. Also, to the loving memories of my late parents for raising me with love, care, for teaching me to respect all people around me, and staying humble.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my supervisors, Prof TL Tyasi and Prof JW Ng`ambi, for guiding me through the whole dissertation writing process, supporting me and for the courage I got throughout the journey. Their building words kept me encouraged to the end of this dissertation.

My appreciation goes to the Daybreak Foods located at Merino Vlake for allowing me to use their eggs conduct this study.

Many thanks to the Tyasi Research team members led by Prof Tyasi, for their support and assistance.

ABSTRACT

Poultry products such as chicken eggs and meat continue to have an important economic impact and are important to the growth of a country's economy. Moreover, poultry products are globally consumed in greater quantities than any other source of animal protein, because they are reasonably priced. Ross 308 broiler chicken is the best breed of chicken nationally which was bred specifically for meat. Poultry breeders focus on egg characteristics in their selection process for reproduction, because poor egg quality results in economic losses during production. This study was conducted to investigate the characteristics of egg quality traits, the correlations among these factors, how the egg weight influences egg quality traits, and to estimate the weight of the egg from egg quality traits in Ross 308 broiler breeder chickens. A total of 1000 eggs were purchased from Daybreak Farm in Bela Bela Local Municipality, Limpopo province of South Africa to conduct the study. Eight external traits of egg quality, including egg length, egg width, shell weight, shell index, shell surface area, unit surface shell weight and shell ratio, and five internal egg quality traits such as yolk weight, albumen weight, albumen ratio, yolk ratio and yolk/albumen. The descriptive statistics were used to quantify the egg quality traits, and the correlation between weight and quality traits of egg was investigated using Pearson's correlation, One-way Analysis of Variance (ANOVA) was applied to investigate which egg quality traits are affected by egg weight and stepwise regression analysis was used to come up with best fit model to predict egg weight from egg quality traits. The descriptive statistics revealed that egg weight had a minimum and maximum value of 32.59 g and 98.25, g respectively. Egg length had a minimum value of 46.61 mm and a maximum value of 70.36 mm, and yolk weight had a minimum value of 5.31 g and a maximum value of 34.02 g. One-way ANOVA revealed that egg weight has a substantial effect ($p < 0.05$) on egg length, egg width, shell weight, shell index, shell surface area, unit surface shell weight, shell ratio, yolk weight, albumen weight, albumen ratio, yolk ratio and yolk/albumen. Pearson's correlation findings displayed that egg weight had a highly positive, remarkable association ($p < 0.01$) with egg length, egg width, shell weight, unit surface shell weight, albumen weight, yolk weight, yolk ratio and yolk/albumen. In addition, negative correlation ($p > 0.05$) was identified between egg weight and shell index, shell ratio and albumen ratio. Stepwise regression findings revealed that the model,

including yolk weight, yolk ratio, albumen ratio and albumen weight, was the best-fitted model ($R^2 = 1.00$ and $RMSE = 0.05$) for estimation of egg weight. The model including yolk weight, albumen weight and yolk ratio was the second best ($R^2 = 1.00$ and $RMSE = 0.34$). The study concludes that the improvement of yolk weight, yolk ratio, albumen weight and albumen ratio might improve the egg weight of the Ross308 broiler chicken breed. The results of this study may be useful to farmers in considering egg quality traits during breeding to improve the egg weight of Ross 308 broiler breeder chickens.

Keywords: Egg weight, external egg quality traits, Internal egg quality traits, yolk weight, albumen weight, egg length.

THESIS OUTPUTS

Scientific articles

Peer-review Journals

Achy Nkune, Jones Ng'ambi, Victoria Rankotsane Hlokoie and Thobela Louis Tyasi. 2025. Systematic review on egg quality characteristics of broiler breeder chickens.

Journal: Online Journal of Animal and Feed Research

Status: Submitted

Achy Nkune, Jones Ng'ambi and Thobela Louis Tyasi. 2025. Effect of egg weight on egg quality of Ross 308 broiler breeder chickens.

Journal: Animal Health and Production Journal

Status: Accepted

Manuscript ID: MH20250929080905-R1

TABLE OF CONTENT

SUPERVISORY COMMITTEE	ii
DECLARATION	iii
DEDICATION	iv
ACKNOWLEDGEMENTS	v
ABSTRACT	vi
THESIS OUTPUTS	viii
TABLE OF CONTENT	ix
LIST OF TABLES	xii
LIST OF FIGURES	xiii
LIST OF ABBREVIATIONS	xiv
CHAPTER 1	1
1.1 Introduction	1
1.2 Problem statement	1
1.3 Rationale	2
1.4 Aim	3
1.5 Objectives	3
1.6 Research Question	4
1.7 Hypotheses	4
1.8 Thesis organization	4
1.9 References	4
CHAPTER 2	7
2.1 Introduction	7
2.2 Broiler production industry	7
2.3 Ross 308 broiler breeder	8
2.4 External egg quality traits	8
2.5 Internal egg quality traits	9
2.6 Association between egg weight and egg quality traits	9
2.7 Influence of egg weight on egg quality traits	10
2.8 Conclusion	11
2.9 References	12
CHAPTER 3	17

3.1	Abstract.....	17
3.2	Introduction.....	17
3.3	Materials and methods.....	18
3.3.1	Eligibility criteria.....	18
3.3.2	Literature search	18
3.3.3	Inclusion criteria.....	18
3.3.4	Exclusion criteria	19
3.3.5	Data extraction	19
3.4	Results.....	19
3.4.1	Searched results.....	19
3.4.2	Characteristics of included articles	20
3.4.3	Publications by year.....	23
3.4.4	Publications by country.....	23
3.4.5	Publications by breed	24
3.4.6	Publication by journals.....	25
3.4.7	Studied internal egg quality traits.....	26
3.4.8	Studied external egg quality traits.....	27
3.4.9	Characterization of internal egg quality traits	28
3.4.10	Characterization of external egg quality traits.....	31
3.5	Discussion.....	34
3.6	Conclusion	35
3.7	References.....	35
CHAPTER 4.....		38
4.1	Introduction.....	38
4.2	Materials and methods.....	39
4.2.1	Eggs purchase	39
4.2.2	Breeding stock management	39
4.2.3	Experimental design.....	39
4.2.4	External egg quality traits collection	40
4.2.5	Internal egg quality traits collection.....	40
4.2.6	Statistical analysis	41
4.3	Results.....	41
4.3.1	Descriptive statistics of external egg quality traits.....	41

4.3.2	Descriptive statistics of internal egg quality traits	42
4.3.3	Effect of egg weight on external egg quality traits	43
4.3.4	Effect of egg weight on internal egg quality traits	44
4.3.5	Correlation matrix between external egg quality traits	44
4.3.6	Correlation matrix between internal egg quality traits	45
4.3.7	Correlation matrix between external and internal egg quality traits	47
4.3.8	Prediction of egg weight	49
4.4	Discussion	50
4.5	Conclusion	52
4.6	References	53
CHAPTER 5	56
5.1	Conclusion	56
5.2	Recommendations	56

LIST OF TABLES

Table	Title	Page
Chapter 3:		
Table 3.1	Characteristics of included articles	19
Table 3.2	Characterisation of internal egg quality traits	27
Table 3.3	Characterisation of external egg quality traits	31
Chapter 4:		
Table 4.1	Descriptive statistics of external egg quality traits	40
Table 4.2	Descriptive statistics of internal egg quality traits	41
Table 4.3	Effect of egg weight on external egg quality traits	42
Table 4.4	Effect of egg weight on internal egg quality traits	43
Table 4.5	Correlation between external egg quality traits	43
Table 4.6	Correlation between internal egg quality traits	44
Table 4.7	Correlation between internal and external egg quality traits	46
Table 4.8	Best fitted regression models with stepwise regression analysis	48

LIST OF FIGURES

Figure	Title	Page
Chapter 2		
Figure 2.1	Ross 308 broiler breeder chicken	8
Chapter 3		
Figure 3.1	Flow chart of identification and selection of studies used in the systematic review	19
Figure 3.2	Publications by year	22
Figure 3.3	Publications by country	23
Figure 3.4	Publications by breed	24
Figure 3.5	Publication by journals	25
Figure 3.6	Internal egg quality traits	26
Figure 3.7	External egg quality	27

LIST OF ABBREVIATIONS

PEO	Population, Exposure, and Outcomes
DAR	Ascites-resistant dam line
DAS	Ascites-sensitive dam line
SASL	Ascitessensitive sire line
g	Grams
ANOVA	Analysis of Variance
EW	Egg weight
EL	Egg length
EWD	Egg width
SW	Shell weight
SI	Shell index
SA	Shell surface area
USW	Unit surface shell weight
SR	Shell ratio
YW	Yolk weight
AW	Albumen weight
AR	Albumen ratio
YR	Yolk ratio
Y/A	Yolk/albumen
ns	Not significant
MSE	Mean square error

R^2

Root square

CHAPTER 1

GENERAL INTRODUCTION

1.1 Introduction

In the poultry industry, products such as chicken eggs and meat have an important economic impact and are critical to the growth of a country's economy (Orhan *et al.*, 2016). South Africa is ranked as one of the leading consumers of poultry in the world, mainly chickens. Poultry products continue to be consumed in greater quantities than any other source of animal protein (Shi *et al.*, 2009; Dilawar *et al.*, 2021). This is because it is abundantly available and reasonably priced. Poultry meat has become the main source of protein for most parts of the world (Welelaw *et al.*, 2018; Assefa *et al.*, 2019). To meet this demand, different broiler breeds/strains have been developed such as Cobb 500 and Ross 308. Ross 308 broiler chicken is the world's best breed of chicken, which was bred specifically for meat as a white hybrid. The chickens are fast-growing with a high meat production, and they have excellent survival statistics (Rebolledo *et al.*, 2023).

A chicken egg is naturally designed for the reproduction and nourishment of the developing embryo (Shi *et al.*, 2009). The poultry industry wants fast-growing and uniform broiler chickens; however, the chick quality is affected by some factors, such as egg quality. Other traits, including egg weight, size, surface area, shell integrity, and shape index, all contribute to the physiological processes necessary for a successful hatch. One of the most crucial egg physical characteristics that protects the embryo from harm and unfavourable environmental conditions is the quality of the eggshell, whereas the internal characteristics of the egg supply the embryo with nutrition (Alabi *et al.*, 2018). Egg's best traits are the best criteria when breeding to increase chicken egg weight (Ukwu *et al.*, 2017; Khaskheli *et al.*, 2020).

1.2 Problem statement

Poor egg characteristics on hatching eggs that result in poor hatchability and chicks are not good from breeding stocks such as Ross 308 and Ross 508 broiler breeder chickens (Tong *et al.*, 2013). These factors significantly affect the egg's biological importance, which influences the typical development of the embryo to produce a viable chick

(Kontecka *et al.*, 2012). Egg characteristics such as egg weight influences normal embryo development to produce viable chicks; thus, smaller eggs weight may lead to economic losses (Kontecka *et al.*, 2012). Poultry breeders focus on egg characteristics in their selection process for reproduction, because poor egg quality results in economic losses at every stage of production (Singh *et al.*, 2020). Therefore, producing eggs with good quality traits will result in improved embryo development (Kontecka *et al.*, 2012), which will lead to the production of good quality chicks (Welelaw *et al.*, 2018). Furthermore, that will help the farmers with improved profit margins (Alabi *et al.*, 2018). Hence, there is a need to improve the egg weight and egg quality traits of broiler breeders for improved embryo development to produce viable chicks (Kontecka *et al.*, 2012).

1.3 Rationale

The characteristics of an egg influence its embryonic development, ultimately the survival of the hatched chick, and the future performance of the breeding stock (Kontecka *et al.*, 2012). Alabi *et al.* (2018) reported that although the chicken egg is known to have an accessible amount of many higher nutrients that can support the embryonic growth to hatch, the egg weight may have an impact on hatching success, and internal and external egg quality traits. Therefore, characteristics of eggs are important for reproductive purposes and breeding programs (Welelaw *et al.*, 2018, Celik *et al.*, 2018). The quality of eggs plays an important role in chicken production (Celik *et al.*, 2018).

Numerous studies have been conducted on the relationship between egg weight and the internal and external egg quality traits in Southeastern Nigeria local chickens (Adeolu and Oleforuh-Okoleh, 2011), in the indigenous Sakini chicken breed (Saroj *et al.*, 2020) and in French broiler Guinea fowl (Dzungwe *et al.*, 2018). The studies revealed a significant correlation between egg weight and egg characteristics, namely egg width, egg length, yolk weight, albumen weight and shell weight.

Tyasi *et al.* (2019) conducted a study, to investigate the impact of egg weight on the Potchefstroom Koekoek chicken genotype's egg quality characteristics, and they found that egg weight had a significant effect on the egg quality traits such as the egg length, yolk weight, albumen weight and shell weight. Nhan *et al.* (2018) observed that the egg

weight of Japanese quail had a positive impact mostly on the yolk traits and albumen whereas on the albumen height and yolk index it had a negative impact. Singh *et al.* (2020) conducted a study on indigenous chickens to evaluate the egg quality traits, and they found that the internal and external egg qualities are very important in breeding for improved chick quality.

However, there is limited literature on the influence of egg quality traits on egg weight of broiler breeder chickens, like Ross 308 (Dorosti *et al.*, 2024), Cobb 500 (Bueno *et al.*, 2016), Arbor Acre (Hassan and Ali, 2018), Ross 708 (Romeo *et al.*, 2009), Novoponte (Halgrain *et al.*, 2024), CARIBRO Vishal (Chaudhary *et al.*, 2018) and FUNAAB Alpha (Aloe *et al.*, 2024). Thus, there is a need to investigate the egg quality characteristics of Ross 308 broiler breeder chickens. The results of the study will help the poultry breeders on the egg quality traits to focus on during selection when breeding for improved egg weight of Ross 308 broiler breeder chickens. They will also assist during breeding for improved embryo development and production of good quality chicks, which may give farmers improved profit margins.

1.4 Aim

The aim of the study was to quantitatively characterize and estimate the egg weight from egg quality traits of Ross 308 broiler breeder chickens.

1.5 Objectives

Objectives of the study were:

- i. To quantify the egg weight and egg quality traits of Ross 308 broiler breeder chickens.
- ii. To determine the effect of egg weight on egg quality traits of Ross 308 broiler breeder chickens.
- iii. To determine the correlation between egg weight and egg quality traits of Ross 308 broiler breeder chickens.
- iv. To estimate egg weight from egg quality traits of Ross 308 broiler breeder chickens.

1.6 Research Question

- i.** To what extent can external morphometric measurements and internal quality indicators be integrated into a robust mathematical model to accurately predict the total egg weight of Ross 308 broiler breeders?

1.7 Hypotheses

- i.** Egg weight does not affect egg quality traits of Ross 308 broiler breeder chickens.
- ii.** There is no correlation between egg weight and egg quality traits of Ross 308 broiler breeder chickens.
- iii.** Egg weight cannot be estimated from egg quality traits of Ross 308 broiler breeder chickens.

1.8 Thesis organization

This thesis consists of three chapters, introducing introduction (Chapter 1), a literature review chapter (Chapter 2) which makes up literature review chapter, and a systematic review chapter prepared as a publication article (Chapter 3). Additionally, the one investigational chapter was prepared as a publication article (Chapter 4). The thesis is completed with a general conclusion and upcoming studies (Chapter 5) and addendum (Chapter 6).

1.9 References

- Adeolu, A.I. and Oleforuh-Okoleh, V.U. (2011). Phenotypic relations between egg weight and other egg quality traits of south-eastern Nigeria local chicken. *Nigerian Journal of Animal Production*, 7(3): 15-19.
- Assefa, S., Aberra Melesse. and Banerjee, S. (2019). Egg Production and Egg Quality Traits of Local and Exotic Chicken Breeds Reared in Two Agroecologies under Traditional Management System. *Research Journal of Food and Nutrition*, 3(1): 11–17.

- Dilawar, M.A., Mun, H.S., Rathnayake, D., Yang, E.J., Seo, Y.S., Park, H.S. and Yang, C.J. (2021). Egg Quality Parameters, Production Performance and Immunity of Laying Hens Supplemented with Plant Extracts. *Animals*, [online] 11(4): 975.
- Dzungwe, J.T., Gwaza, D.S. and Egahi, J.O. (2018). Phenotypic correlation between egg weight and egg linear measurements of the French broiler guinea fowl raised in the humid zone of Nigeria. *Current Trends on Biostatistics and Biometrics*, 1(1): 145-151.
- Halgrain, M., Schneider, M., Jia, S., Narcy, A., Gambier, E., Hincke, M.T., McKee, M.D., Réhault-Godbert, S. and Reznikov, N. (2024). A 3D micro-computed tomography study comparing embryonic skeletal development in layer versus broiler strains of the domestic chicken. *Poultry Science*, 103(12), pp.104308–104308.
- Khaskheli, A.A., Khaskheli, M.I., Khaskheli, A.J. and Khaskheli, A.A. (2020). Dietary influence of *Yucca schidigera* on broilers and layers: A review. *International Journal of Veterinary Science*, 9(1): 458-461.
- Kontecka, H., Nowaczewski, S. and Sierszuła, M.M. (2012). Analysis of changes in egg quality of broiler breeders during the first reproduction period. *Annals of Animal Science*, 12(4): 609–620.
- Orhan, H., Eyduran, E., Tatliyer, A. and Saygici, H. (2016). Prediction of egg weight from egg quality characteristics via ridge regression and regression tree methods. *Revista Brasileira de Zootecnia*, 45(7): 380–385.
- Rebolledo, O.F.P., López, M.F.A., Rivera, J. A. H., Canul, A.C., Isaias, G.T. and Casillas, A.C.G. (2023). Effect of the Line and Age of Female Broiler Breeder on Hatchability Performance of Eggs. *Brazilian Journal of Poultry Science*, [online] 25(01): 50.
- Saroj, S., Mana, R.K., Naba, R.D., Neena, A.G. and Nirajan B. (2020). Evaluation of external and internal egg quality traits of indigenous Sakini chicken in different

generations of selection. *International Journal of Agriculture and Forestry*, 10(2): 41-48.

Shi, S.R., Wang, K.H., Dou, T.C. and Yang, H.M. (2009). Egg weight affects some quality traits of chicken eggs. *Journal of Food, Agriculture and Environment*, 7(2): 432-434.

Tong, Q., Romanini, C.E., Exadaktylos, V., Bahr, C., Berckmans, D., Bergoug, H., Eterradossi, N., Roulston, N., Verhelst, R., McGonnell, I.M. and Demmers, T. (2013). Embryonic development and the physiological factors that coordinate hatching in domestic chickens. *Poultry Science*, 92(2): 620-628.

Ukwu, H.O., Ezihe, C.O., Asaa., S.K. and Anyogo, M.E. (2017). Effect of egg weight on external and internal egg quality traits of Isa Brown egg layer chickens in Nigeria. *Journal of Animal Science and Veterinary Medicine*, 2(3): 126-132.

Welelaw, E., Abera, M., Beyan, M. and Taye, M. (2018). Assessing the Performance, Egg Quality, and Carcass Characteristics of Indigenous Chickens Reared Under Traditional Management System. *International Journal of Research Studies in Agricultural Sciences*, 4(10): 27–35.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

Chicken egg has a naturally occurring structure that facilitates reproduction and supplies the growing embryo with nutrients for nourishment (Shi *et al.*, 2009; Alabi *et al.*, 2018). In poultry flocks, collecting plenty of eggs with good quality characteristics like normal structure, ideal morphological composition, and interior quality is important; because they have a huge influence on the developing embryo (Kontecka *et al.*, 2012). Alabi *et al.* (2018) also reported that the external and internal quality of eggs have an influence on the hatching success of the egg. Egg quality is a broad phrase referring to a number of criteria that specify both external and internal quality (Hegab and Hanafy, 2019). The albumen, Haugh unit, yolk quality, and the existence of blood and meat stains are the factors that determine its internal quality whereas external quality is determined by egg weight, egg size, shell strength, shell weight and shell thickness (Ahmadi *et al.*, 2011). Egg quality characteristics are important in the poultry production industry and breeding strategies (Welelaw *et al.*, 2018). The current review will focus on the broiler production industry, external and internal egg quality traits and their association with egg weight. Lastly, the influence of age and egg weight on egg quality traits.

2.2 Broiler production industry

The global broiler industry is expanding yearly. In 2018, it was recorded that poultry exceeded pork as the most consumed meat (Brevik *et al.*, 2020). The poultry industry wants fast-growing and uniform broiler chickens (Rebolledo *et al.*, 2023). In South Africa, the poultry industry is the largest single contributor to the agricultural sector. Broiler production dominating the poultry industry as the main supplier of protein (Mdletshe and Obi, 2023). Welelaw *et al.* (2018) reported that chicken products are the main affordable sources of animal protein, making it easy for rural households to purchase. Broiler chicken production is time-efficient and adaptable to market changes (Brevik *et al.*, 2020). They grow quickly, reaching market weights of 2 or more kilograms at less than seven weeks of age (Kpomasse *et al.*, 2021). Thus, chicken production is vital to meet food security by producing a high-quality animal source of protein (Welelaw *et al.*, 2018).

2.3 Ross 308 broiler breeder

The Ross 308 (Figure 1) is globally recognised as a broiler that gives consistent performance in the broiler house, producing a high number of eggs with good hatchability (Ross, 2018). Alzawqari *et al.* (2018) reported that broiler breeder Ross 308 chickens reach their maximum production in the second and third stages of production and have a higher percentage of double yolk eggs and mortality, and they give the highest double yolk eggs in the third stage and the fewest in the last two production stages.



Figure 2.1: Ross 308 broiler breeder chicken (Ross, 2018).

2.4 External egg quality traits

An egg's external quality can be evaluated in multiple ways; external traits such as egg and shell weights, cleanliness, shell colour, shell breaking strength, egg size, and shell thickness are among the crucial ones (Walkite *et al.*, 2019). In poultry production, the size and quality of the eggs are crucial factors (Dinesh *et al.*, 2022). Egg weight affects every component of the egg. Therefore, it is considered one of the most crucial traits (Tumova *et al.*, 2009). Egg weight varies greatly based on several factors, including breed, age of the chicken, and temperature of the surrounding environment (Ledvinka *et al.*, 2012). The weight of an egg varies from 35 to 65 g in Africa (Ledvinka *et al.*, 2012). The weight of the eggs increases as the chicken ages (Walkite *et al.*, 2019); another factor that influences egg weight is the weight of the hen. Heavier hens lay heavier eggs (Ledvinka *et al.*, 2012). Studies have revealed that eggs laid in the morning have a heavier weight

than eggs laid later in the day, but the qualities of the eggshell are better (Tumova *et al.*, 2009).

Egg shell is both rigid and porous but resistant to pathogens when kept dry and resistance to moisture loss through evaporation (Walkite *et al.*, 2019). Quality of the eggshell is described by its actual thickness, weight and weight ratio, and strength (Ledvinka *et al.*, 2012). One of the most essential traits of eggs is their shell quality, because the embryo's development and gas exchange are facilitated by the incubation environment that the eggshell provides (Alabi *et al.*, 2018; Rebolledo *et al.*, 2023). A shell should be strong enough to withstand a fair amount of handling without cracking, as weaker shells result in a higher percentage of damaged eggs, which raises economic losses (Walkite *et al.*, 2019). Alabi *et al.* (2018) reported that external traits contribute to the physiological processes necessary for eggs to successfully hatch.

2.5 Internal egg quality traits

The internal egg quality can be studied by its albumen, yolk, and possible components of flesh or blood (Walkite *et al.*, 2019). The interior of chicken eggs consists of the yolk and albumen (Dinesh *et al.*, 2022). One of the internal traits of hatching eggs that is crucial to the embryonic growth and hatchability is albumen (Alabi *et al.*, 2018). The albumen contains more protein than the yolk and has a significant impact on the overall quality of the inside of an egg (Walkite *et al.*, 2019). The main measures used to characterize albumen quality are Haugh units, which indicate the quantity of albumen and egg weight (Ledvinka *et al.*, 2012).

Immediately after the egg is laid, its interior quality starts to deteriorate (Dinesh *et al.*, 2022). For optimal growth, chicken embryos primarily depend on nutrients found in the yolk and albumen (Alabi *et al.*, 2018). Yolk quality is determined by the colour, texture, firmness, and smell of the yolk (Walkite *et al.*, 2019).

2.6 Association between egg weight and egg quality traits

Ayorinde and Toyé (2021) showed that body weight had a remarkable negative correlation with shell thickness and a non-significant association with egg weight. Shi *et*

al. (2009) reported that egg weight had a significant correlation with albumen weight, yolk weight and shell weight in the partridge (*Alectoris Chukar*). The study further reported that there are limited studies about the correlation between egg weight and various traits of egg quality, including yolk colour, yolk percentage, albumen percentage, Haugh unit, albumen height, shell index, shell colour, strength and thickness.

It was reported by Alkan *et al.* (2014) that there was no significant relationship between egg weight and eggshell index in the partridge (*Alectoris Chukar*). The study further indicated that in many studies carried out on chickens, researchers reported a negative, although not always significant, correlation between the egg shape index and its weight. Alkan *et al.* (2014) moreover reported, in a study conducted on partridges (*Alectoris Chukar*), a significant positive correlation between the shape of eggs and their weight.

Tyasi *et al.* (2022) reported that egg weight had positively significant correlations with egg length, albumen weight, and shell weight in Potchefstroom Koekoek Chickens, indicating that improving egg weight might also be achieved by increasing egg length, albumen weight, and shell weight of Potchefstroom Koekoek chickens. Alkan *et al.* (2013) indicated that egg weight had a significant correlation with the albumen ratio and yolk weight. Ukwu *et al.* (2017) in Nigerian Isa Brown egg layer chickens and Saroj *et al.* (2020) in indigenous Sakini chickens also found a link between egg weight and internal egg quality traits such as the yolk weight, albumen weight, albumen ratio and egg volume.

2.7 Influence of egg weight on egg quality traits

Egg weight is among the important traits that influence egg quality, the egg size and internal quality of an egg, which are important for both hatching and table eggs (Shi *et al.*, 2009; Alkan *et al.*, 2014), and it is well accepted that egg size positively influences incubation success and embryonic survival (Hegab and Hanafy, 2019). Egg size influences eggshell characteristics and external egg quality traits (Hegab and Hanafy, 2019). Şekeroğlu and Altuntas (2008) reported that the egg weight influenced the eggshell thickness and albumen height, with the medium eggs having significantly higher eggshell thickness and extra-large eggs having a significantly lower eggshell thickness in the brown-egg layer strain of Lohmann hens.

Egg weight had no significant effect on the albumen ratio and yolk ratio in Potchefstroom Koekoek layers (Tyasi *et al.*, 2022). The study also found that compared to medium and large eggs, small eggs had higher egg length, albumen weight, yolk weight, shell ratio, and shell weight. Shi *et al.* (2009) reported that egg weight significantly affected the shape index, shell thickness, yolk weight percentage, albumen weight percentage, albumen height and Haugh unit in the brown-egg layer strain of Nike. Additionally, shape index, shell thickness and albumen weight percentage increased with an increase in egg weight, but the percentage of yolk weight decreased as egg weight increased. The albumen height shifted from low to medium to high in the order of medium eggs, small eggs and large eggs, respectively. Whereas the Haugh unit was low in medium-sized eggs, medium in large eggs, and highest in small eggs.

A study conducted on Broiler breeders by Iqbal *et al.* (2017) found that egg weight did not significantly affect the albumen and yolk weight percentage; however, it affected the shape index. Furthermore, another study showed that egg Haugh unit, yolk index, albumen width, unit surface shell weight and shape index were not significantly affected by egg weight. Whereas egg weight had a substantial impact on egg length, egg breadth, shell weight, shell thickness, shell surface area, egg volume, yolk weight, yolk height, yolk width, yolk ratio, albumen height, albumen length, albumen weight, albumen index, albumen ratio, and yolk/albumen ratio (Alkan *et al.*, 2014).

2.8 Conclusion

Egg quality is determined by both its external and internal factors. The internal quality is determined by the albumen, Haugh unit, yolk quality and the presence of blood and meat spots in the egg, and the external quality is determined by egg size, weight, shell strength, shell weight and shell thickness. However, the literature is not conclusive on the characterization of Ross 308 and estimation of the egg weight from egg quality traits of Ross 308 broiler breeder chickens. These attributes contribute a lot towards hatching of the egg, which is why they need to be given attention at all stages of production. One attribute may influence the other in a good or bad way, like the influence of egg weight and age on the egg quality traits.

2.9 References

- Adeolu, A.I. and Oleforuh-Okoleh, V.U. (2011). Phenotypic relations between egg weight and other egg quality traits of south-eastern Nigeria local chicken. *Nigerian Journal of Animal Production*, 7(3): 15-19.
- Ahmadi, F. and Rahimi, F. (2011). Factors affecting quality and quantity of egg production in laying hens: a review. *World Applied Sciences Journal*, 12 (3): 3.
- Alabi, J.O., Bhanja, S.K., Goel, A., Mehra, M. and Fafiolu, A.O. (2018). Chicken embryogenesis: Influence of egg quality traits on embryo morphology. *Indian Journal of Poultry Science*, 53(3): 324-330.
- Alkan, S., Galiç, A., Karsli, T. and Karabağ, K. (2014). Effects of egg weight on egg quality traits in partridge (*Alectoris Chukar*). *Journal of Applied Animal Research*, 43(4): 450–456.
- Alkan, S., T. Karsli., Galiç, A. and Karabağ, K. (2013). Determination of phenotypic correlations between internal and external quality traits of guinea fowl eggs. *Kafkas Univ. Vet. Fak. Derg.* 19(5): 861-7.
- Alzawqari, M., Al-Baadani, H., Alsobayel, A. and Al-Baadani, S. (2018). A comparative study of reproductive performance of Ross 308 and Marshall R Plus Broiler Breeder females strain stocks during production period. *University of Aden Journal of Natural and Applied Sciences*, 22(2): 395–406.
- Assefa, S., Aberra Melesse. and Banerjee, S. (2019). Egg Production and Egg Quality Traits of Local and Exotic Chicken Breeds Reared in Two Agroecologies under Traditional Management System. *Research Journal of Food and Nutrition*, 3(1): 11–17.

- Ayorinde, K.L. and Toye, A.A. (2021). Association between body weight and some egg production traits in a strain of commercial layer. *Nigerian Journal of Animal Production*, 15(1998): 199-125.
- Brevik, E., Lauen, A.Ø., Rolke, M.C.B., Fagerholt, K. and Hansen, J.R. (2020). Optimisation of the broiler production supply chain. *International Journal of Production Research*, 58(17): 5218–5237.
- Celik, S., Sengul, T., Inci, H., Sodgut, B., Sengul, A.Y., Kuzu, Ç. and Ayasan, T. (2018). Estimation of egg weight from some external and internal quality characteristics in quail by using various data mining algorithms. *Indian Journal of Animal Sciences*, 87(12): 1524–1530.
- Dilawar, M.A., Mun, H.S., Rathnayake, D., Yang, E.J., Seo, Y.S., Park, H.S. and Yang, C.J. (2021). Egg Quality Parameters, Production Performance and Immunity of Laying Hens Supplemented with Plant Extracts. *Animals*, [online] 11(4): 975.
- Dinesh, K., Sankhyan, V., Thakur, D., Verma, N. and Bhardwaj, N. (2022). Effect of age on egg quality traits of Dahlem Red chicken under intensive system of management in Himachal Pradesh. *Indian journal of animal sciences/Indian Journal of Animal Sciences*, 92(3): 347–352.
- Dzungwe, J.T., Gwaza, D.S. and Egahi, J.O. (2018). Phenotypic correlation between egg weight and egg linear measurements of the French broiler guinea fowl raised in the humid zone of Nigeria. *Current Trends on Biostatistics and Biometrics* 1(1): 145-151.
- Hegab, I., and Hanafy, A. (2019). Effect of Egg Weight on External and Internal Qualities, Physiological and Hatching Success of Japanese Quail Eggs (*Coturnix japonica*). *Brazilian Journal of Poultry Science*, [online] 21(3): 57-64.
- Iqbal, J., Nasir M., Zaib U.R., Sohail H.K., Tanveer A., Muhammad SA., Riaz H.P., and Sajid U. (2017). Effects of egg weight on the egg quality, chick quality, and broiler

- performance at the later stages of production (week 60) in broiler breeders. *Journal of Applied Poultry Research*, 26(3): 183–191.
- Khaskheli, A.A., Khaskheli, M.I., Khaskheli, A.J. and Khaskheli, A.A. (2020). Dietary influence of *Yucca schidigera* on broilers and layers: A review. *International Journal of Veterinary Science*, 9(1): 458-461.
- Kontecka, H., Nowaczewski, S. and Sierszuła, M.M. (2012). Analysis of changes in egg quality of broiler breeders during the first reproduction period. *Annals of Animal Science*, 12(4): 609–620.
- Kpomasse, C.C., Oke, O.E., Houndonougbo, F.M. and Tona, K. (2021). Broiler production challenges in the tropics: A review. *Veterinary Medicine and Science*, 7(3): 831–842.
- Ledvinka, Z., Zita, L. and Klesalová, L. (2012). Egg quality and some factors influencing it: a review. *Scientia Agriculturae Bohemica*, 43(1): 46–52.
- Mdletshe, C. and Obi, A. (2023). Investigating the Profitability of Government-Funded Small-Scale Broiler Projects in Northern KwaZulu-Natal, South Africa. *Agriculture*, 13(12): 2269–2269.
- Nowaczewski S., Witkiewicz K., Fraczkak M., Kontecka H., Rutkowski A., Krystianiak S., Rosinski A. (2008). Egg quality from domestic and French guinea fowl. *Nauka Przyr Technology*, 2(2): 8–9.
- Orhan, H., Eyduran, E., Tatliyer, A. and Saygici, H. (2016). Prediction of egg weight from egg quality characteristics via ridge regression and regression tree methods. *Revista Brasileira de Zootecnia*, 45(7): 380–385.
- Rebolledo, O.F.P., López, M.F.A., Rivera, J. a. H., Canul, A.C., Isaias, G.T. and Casillas, A.C.G. (2023). Effect of the Line and Age of Female Broiler Breeder on Hatchability Performance of Eggs. *Brazilian Journal of Poultry Science*, [online] 25(01):50.

- Ross Breeders (2018). Parent Stock Management Handbook. https://en.aviagen.com/assets/Tech_Center/Ross_PS/RossPSHandBook2018.pdf.
- Saroj, S., Mana, R.K., Naba, R.D., Neena, A.G. and Nirajan B. (2020). Evaluation of external and internal egg quality traits of indigenous Sakini chicken in different generations of selection. *International Journal of Agriculture and Forestry*, 10(2): 41-48.
- Şekeroğlu, A. and Altuntas, E. (2008). Effects of egg weight on egg quality characteristics. *Journal of the Science of Food and Agriculture*, 89(3): 379 – 383.
- Shi, S.R., Wang, K.H., Dou, T.C. and Yang, H.M. (2009). Egg weight affects some quality traits of chicken eggs. *Journal of Food, Agriculture and Environment*, 7(2): 432-434.
- Singh, S., Raman, K., Taggar, D., Chakraborty, Kumar, A., Kumar, N. and Kumar, D. (2020). Evaluation of egg quality traits of indigenous chickens of India. *Haryana Vet*, 59(2): 157-159.
- Tong, Q., Romanini, C.E., Exadaktylos, V., Bahr, C., Berckmans, D., Bergoug, H., Etteradossi, N., Roulston, N., Verhelst, R., McGonnell, I.M. and Demmers, T. (2013). Embryonic development and the physiological factors that coordinate hatching in domestic chickens. *Poultry Science*, 92(2): 620-628.
- Tumova, E., Skřivan, M., Englmaierová, M. and Zita, L. (2009). The effect of genotype, housing system and egg collection time on egg quality in egg type hens. *Czech Journal of Animal Science*, 54(1): 17–23.
- Tyasi, T.L., Rashijane, L.T., Mokoena, K., Molabe, K.M., Mathapo, M.C., Hloko, V.R., Selala, L.J., Maswana, M. and Bila, L. (2022). Effects of Egg's Weight on Egg Quality Traits of the Potchefstroom Koekoek Chicken Genotype. *Pakistan Journal of Zoology* 54(4):1973-1976.

- Ukwu, H.O., Ezihe, C.O., Asaa., S.K. and Anyogo, M.E. (2017). Effect of egg weight on external and internal egg quality traits of Isa Brown egg layer chickens in Nigeria. *Journal of Animal Science and Veterinary Medicine*, 2(3): 126-132.
- Walkite, F., Habtamu, T., Misgana, D. and Lema, Y. (2019). Review on Chicken Egg Quality Determination, Grading an Affecting Factors. *Asian Journal of Medical Science Research & Review*, 1(1): 34-42.
- Welelaw, E., Aberra, M., Beyan, M. and Taye, M. (2018). Assessing the Performance, Egg Quality, and Carcass Characteristics of Indigenous Chickens Reared Under Traditional Management System. *International Journal of Research Studies in Agricultural Sciences*, 4(10): 27–35.

CHAPTER 3

Systematic review on egg quality characteristics of broiler breeder chickens

3.1 Abstract

Egg quality characteristics influence the performance parameters such as hatchability of broiler breeder chickens. To improve production of broiler breeder chickens, egg quality characteristics require attention. The objective of the current study was to systematically review the literature published on egg quality characteristics of broiler breeder chickens. Four databases such as PubMed, Web of Science, ScienceDirect and Google Scholar were used for searching articles. A total of thirteen articles (n = 13) investigated nineteen egg quality characteristics were found published between the year 2005 and 2024 from Canada, Nigeria, Brazil, Belgium, India, Ghana, Iran, Iraq, Netherlands and China. The results indicated the range of egg weight (53.80 g to 97.05 g), shell weight (5.22 g to 12.09 g), albumen weight (34.2 g to 63.3 g), yolk weight (14.71 g to 31.68 g), Haugh Unit (66.94 to 96.29), albumen weight (34.2 g to 63.3 g), yolk weight (14.71 g to 31.68 g) and egg length (5.38 mm to 5.87 mm). The limitation of the study is that some of the articles did not mention the age of the chickens which makes it difficult to make conclusion per age. In conclusion, egg quality characteristics of broiler breeder chickens had variations on different breeds showing that there might be other factors influencing that such as breed, age and environment factors. More studies need to be conduct on egg characterisations to include many egg quality characteristics.

Keywords: Albumen weight, characterization, egg weight, Haugh Unit, shell thickness.

3.2 Introduction

The broiler industry accounts for over 39% of global meat production (Kpegah *et al.*, 2024). However, the production of chicken meat needs to be optimized to meet the

demand due to the increase in the human population (Alo *et al.*, 2024). As stated by Kpegah *et al.* (2024), egg quality characteristics require attention to improve broiler production. The quality of hatched chicks depends on egg quality characteristics, including egg weight, shell weight, egg length, yolk weight, albumen weight and Haugh unit (Biesek *et al.*, 2023). Alo *et al.* (2024) indicated that egg characteristics influence the performance parameters of broilers, and hatching success of an egg depends on the egg quality characteristics. However, to the best of the authors' knowledge, there is no comprehensive systematic review on egg quality characteristics on broiler breeder chickens. As such, the objective of the study was to systematically review the literature published on egg quality characteristics of broiler breeder chickens. This study will assist in highlighting the egg quality characteristics of broiler breeder chickens.

3.3 Materials and methods

3.3.1 Eligibility criteria

Identification of the Population, Exposure, and Outcomes (PEO) components of the research question was performed for this systematic review. The population was defined as "broiler breeder chickens", with no exposure and outcomes of "egg quality characteristics". Prior to conducting the study, an initial search of the PEO elements on Google Scholar, ScienceDirect, PubMed, and Web of Science was conducted.

3.3.2 Literature search

The literature search for the research publications was done through the use of four data base Google Scholar, PubMed, ScienceDirect, and Web of Science from 2005 to 2024; where the following keywords were made use of: `egg quality characteristics/egg quality traits, egg quality determinants/egg quality attributes` and `broiler breeder chickens/ broiler breeder strain/ broiler breeder genotype`.

3.3.3 Inclusion criteria

Titles and abstracts found using the search strategy were manually screened to recognize articles that were potentially relevant. Articles were included in this systematic review provided that they included egg quality characteristics of broiler breeder chickens.

3.3.4 Exclusion criteria

Studies that were not published in English, the ones using a different species other than chickens, missing one of the keywords, not studying egg quality characteristics and the duplicate studies were also excluded.

3.3.5 Data extraction

The content was extracted independently by the authors. The authors reached a general agreement regarding all key items. The articles that met the criteria had: author, year of publication, country, broiler breed and egg quality traits.

3.4 Results

3.4.1 Searched results

Figure 1 represents the flow chart of the identification and selection of studies for the systematic review. In the primary search, a total of seventy-four ($n = 74$) articles were retrieved. After excluding seven ($n = 7$) duplicate publications, sixty-seven ($n = 67$) articles remained. The articles were screened for title and abstract; thirty-two ($n = 32$) articles were removed. About twenty-seven ($n = 27$) articles were selected for full-text search and eligibility verification, and a total of thirteen ($n = 13$) articles were included in this systematic review.

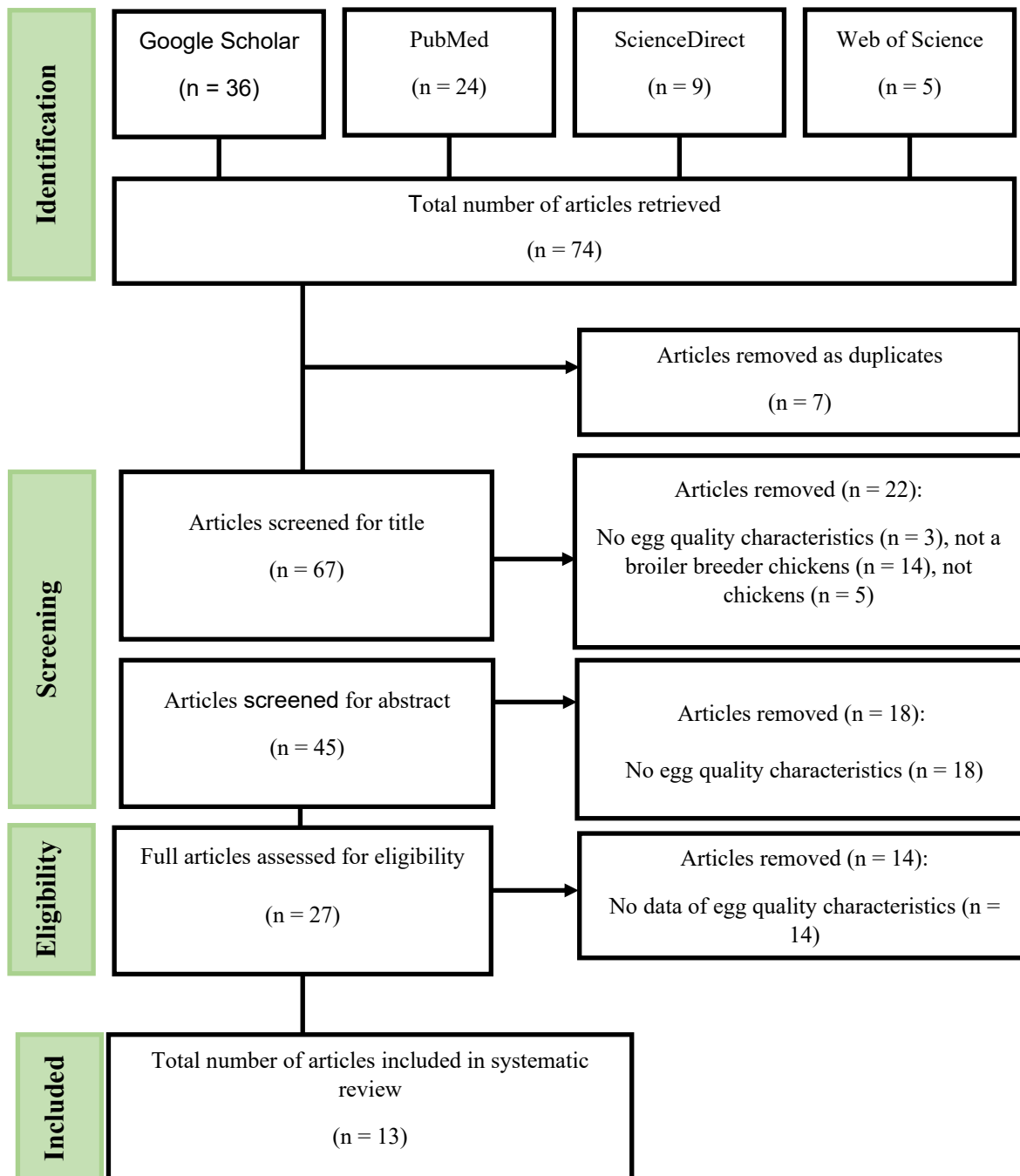


Figure 3.1: Flow chart of identification and selection of studies used in the systematic review

3.4.2 Characteristics of included articles

The characteristics of the thirteen included articles ($n = 13$), which were accessed and selected as meeting the criteria for inclusion in the review, are presented in Table 1. The selected articles ranged from the year 2005 to 2024. These studies were from ten different

countries (n = 10), Canada ranking first with three studies (n = 3), followed by Nigeria with two studies (n = 2); the other countries only had one study each, as shown in Table 1. A total of twelve different chicken breeds (n = 12), including FUNAAB-alpha, Cobb 500, CARIBRO-Vishal, Ross 308, Novoponte, Ross 708, Arbor Acres, SA51A, SA31L, Ascites-resistant dam line (DAR), Ascites-sensitive dam line (DAS), and Ascitesensitive sire line (SASL) chicken breeds, were used within the reviewed articles. All included articles investigated egg quality characteristics of broiler breeder chickens, with egg weight being investigated in all reviewed articles.

Table 3.1: Characteristics of included articles

Authors	Years	Country	Chicken breed	Egg characteristics
Alo et al.	2024	Nigeria	FUNAAB-alpha	Egg weight, egg length, egg width, albumen thickness, albumen diameter, yolk diameter, and Haugh unit.
Bueno et al.	2016	Brazil	Cobb 500	Egg weight, shape index, shell weight, shell thickness, egg width, egg length, and egg specific gravity.
Chaudhary et al.	2018	India	CARIBRO-VISHAL	Egg weight, shell colour, shell thickness, albumen index, Haugh unit, yolk index, shape index and yolk colour.
Dorosti et al.	2019	Iran	Ross 308	Egg weight, shell weight, yolk weight, albumen weight, Haugh unit, and albumen pH.
Halgrain et al.	2024	Canada	Ross 308 and Novoponte	Egg weight, yolk weight, albumen weight, and shell weight.
Hassan and Ali	2018	Iraq	Ross 308 and Arbor Acres	Egg weight, Shell weight, yolk weight, albumen weight, albumen height, yolk height,

				yolk diameter, shell thickness, shape index, and Haugh unit.
Heijmans et al.	2022	Netherlands	Ross 308	Egg weight, shell breaking strength, albumen height, and shell thickness.
Yang et al.	2020	China	Ross 308	Egg weight, albumen height, Haugh unit, yolk colour, and yolk ratio.
Kpegah et al.	2024	Ghana	SA51A and SA31L	Egg weight, egg height, egg width, albumen height, albumen weight, yolk colour, shell thickness, and yolk weight.
Romero et al.	2009	Canada	Ross 708	Egg weight, albumen height, yolk weight, shell weight, albumen weight, and Haugh unit.
Tona et al.	2005	Belgium	Ascites-resistant dam line (DAR), ascites-sensitive dam line (DAS), and ascitesensitive sire line (SASL)	Egg weight, yolk weight, albumen height, Haugh unit, yolk weight, albumen weight, and albumen pH.
Ulmer-Franco et al.	2010	Canada	Cobb 500	Egg weight, shell weight, yolk weight, albumen weight, dry yolk weight, and dry albumen weight.
Biesek et al.	2023	Nigeria	Arbor Acres	Albumen diameter, egg weight, yolk diameter, yolk weight, albumen height, Haugh unit and albumen weight.

3.4.3 Publications by year

Figure 2 below shows the publication by year of included articles (n = 13) in the current systematic review. The findings showed that the included articles were published from the year 2005 to 2024. Most of the articles were published in 2024, with 3 out of 13 included articles (Alo *et al.*, 2024; Halgrain *et al.*, 2024; Kpegah *et al.*, 2024), followed by 2018 (Chaudhary *et al.*, 2018; Hassan and Ali, 2018). The other years (2005, 2009, 2010, 2016, 2019, 2020, 2022, and 2023) had 1 article each out of 13 included articles.

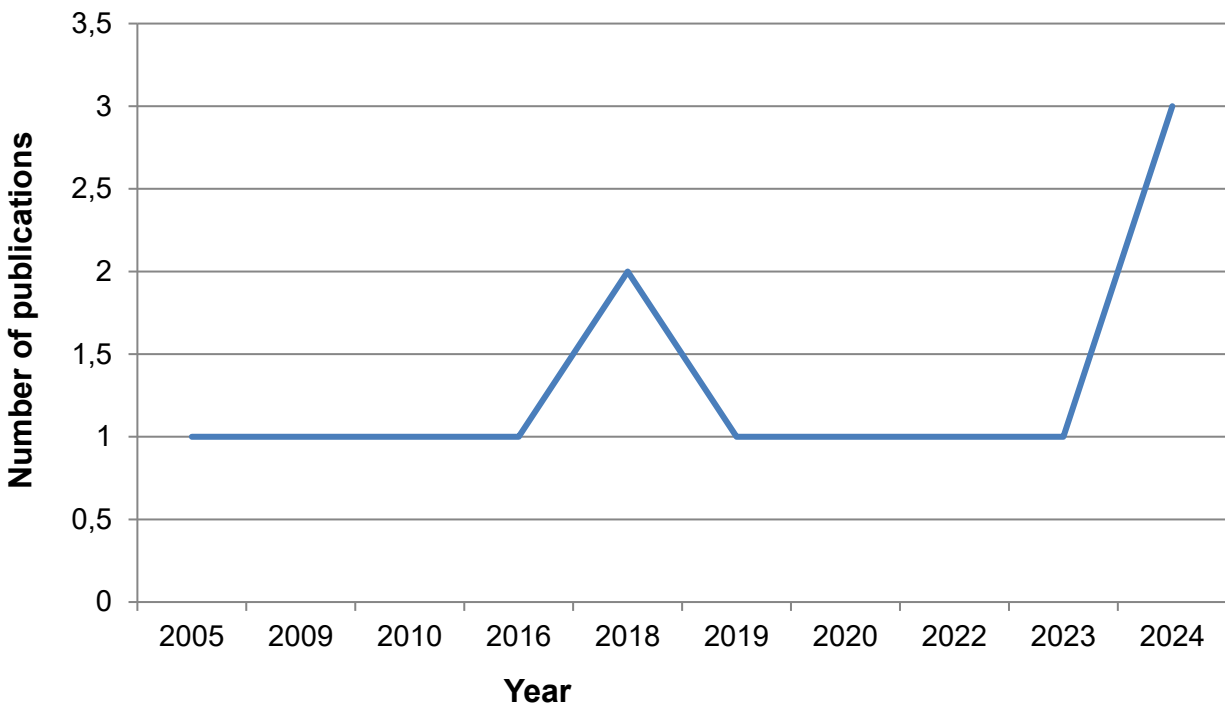


Figure 3.2: Publications by year

3.4.4 Publications by country

Publications by country of included articles in the current systematic review are shown in Figure 3. The results of this systematic review indicated that the included studies were published from ten different countries (n = 10) worldwide. The results indicated that Canada had the highest number of articles (n = 3), followed by Nigeria (n = 2), and Brazil, Belgium, India, Ghana, Iran, Iraq, Netherlands and China had the least number of articles (n = 1) each.

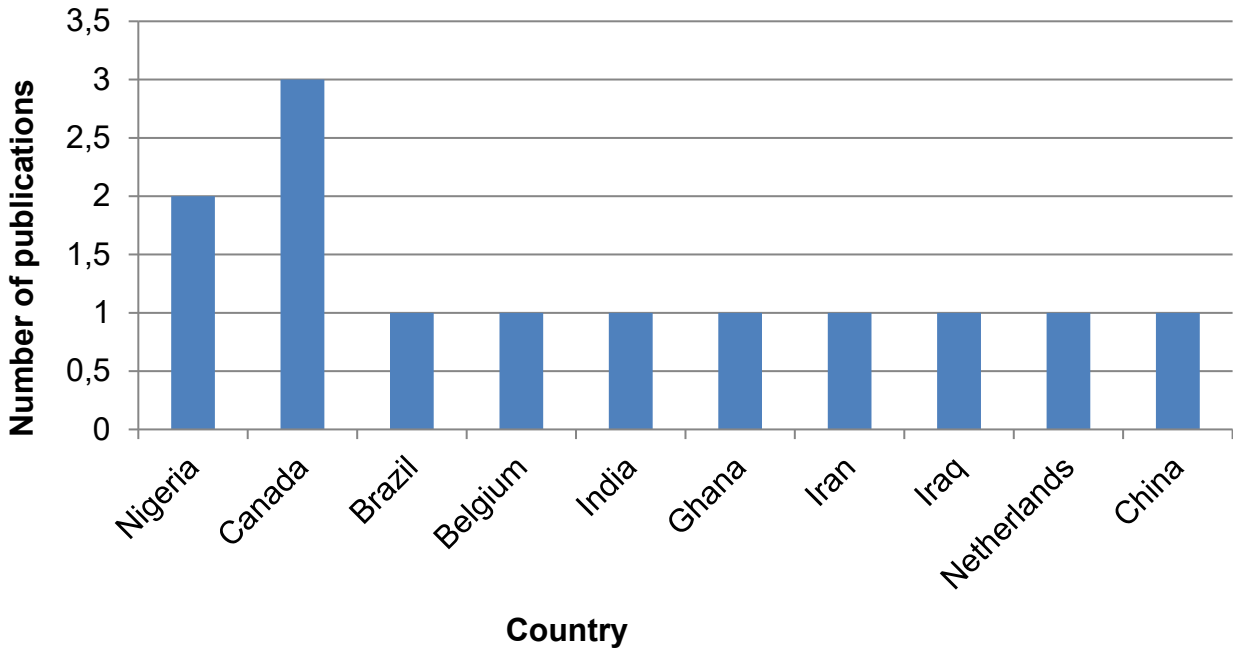


Figure 3.3: Publications by country

3.4.5 Publications by breed

Figure 4 below shows the chicken breeds that were investigated in the included articles. The results indicated that out of the 12 investigated chicken breeds, the Ross 308 chicken breed was the most investigated breed with five articles ($n = 5$). Arbo Acres and Cobb 500 chicken breeds were the second most investigated chicken breeds with two articles ($n = 2$) each. The remaining chicken breeds, such as Funaab-Alpha, Caribo-Vishal, DAR, DAS, SASL, SA51A, Ross 708, Novoponte and SA31 had one article ($n = 1$) each.

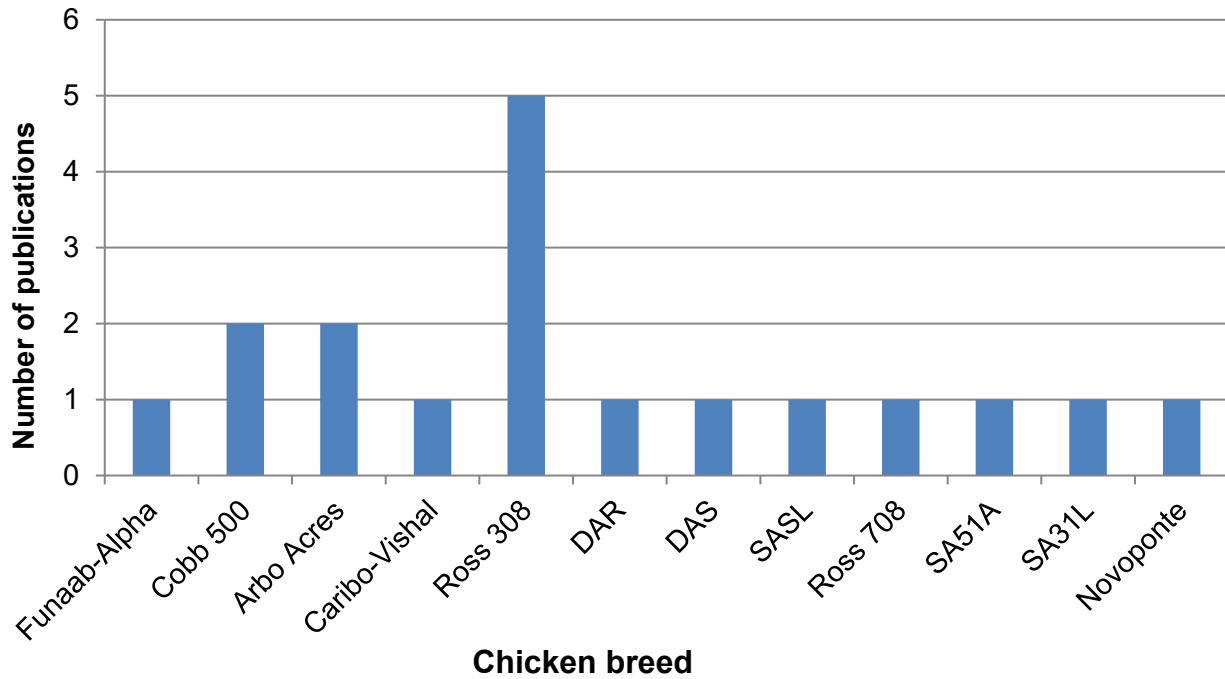


Figure 3.4: Publications by breed

3.4.6 Publication by journals

Article distribution per journals is shown in Figure 5. The results showed that most of the included articles were published in the Poultry Science, with eight articles ($n = 8$), and the other twelve journals used had one article ($n = 1$) each.

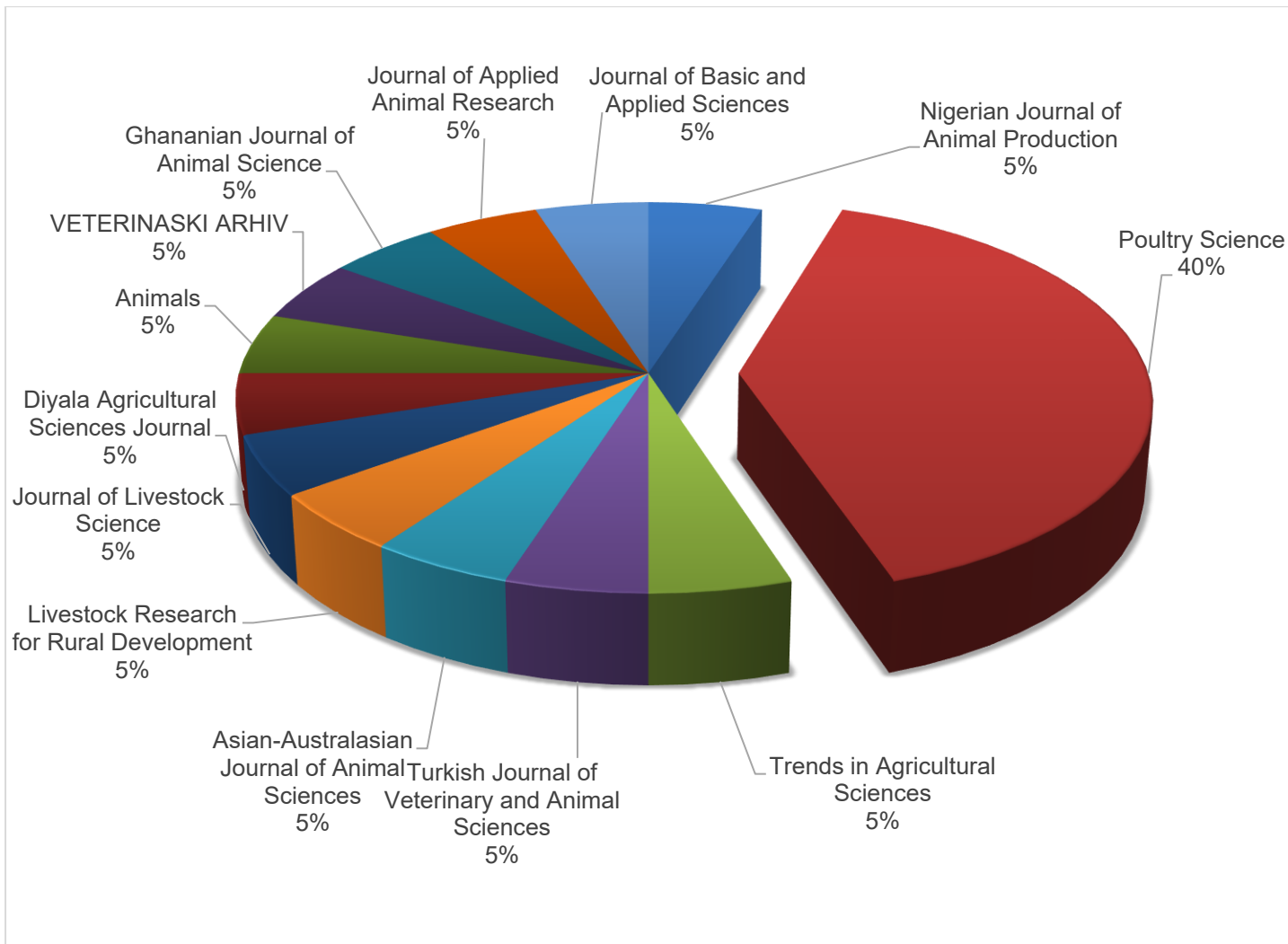


Figure 3.5: Publication by journals

3.4.7 Studied internal egg quality traits

Figure 6 below shows the internal egg quality traits studied in the included articles of the current systematic review. The results showed that about 14 egg quality traits were studied in the included articles. Yolk weight being the most studied internal egg quality trait with nine articles ($n = 9$), followed Haugh unit and albumen weight with eight articles ($n = 8$) each, albumen height with seven articles ($n = 7$), yolk colour and yolk diameter with three articles ($n = 3$) each, albumen diameter, and albumen pH with two articles ($n = 2$) each, while the least studied were albumen thickness, albumen index, yolk index, yolk ratio, yolk height and dry yolk weight with one article ($n = 1$) each.

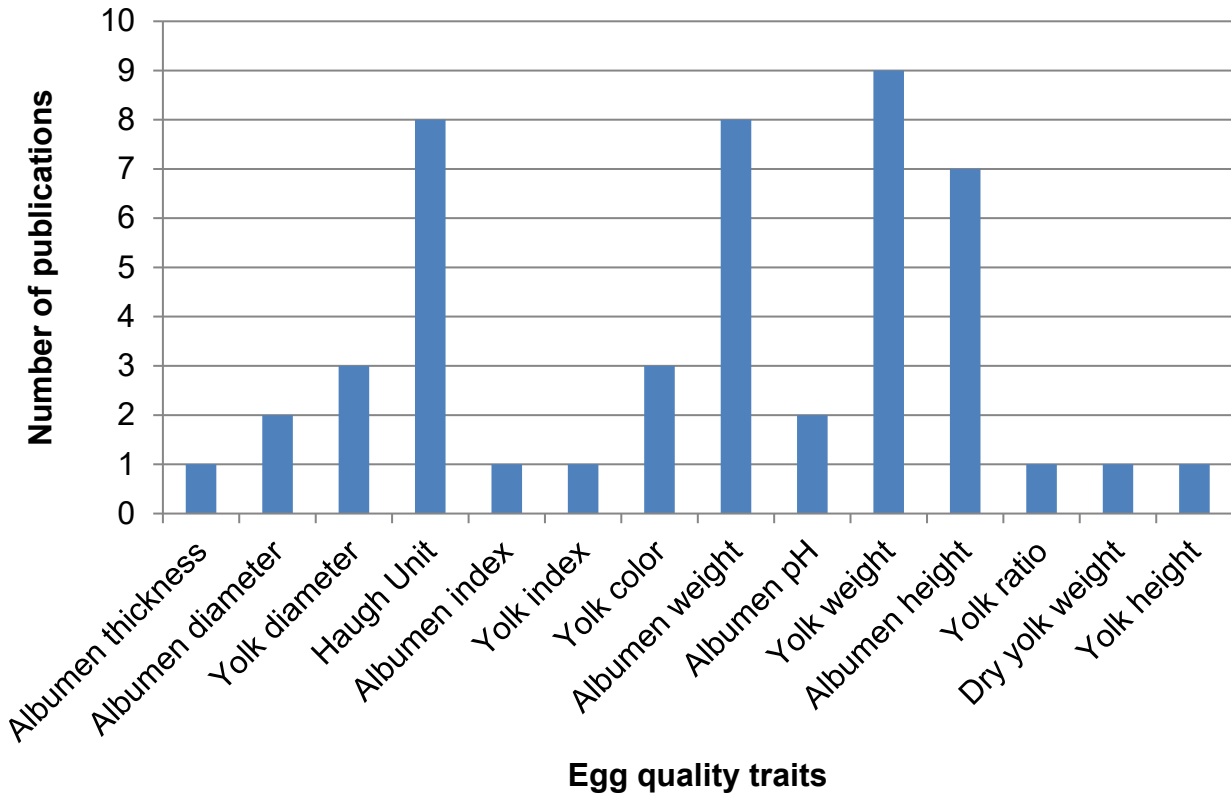


Figure 3.6: Internal egg quality traits

3.4.8 Studied external egg quality traits

Figure 7 below shows the external egg quality traits studied in the included articles in the current systematic review. The results showed that about ten egg quality traits ($n = 10$) were studied in the included articles. Egg weight being the most studied external egg quality trait with thirteen articles ($n = 13$), followed by shell weight with six articles ($n = 6$), shell thickness with five articles ($n = 5$), egg width, and shape index with three articles ($n = 3$) each, egg length, and shell breaking strength with two articles ($n = 2$) each, while the least studied were egg specific gravity, shell colour, and egg height with one article ($n = 1$) each.

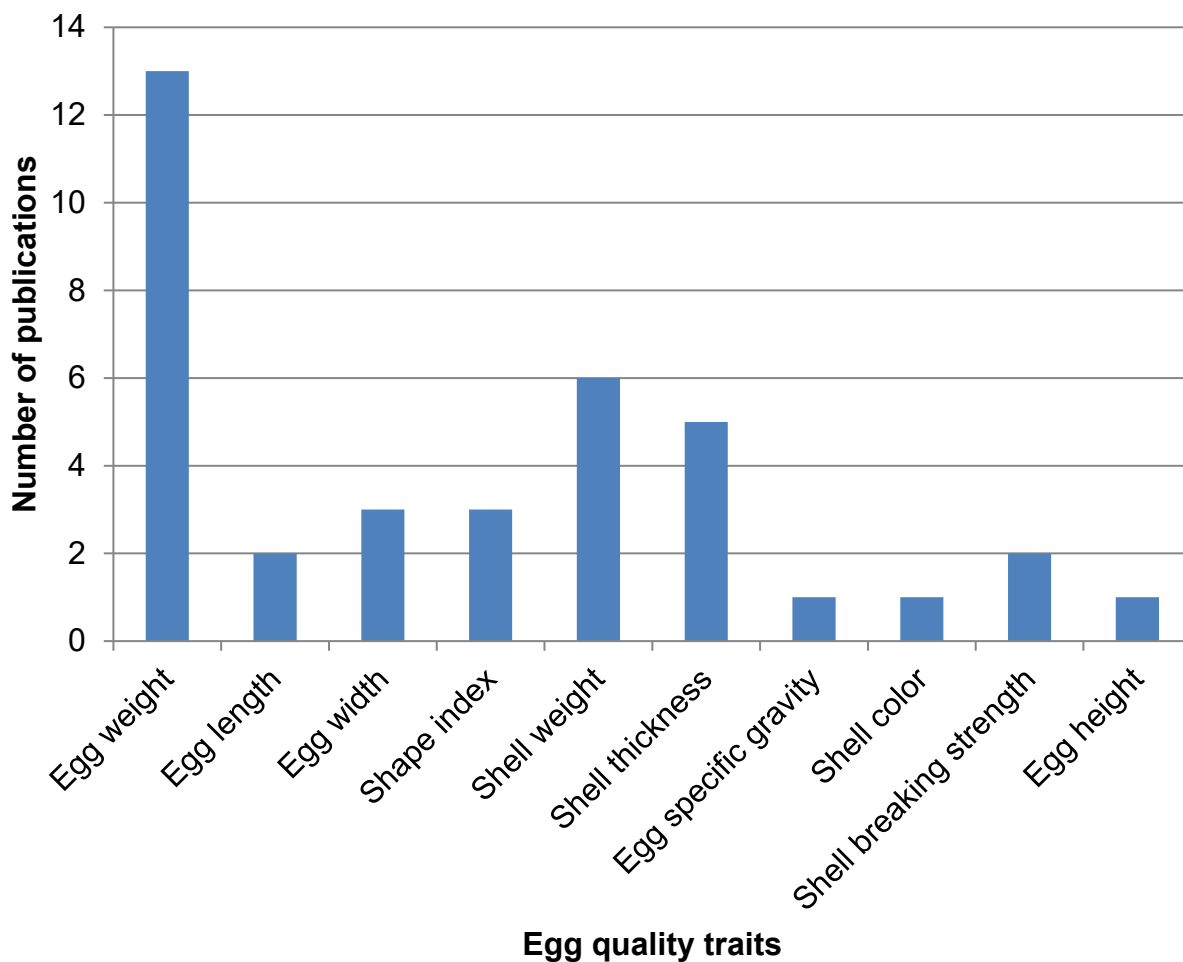


Figure 3.7: External egg quality

3.4.9 Characterization of internal egg quality traits

3.4.9.1 Haugh unit

Table 3 characterises the internal egg quality traits studied from the included articles in this review. Five ($n = 5$) articles out of thirteen ($n = 13$) articles characterised the Haugh unit. The highest value of the Haugh unit was 96.29 (Chaudhar *et al.*, 2018), and the lowest value was 66.94 (Tona *et al.*, 2005).

3.4.9.2 Yolk colour

Two ($n = 2$) articles out of thirteen ($n = 13$) articles characterised the yolk colour as shown in Table 3. The highest value of the yolk colour was 8.22 (Chaudhar *et al.*, 2018), and the lowest value was 3.20 (Kpegah *et al.*, 2024).

3.4.9.3 Albumen weight

Table 3 shows that seven (n = 7) articles out of thirteen (n = 13) articles characterised the albumen weight. The highest value of the albumen weight was 63.3 (Ulmer-Franco *et al.*, 2010), and the lowest value was 34.2 (Alo *et al.*, 2024).

3.4.9.4 Albumen pH

Two (n = 2) articles out of thirteen (n = 13) articles characterised the albumen pH as indicated in Table 3. The highest value of the albumen pH was 0.54 (Tona *et al.*, 2005), and the lowest value was 9.19 (Dorosti *et al.*, 2019).

3.4.9.5 Yolk weight

Seven (n = 7) articles out of thirteen (n = 13) articles characterised the yolk weight as shown in Table 3. The highest value of the yolk weight was 31.68 (Dorosti *et al.*, 2019), and the lowest value was 14.71 (Halgrain *et al.*, 2024).

3.4.9.6 Albumen height

Table 2 shows that two (n = 2) articles out of thirteen (n = 13) articles characterised the albumen height. The highest value of the albumen height was 6.2 (Alo *et al.*, 2024), and the lowest value was 4.74 (Hassan and Ali, 2018).

Table 3.2: Characterisation of internal egg quality traits

Chicken breed	Author
FUNAAB-alpha	Alo et al. (2024)
Cobb 500	Bueno et al. (2016)
CARIBRO-VISHAL	Chaudhar et al. (2018)
Ross 308	Dorosti et al. (2019)
Ross 308	Halgrain et al. (2024)
Novoponte	
Ross 308	Hassan and Ali (2018)
Arbor Acres	
Ross 308	Heijmans et al. (2022)
Ross 308	Yang et al. (2020)
SA51A	Kpegah et al. (2024)
SA31L	
Ross 708	Romero et al. (2009)
DAR	Tona et al. (2005)
DAS	
SASL	
Cobb 500	Ulmer-Franco et al. (2010)
Arbor Acres	Bieseck et al. (2023)

YR	AH	YW	AP	AW	YC	YI	AI	ES	HU	Age	
										HU	(weeks)
-	6.20	15.9	-	34.2	-	-	-	-	79.0	32	
-	5.90	16.8	-	35.2	-	-	-	-	76.1	60	
-	-	-	-	-	-	-	-	1.07	-	74 - 77	
-	-	-	-	-	8.22	50.96	12.76	-	96.29	38	
-	-	31.68	9.19	58.82	-	-	-	-	73.31	41	
-	-	17.55	-	42.81	-	-	-	-	-	45	
-	-	14.71	-	45.54	-	-	-	-	-	33	
-	4.74	23.67	-	44.07	-	-	-	-	74.56	67	
-	-	-	-	-	-	-	-	-	-	67	
-	-	-	-	-	-	-	-	-	-	25 - 28	
-	-	-	-	-	-	-	-	-	-	71	
-	-	15.47	-	38.65	3.20	-	-	-	-	36	
-	-	15.26	-	38.42	3.20	-	-	-	-	36	
-	-	-	-	-	-	-	-	-	-	41	
30.79	-	20.80	9.49	-	-	-	-	-	69.40	-	
32.30	-	20.57	9.49	-	-	-	-	-	68.34	-	
31.14	-	20.60	9.54	-	-	-	-	-	66.94	-	
-	-	-	-	63.3	-	-	-	-	-	29	
-	-	-	-	58.5	-	-	-	-	-	59	
-	-	18.43	-	36.97	-	-	-	-	-	35	

Table 3.3: Characterisation of external egg quality traits

Author	Chicken breed	Age (wks)	Traits						
			ST	SW	SI	EWD	EW	EL	SC
Alo et al. (2024)	FUNAAB-alpha	32	-	6.9	-	4.22	57.0	5.56	-
		60	-	7.4	-	4.28	59.4	5.68	-
Bueno et al. (2016)	Cobb 500	74 – 77	0.39	6.36	0.73	-	71.3	-	-
Chaudhary et al. (2018)	CARIBRO-VISHAL	38	0.69	-	71.63	-	60.42	-	4.00
Dorosti et al. (2019)	Ross 308	41	-	8.54	-	-	97.05	-	-
Halgrain et al. (2024)	Ross 308	45	0.38	5.22	-	-	60.36	-	-
	Novoponte	33	0.42	5.96	-	-	60.25	-	-
Hassan and Ali (2018)	Ross 308	67	0.41	12.09	62.53	-	79.85	-	-
	Arbor Acres	67	-	-	-	-	-	-	-
Kpegah et al. (2024)	SA51A	36	0.35	-	77.27	4.53	60.63	5.87	-
	SA31L	36	0.36	-	76.15	4.47	59.59	5.47	-
Tona et al. (2005)	DAR	-	-	-	-	-	64.93	-	-
	DAS	-	-	-	-	-	62.38	-	-

	SASL	-	-	-	-	-	65.36	-	-
Ulmer-Franco et al. (2010)	Cobb 500	29	-	8.8	-	-	53.80	-	-
		59	-	8.6	-	-	71.30	-	-
Biesek et al. (2023)	Arbor Acres	35	-	5.61	77.17	4.14	61.01	5.38	-

- : not indicated, EW: Egg weight (g), EL: Egg length (mm), EWD: Egg width (mm), SI: Shape index (%), SW: Shell weight (g), ST: Shell thickness (mm), SC: Shell colour

3.5 Discussion

Egg quality characteristics are important for the growing embryo (Ulmer-Franco *et al.*, 2010). Study of egg quality characteristics that influence the production of high-quality chicks is of great interest to broiler breeders (Ulmer-Franco *et al.*, 2010). The objective of this chapter was to systematically review thirteen (n = 13) articles on egg quality characteristics of broiler breeder chickens published from the year 2005 to 2024. The results indicated that 19 egg quality characteristics were studied in the included articles. Egg weight was the most studied egg quality characteristic, showing the highest value of 97.05 g and the lowest value of 53.80 g. The majority of the reviewed articles emphasized the egg weight as one of the most important egg quality characteristics, influencing the subsequent productivity of broiler breeder chickens (Kpegah *et al.*, 2024). Romero *et al.* (2009) reported that a greater egg weight and a greater proportion of albumen provide broilers with advantages for embryonic growth. It is known that as hen ages, egg weight increases, shell thickness decreases, and the proportion of yolk increases at the expense of albumen and eggshell (Ulmer-Franco *et al.*, 2010). The shell controls the exchange of water and gases through the pores in the shell and serves as a calcium source (Heijmans *et al.*, 2022). The highest value of yolk weight was 63.3 g, the lowest value was 34.2 g, and the highest value of the albumen weight was 63.3 g, and the lowest value was 34.2 g. Ulmer-Franco *et al.* (2010) reported that the proportions of components of the hatching egg are also affected by egg size, with small eggs having a greater proportion of yolk than large eggs from the same flock age. Heijmans *et al.* (2022) explained that both the albumen and the yolk are important sources of protein for tissue synthesis in the growing embryo, and the yolk is an essential source of energy. In turn, it is expected that a larger yolk will be beneficial for chick quality (Heijmans *et al.*, 2022). Among other factors, the quantity and quality of nutrients, albumen and shell of the egg, are some of the factors that determine the quality of the day-old chick (Heijmans *et al.*, 2022). The strength of this systematic review is based on the authors' knowledge; it is the first systematic review reporting on the egg quality characteristics of broiler breeder chickens. Therefore, there is no comparison of other systematic review findings in the topic. The implication of this systematic review is that the egg quality characteristics are different from broiler breed to boiler breed. The contribution of this systematic review to the body of knowledge is that

egg quality characteristics showed different values in different broiler breeders. The limitations of this systematic review are: (i) some of the articles did not mention the age of the chickens which makes it difficult to conclude per age (ii) no similar data were found to proceed to meta-analysis. This systematic review suggests that there were insufficient studies on egg quality characteristics of broiler breeder chickens. Therefore, there is a need to conduct more studies that will focus on investigating this topic to provide more information.

3.6 Conclusion

In the current systematic review, the results indicated that of the egg quality characteristics investigated, egg weight was the most characterised egg quality characteristic in the included articles. All the studied egg quality traits showed different values in different broiler breeders. Therefore, more research is required to characterise more of the quality of the egg characteristics.

3.7 References

- Alo, E.T., Daramola, J.O., Wheto, M. and Oke, O.E. (2024). Impact of broiler breeder hens' age and egg storage on egg quality, embryonic development, and hatching traits of FUNAAB-alpha chickens. *Poultry Science*, 103(2): 103313–103313.
- Bettany-Saltikov, J., (2010): Learning how to undertake a systematic review: Part 2. *Nursing Standard*, 24(9): 47–56.
- Biesek, J., Wlaźlak, S. and Adamski, M. (2023). The biological value of hatching eggs of broiler chicken in the early-mid incubation period based on physicochemical and morphologic features. *Poultry Science*, 102(6): 102-689.
- Bueno, I.J.M., Surek, D., Rocha, C., Schramm, V.G., Muramatsu, K., Dahlke, F. and Maiorka, A. (2019). Effects of different limestone particle sizes in the diet of broiler breeders post molting on their performance, egg quality, incubation results, and pre-starter performance of their progeny. *Poultry Science*, 95(4), 860–866.
- Chaudhary, S.K., Mandal, A.B., Bhar, R., Gopi, M., Kannan, A., Jadhav, S.E. and Rokade, J.J. (2019). Effect of graded levels of soapnut (*Sapindus mukorossi*)

- shell powder on reproductive performance in broiler breeders. *Asian-Australasian Journal of Animal Sciences*, 32(1): 118–125.
- Dorosti, M.A., Teli, A.Shaddel. and Salmanzadeh, M. (2019). Effects of coating breeding eggs with different materials on quality of stored eggs and hatching results. *Journal of Livestock Science*, 2(2):38.
- Hassan, K.H. and Ali, W.F. (2018a). Effect of force molting on egg production and egg quality traits of broiler breeder hens. *Diyala Agricultural Sciences Journal*, [online] 10(special Issue): 210–216.
- Halgrain, M., Schneider, M., Jia, S., Narcy, A., Gambier, E., Hincke, M.T., McKee, M.D., Réhault-Godbert, S. and Reznikov, N. (2024). A 3D micro-computed tomography study comparing embryonic skeletal development in layer versus broiler strains of the domestic chicken. *Poultry Science*, 103(12), pp.104308–104308.
- Heijmans, J., Duijster. M., Gerrits, W.J.J., Kemp., B., Kwakkel., R.P and van den Brand., H. “Impact of Growth Curve and Dietary Energy-To-Protein Ratio on Productive Performance of Broiler Breeders.” *Poultry Science*, 100(7): 101131–101131.
- Kpegah, D.K., Adomako., K and Olympio., O.S. “The evaluation of laying performance, egg quality, fertility, hatchability, and chick quality of SA51A and SA31L broiler breeders in Ghana.” *Ghanaian Journal of Animal Science*, 15(1), 2024: 677-788.
- Maeva Halgrain, Schneider, M., Jia, S., Agnès Narcy, Gambier, E., Hincke, M.T., McKee, M.D., Réhault-Godbert, S. and Reznikov, N. (2024). A 3D micro-computed tomography study comparing embryonic skeletal development in layer versus broiler strains of the domestic chicken. *Poultry Science*, 103(12):104308–104308.
- Romero, L.F., Zuidhof, M.J., Renema., R.A., Naeima., A.N and Robinson., F. “Effects of Maternal Energetic Efficiency on Egg Traits, Chick Traits, Broiler Growth, Yield, and Meat Quality.” *Poultry Science*, 88(1): 236–245.
- Tona, K., Kemps, B., Bruggeman, V., Bamelis, F., De Smit, L., Onagbesan, O., De Baerdemaeker, J. and Decuypere, E. (2005). Comparison of three lines of broiler breeders differing in ascites susceptibility or growth rate. 1. Relationship between

acoustic resonance data and embryonic or hatching parameters. *Poultry Science*, 84(9): 1439–1445.

Ulmer-Franco, A.M., Fasenko, G.M and O'Dea Christopher, E.E. “Hatching egg characteristics, chick quality, and broiler performance at 2 breeder flock ages and from 3 egg weights.” *Poultry Science*, 89 (12): 2735–2742.

Yang, J., Ding, X., Bai, S., Wang, J., Zeng, Q., Peng, H., Xuan, Y., Su, Z. and Zhang, K. (2020). The Effects of Broiler Breeder Dietary Vitamin E and Egg Storage Time on the Quality of Eggs and Newly Hatched Chicks. *Animals*, 10(8), 409.

CHAPTER 4

Effect of egg weight on egg quality and prediction of egg weight of Ross 308 broiler breeder chickens

4.1 Introduction

Chicken egg is a naturally designed for reproduction and nourishing the developing embryo (Ukwu *et al.*, 2017). In addition to being used for reproduction, chicken eggs are an important source of food for humans (Alkan *et al.*, 2014), which is accessible to all social classes, regardless of wealth status (Ukwu *et al.*, 2017). In the poultry industry, chicken eggs are quite essential for the growth of the economy of a country (Orhan *et al.*, 2016). In the egg production industry, egg weight is one of the crucial traits that need serious attention (Tyasi *et al.*, 2022), and they must be regularly inspected for quality (Shi *et al.*, 2009). Shi *et al.* (2009) and Hegab *et al.* (2019), reported that among the external and internal egg quality traits that are important for both reproduction and table eggs, egg weight is one of the primary factors that influence internal and external egg quality traits in poultry. Egg weight can be determined without breaking or shattering the egg and it is directly proportional to yolk, albumen, and shell (Shi *et al.*, 2009; Alkan *et al.*, 2014). Chicken egg weight is affected by many factors such as breed, age, diseases, strain, hen body size, water and feed consumption (Alkan *et al.*, 2014). When determining the quality of poultry eggs, various factors including egg weight in relation to internal and external quality traits should be taken into consideration, because the quality of the egg affects chick quality and future herd performance in breeding stocks (Celik *et al.*, 2018). To the best authors' knowledge, there is no documented study on the effect of egg weight and its prediction from egg quality traits of Ross 308 broiler breeder chicken breed. Hence, the objectives of the study were i) to quantify the egg weight and egg quality traits, ii) to determine effect of egg weight on egg quality traits iii) to quantify the egg weight and egg quality traits, and iv) to estimate egg weight from egg quality traits of Ross 308 broiler chicken breed. This study will help Ross 308 broiler breeder farmers on traits to focus on when breeding for improved egg weight.

4.2 Materials and methods

4.2.1 Eggs purchase

A total of 1000 Ross 308 broiler breeder eggs were purchased and used for this study from Daybreak Farms at Merino Vlakte near Bela Bela town. The farm is located at 24°992 S longitude and 28°294 E latitude, and the estimated terrain elevation above sea level is 1100 meters. The maximum and minimum temperatures in this location are 30 °C and 19 °C, respectively. The farm receives annual rainfall of less than 636 mm, with most rainfall occurring during summer (Shabalala *et al.*, 2019). The eggs were bought during the peak period (hens aged 30 weeks) and transported with suitable transport and a portable refrigerator to avoid possible deterioration to the University of Limpopo Animal laboratory for data collection.

4.2.2 Breeding stock management

The chickens were housed under intensive production conditions at Daybreak Farms. The chicken houses were well-ventilated, where curtains opened automatically to control the ventilation and the temperature in the chicken houses. Wood shavings were used as bedding material in the nest boxes and on the floor. The chicken houses were cleaned seven days before the chickens arrived and disinfected to avoid transmission of pathogenic diseases to the chickens. The biosecurity protocols were followed in the area, where the footbaths and hand sprays with disinfectants were placed at the door for disinfection before entering the chicken houses. The feed and water were provided *ad libitum*. Feeds, light program and other management conditions were administered to broiler breeder chickens in accordance with Ross breeder guidelines and recommendations (Ross Breeders, 2018). Vaccinations and medication were carried out following the company's comprehensive health management plan.

4.2.3 Experimental design

A completely randomized design was used. A total of 1000 eggs were randomly selected during the purchase from the Ross 308 broiler breeder chickens. The eggs were classified into three (3) different egg weight groups such as small egg (< 60 g), medium egg (60-69 g) and large egg (> 69 g).

4.2.4 External egg quality traits collection

The egg weight and external egg quality traits such as egg length, egg width and shell weight were measured in the study as described by Kgwatalala *et al.* (2013). Egg weight was measured using an electronic scale with a precision of 0.01 g, whereas egg length and width were determined with a digital vernier calliper with an accuracy of 0.01 mm. Shell weight was determined by weighing the shell on the electronic weighing scale. Other external egg quality traits, including egg shape index, shell surface area, unit surface shell weight and shell ratio, were calculated using formulas as recommended by Tyasi *et al.* (2022):

$$\text{Shape index (\%)} = (\text{Egg width}) / (\text{Egg length}) \times 100$$

$$\text{Shell surface area (cm}^2\text{)} = 3.9782 \times \text{egg weight}^{0.75056}$$

$$\text{Unit surface shell weight (g/cm}^2\text{)} = (\text{Shell weight}) / (\text{Shell surface area})$$

$$\text{Shell ratio (\%)} = (\text{Shell weight}) / (\text{Egg weight}) \times 100$$

4.2.5 Internal egg quality traits collection

The internal egg quality traits that were measured include egg yolk weight and albumen weight. Internal egg quality traits were measured following the procedure of Ashraf *et al.* (2016). Briefly, the individual eggs were carefully broken out, cautious not to break the membranes that enclose the egg yolk and albumen. The egg yolk was carefully separated from the albumen using an egg yolk separator, and the weight of the egg yolk was determined using an electronic scale. Albumen weight was calculated by subtracting the yolk weight and the shell weight from the whole egg weight. Other internal egg quality traits like albumen ratio, yolk ratio, yolk/albumen and egg volume were calculated using the formulas as indicated by Tyasi *et al.* (2022).

$$\text{Albumen weight (g)} = \text{egg weight} - (\text{yolk weight} + \text{shell weight})$$

$$\text{Albumen ratio (\%)} = \text{albumen weight} / \text{egg weight} \times 100$$

$$\text{Yolk ratio (\%)} = \text{yolk weight} / \text{egg weight} \times 100$$

$$\text{Yolk / albumen} = \text{yolk weight} / \text{albumen weight} \times 100$$

4.2.6 Statistical analysis

Statistical Package for Social Sciences version 29.0 (IBM SPSS, 2023) was used to analyze the data. Descriptive statistics, One-way Analysis of Variance (ANOVA), Pearson's Correlation and Stepwise regression were used as statistical techniques for data analysis. The following ANOVA model was used:

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

Where,

Y_{ij} : j^{th} observation (egg quality traits) of the j^{th} treatment (egg weight).

μ : Overall mean.

S_i : Effect of the i^{th} treatment (i = age and egg weight).

e_{ij} : Residual error.

The following stepwise regression model was used:

$$Y = a + b_1X_1 + \dots + b_nX_n$$

Where,

Y = dependent variable (egg weight), a = intercept, $b_1 - b_n$ = coefficient of regression, and $X_1 - X_n$ = independent variables (egg quality traits). The significance was observed at $p < 0.05$.

4.3 Results

4.3.1 Descriptive statistics of external egg quality traits

Descriptive statistics of external egg quality traits such as egg weight (EW), egg length (EL), egg width (EWD), shell weight (SW), shape index (SI), shell surface area (SA), unit surface shell weight (USW) and shell ratio (SR) are presented in Table 1. The results indicated that SA had the highest mean value (84.95), and the lowest mean value (0.10) was found in USW, compared to the other external egg quality traits.

Table 4.1: Descriptive statistics of external egg quality traits

Trait	Minimum	Maximum	Mean	Standard error	Standard deviation
Egg weight (g)	32.59	98.25	59.30	1.04	11.20
Egg length (mm)	46.61	70.36	56.09	0.41	4.44
Egg width (mm)	23.07	51.75	42.87	0.29	3.08
Shell weight (g)	4.37	9.84	6.94	0.09	0.92
Shape index (%)	37.58	82.73	76.66	0.47	5.08
Shell surface area (mm ²)	54.37	124.47	84.95	1.10	11.75
Unit shell weight (g)	0.04	0.10	0.08	0.00	0.01
Shell ratio (%)	5.51	16.38	11.87	0.12	1.30

4.3.2 Descriptive statistics of internal egg quality traits

Descriptive statistics of internal egg quality traits such as yolk weight (YW), albumen weight (AW), albumen ratio (AR), yolk ratio (YR) and yolk/albumen (Y/A) are presented in Table 2. The results indicated that AR had the highest mean value (59.12), and the YW had the lowest mean value (17.35) than the other internal egg quality traits.

Table 4.2: Descriptive statistics of internal egg quality traits

Trait	Minimum	Maximum	Mean	Standard error	Standard deviation
Yolk weight (g)	5.31	34.02	17.35	0.47	5.00
Albumen weight (g)	15.11	67.68	35.00	0.64	6.87
Albumen ratio (%)	46.36	76.78	59.12	0.39	4.16
Yolk ratio (%)	14.94	40.23	29.01	0.40	4.25
Yolk/Albumen (%)	21.02	86.76	49.78	1.00	10.58

4.3.3 Effect of egg weight on external egg quality traits

The effect of egg weight on external egg quality traits are shown in Table 4. The results showed that egg weight affects all measured external egg quality traits. The results showed that the medium egg weight group had a higher ($P < 0.05$) EW, EL, EWD, SW, SI and SA than the small and large egg weight groups.

Table 4.3: Effect of egg weight on external egg quality traits

Trait	Egg weight groups		
	Small	Medium	Large
Egg weight (EW)	54.53 ± 0.52 ^c	62.18 ± 0.50 ^b	84.99 ± 2.31 ^a
Egg length (EL)	54.18 ± 0.22 ^c	57.58 ± 0.64 ^b	65.97 ± 0.72 ^a
Egg width (EWD)	42.10 ± 0.17 ^b	42.59 ± 1.33 ^b	47.87 ± 0.57 ^a
Shell Weight (SW)	6.66 ± 0.07 ^c	7.24 ± 0.13 ^b	8.32 ± 0.35 ^a
Shell index (SI)	77.77 ± 0.30 ^a	74.29 ± 2.69 ^b	72.62 ± 0.85 ^b

Shell surface area (SA)	79.94 ± 0.53 ^b	88.28 ± 0.53 ^b	111 ± 2.28 ^a
Unit surface shell weight (USW)	0.08 ± 0.00 ^a	0.08 ± 0.00 ^a	0.07 ± 0.00 ^b
Shell ratio (SR)	12.25 ± 0.11 ^a	11.65 ± 0.16 ^a	9.81 ± 0.38 ^b

a, b, c: means in the same row with different superscripts are significantly ($P < 0.05$) different.

4.3.4 Effect of egg weight on internal egg quality traits

Table 3 presents the effect of egg weight on internal egg quality traits. The results indicated that egg weight affected ($P < 0.05$) all the measured internal egg quality traits. The results indicated that the large egg weight group had higher ($P < 0.05$) YW (28.16 ± 1.62), YR (33.32 ± 1.92) and Y/A (33.32 ± 1.92) than small and medium egg weight groups.

Table 4.4: Effect of egg weight on internal egg quality traits

Trait	Egg weight groups		
	Small	Medium	Large
Yolk weight (YW)	15.55 ± 0.25 ^c	17.48 ± 0.26 ^b	28.16 ± 1.62 ^a
Albumen weight (AW)	32.31 ± 0.35 ^a	37.46 ± 0.51 ^b	48.51 ± 2.53 ^c
Albumen Ratio (AR)	59.27 ± 0.36 ^{ab}	60.22 ± 0.51 ^a	56.86 ± 2.20 ^b
Yolk ratio (YR)	28.47 ± 0.38 ^b	28.13 ± 0.47 ^b	33.32 ± 1.92 ^a
Yolk/albumen (Y/A)	48.50 ± 0.95 ^b	46.86 ± 1.17 ^b	33.32 ± 1.92

a, b, c: means in the same row with different superscripts are significantly ($P < 0.05$) different.

4.3.5 Correlation matrix between external egg quality traits

The relationship between external egg quality traits of Ross 308 broiler breeder chickens is presented in Table 5. The results indicated that EW had a highly significant positive

correlation ($P < 0.01$) with EL ($r = 0.92$), EWD ($r = 0.73$), SW ($r = 0.75$) and SA ($r = 1.00$); and negative statistical correlation with SI ($r = -0.28$), USW ($r = -0.37$) and SR ($r = -0.67$).

Table 4.5: Correlation between external egg quality traits

Trait	EW	EL	EWD	SW	SI	SA	USW	SR
EW	1							
EL	0.92**	1						
EWD	0.73**	0.56**	1					
SW	0.75**	0.64**	0.55**	1				
SI	-0.28**	-0.54**	0.40**	-0.14 ^{ns}	1			
SA	1.00**	0.92**	0.73**	0.75**	-0.27**	1		
USW	-0.37**	-0.41**	-0.30**	0.33**	0.18*	-0.37**	1	
SR	-0.67**	-0.67**	-0.49**	-0.03 ^{ns}	0.24*	-0.67**	0.93**	1

^{ns}= not significant; * = Correlation is significant at the 0.05 level, ** = Correlation is significant at the 0.01 level, EW = Egg weight; EL = Egg length; EWD = Egg width; SW = Shell weight; SI = Shell index; SR = Shell ratio; USW = Unit surface shell weight; SA = Shell surface area.

4.3.6 Correlation matrix between internal egg quality traits

Table 6 shows the relationship between internal egg quality traits of Ross 308 broiler breeder chickens. The results indicated that YW had a high positive correlation ($P < 0.01$) with AW ($r = 0.57$), YR ($r = 0.74$) and Y/A ($r = 0.71$), and a negative correlation with AR ($r = -0.59$).

Table 4.6: Correlation between internal egg quality traits

Trait	YW	AW	AR	YR	Y/A
YW	1				

AW	0.57**	1		
AR	-0.59**	0.28**	1	
YR	0.74**	-0.06 ^{ns}	-0.95**	1
Y/A	0.71**	-0.10 ^{ns}	-0.96**	0.99 1

**

^{ns}= no significant, **= Correlation is significant at the 0.01 level.

YW= Yolk weight; AW= Albumen weight; AR= Albumen ratio; YR= Yolk ratio; Y/A= Yolk/Albumen

4.3.7 Correlation matrix between external and internal egg quality traits

The relationship between external and internal egg quality traits of Ross 308 broiler breeder chickens is presented in Table 7. The results indicated that EW had a highly significant positive correlation ($P < 0.01$) with EL ($r = 0.92$), EWD ($r = 0.73$), SW ($r = 0.75$) and SA ($r = 1.00$); and negative statistical correlation with SI ($r = -0.28$), USW ($r = -0.37$) and SR ($r = -0.67$).

Table 4.7: Correlation between internal and external egg quality traits

Trait	EW	EL	EWD	SW	SI	SA	USW	SR	YW	AW	AR	YR	Y/A
EW	1												
EL	0.92**	1											
EWD	0.73**	0.56**	1										
SW	0.76**	0.64**	0.55**	1									
SI	-0.3**	-0.54**	0.40**	-0.14 ^{ns}	1								
SA	1.00**	0.92**	0.73**	0.75**	-0.27**	1							
USW	-0.37**	-0.41**	-0.26**	0.33**	0.18*	-0.37**	1						
SR	-0.70**	-0.70**	-0.49**	-0.03 ^{ns}	0.24*	-0.67**	0.93**	1					
YW	0.85**	0.82**	0.63**	0.69**	-0.27**	0.85**	-0.27**	-0.53**	1				
AW	0.91**	0.82**	0.66**	0.58**	-0.24*	0.91**	-0.46**	-0.69**	0.57**	1			
AR	-0.12 ^{ns}	-0.16 ^{ns}	-0.12 ^{ns}	-0.29**	0.06 ^{ns}	-0.12 ^{ns}	-0.18 ^{ns}	-0.09 ^{ns}	-0.59**	0.28**	1		

YR	0.32**	0.36**	0.27**	0.29**	-0.13 ^{ns}	0.32**	-0.11 ^{ns}	-0.22*	0.74**	-0.06 ^{ns}	-0.95**	1	
Y/A	0.28**	0.33**	0.23*	0.28**	-0.13 ^{ns}	0.28**	-0.06 ^{ns}	-0.16 ^{ns}	0.71**	-0.10 ^{ns}	-0.96**	0.99**	1

^{ns}= no significant; * = Correlation is significant at the 0.05 level, ** = Correlation is significant at the 0.01 level, EW = Egg weight; EL = Egg length; EWD = Egg width; YW = Yolk weight; AW = Albumen weight; SW = Shell weight; SI = Shell index; SR = Shell ratio; AR = Albumen ratio; YR = Yolk ratio; Y/A = Yolk/Albumen; USW = Unit surface shell weight; SA = Shell surface area.

4.3.8 Prediction of egg weight

Stepwise regression exploration was conducted to fit the best model for prediction of egg weight of Ross 308 broiler breeder chickens as shown in Table 8. The results revealed that in the case of external traits, SA alone accounted for 100% variation in egg weight, and the addition of other traits did not make any remarkable difference in improving the egg weight of Ross 308 broiler breeder chickens. Further, the results showed that under internal egg quality traits, YW alone accounted for 72% of the variation in egg weight. Meanwhile, the inclusion of YR improved the accuracy to 95%, while the inclusion of AW and AR improved the accuracy to 100%.

Table 4.8: Best-fitted regression models with stepwise regression analysis

Estimators	Models	R ²	MSE	P-value
External traits as estimators				
SA	$EW = -21.60 + 0.95SA$	1.00	14284.31	0.000
Internal traits as estimators				
YW	$EW = 26.26 + 1.90YW$	0.72	35.17	<0.001
YW and YR	$EW = 59.79 + 3.08YW - 0.951.86YR$	0.95	7.06	<0.001
YW, YR and AW	$EW = 8.97 + 1.28YW - 1.86YR + 0.96AW$	1.00	0.34	<0.001
YW, YR, AW and AR	$EW = 58.72 + 1.10YW - 1.000.64YR + 1.12AW - 0.67AR$	1.00	0.05	<0.001

EW = Egg weight, SA = Shell surface area, YW = Yolk weight, YR = Yolk ratio, AW = Albumen weight, AR = Albumen ratio.

4.4 Discussion

Egg quality characteristics influence the development of the embryo, egg hatchability, and growth performance of the produced chicks (Ukwu *et al.*, 2017). Egg weight is one of the most important characteristics because each component of the egg depends on it (Tumova *et al.*, 2009). Egg weight is important in broilers because egg weight together with other egg quality traits affect both hatchability and hatching weight of chickens Hegab *et al.* (2019). Hence, this study was conducted firstly to quantify the egg weight and egg quality traits of Ross 308 broiler breeder chickens. Descriptive statistics were used, and the results indicated that egg weight, egg length, egg width and shell weight had a mean of 59.30 g, 56.09 mm, 42.87 mm and 6.94 g, respectively. The findings of the present study were similar to those reported by Abanikannda *et al.* (2007) on Harco-chicken layer genotype. However, the results of Ukwu *et al.* (2017) on Isa Brown egg layer chickens and Tyasi *et al.* (2022) on the Potchefstroom Koekoek chicken genotype are higher than the results of the present study. These differences may be the result of breed differences, as Khan. *et al* (2004) showed that the breed of the bird affects egg quality traits of chickens. Descriptive statistics do not reveal the effect of the egg weight on the measured characteristics; hence, the second objective reveals the effect of egg weight on the measured traits.

The second objective was to use Analysis of Variance to examine the effect of egg weight on the egg quality traits. The results revealed that egg weight significantly ($p < 0.05$) affected yolk weight, albumen weight, albumen ratio, yolk ratio and yolk/albumen. Yolk weight and albumen weight increased with increasing egg weight. The results agree with a study of Hegab *et al.* (2019), who reported similar results on Japanese Quail eggs (*Coturnix coturnix japonica*). Moreover, it has been reported that egg weight influences the internal egg characteristics in the brown egg layer strain of Nike (Shi *et al.*, 2009). Results of the present study disagree with the study of Tyasi *et al.* (2022), who reported no effect of egg weight on albumen ratio and yolk ratio in the Potchefstroom Koekoek chicken genotype. The results of the present study imply that yolk weight, albumen weight, albumen ratio, yolk ratio and yolk/albumen should be considered when improving egg weight of Ross 308 broiler breed.

The effect of egg weight was further examined on external egg quality traits. The results revealed a significant ($p < 0.05$) effect of egg weight on egg length, egg width, shell weight, shell index, shell surface area, unit surface shell weight and shell ratio. Egg length, egg width, shell weight, shell index and unit surface shell weight increase as egg weight increases. Shell index and shell ratio decreased with the increase in egg weight. Results of Hegab *et al.* (2019) and Ukwu *et al.* (2017) indicate that egg weight affects the external egg quality traits, which agree with the results of the present study. However, Alkan *et al.* (2014) results indicate that unit surface shell weight is not affected by egg weight in partridge (*Alectoris Chukar*), which disagrees with the present study. The variation might be due to the difference in breed and production system, since Alkan *et al.* (2014) used a cage system. These results suggest that egg length, egg width, shell weight, shell index, shell surface area, unit surface shell weight and shell ratio should be considered when breeding to improve the weight of the egg. Analysis of Variance does not reveal the correlation between the measured characteristics; the third objective focuses the correlation between the measured characteristics.

Pearson's correlation technique was used to investigate the correlation between egg weight and egg quality traits of the Ross 308 broiler breed, to accomplish the third objective. The findings revealed that egg weight positively correlated with external traits, egg length, egg width, shell weight, and unit surface shell weight, and negatively correlated with shell index and shell ratio. The study of Alkan *et al.* (2014) and Tyasi *et al.* (2024) agrees with the current study that the weight of the egg has a positive correlation with egg length, egg width, shell weight and a negative correlation with shell ratio. These results imply that egg weight might improve when improving egg length, egg width, and shell weight, and decrease when increasing the shell ratio.

The correlation between egg weight and internal egg quality traits of Ross 308 broiler breed was also investigated. The results revealed that egg weight has a positive relationship with albumen weight, yolk weight, yolk ratio, yolk/albumen and a negative correlation with albumen ratio. Hegab *et al.* (2019), who reported a positive correlation between egg weight and albumen weight, which agrees with the present study. However, Tyasi *et al.* (2022) reported a positive correlation between egg weight and albumen ratio,

which disagrees with the present study. Furthermore, the results of the study also disagree with the study of Tyasi *et al.* (2024), who reported a positive correlation between egg weight and albumen ratio. These results imply that egg weight might increase when increasing the yolk ratio, albumen weight, and yolk/albumen, and decrease when increasing the albumen ratio. Therefore, egg length, egg width, shell weight, unit surface shell weight, albumen weight, yolk weight, yolk, ratio and yolk/albumen might be employed in the selection criteria during breeding to improve egg weight of Ross 308 broiler breeder chickens. Pearson's correlation technique does not estimate egg weight from egg quality traits, but rather the association between them; hence, the following objective reveals models to estimate egg weight from egg quality traits.

Stepwise regression technique was used to investigate which egg quality traits are closely related and what percentage contributes to predicting egg weight from egg quality traits. The regression results indicated that under external estimators, the shell surface area alone contributed 100% to the variation of egg weight in the Ross 308 broiler breeder chicken. Furthermore, the results revealed that the model including yolk weight, yolk ratio, albumen weight and albumen ratio had the greatest coefficient of determination and the least residual mean square error. Thus, it was selected as the best fit model for the prediction of egg weight of the Ross 308 broiler breeder chicken. The results of Tyasi *et al.* (2024) agree with the results of the study. Moreover, this study suggests that egg weight might be best predicted with more egg quality traits. As a result, yolk weight, yolk ratio, albumen weight and albumen ratio might be selected together for the prediction of egg weight of Ross 308 broiler breeder chickens. Portillo-Salgado *et al.* (2021) found that egg weight can be best predicted with egg surface area, egg polar diameter and egg equatorial diameter, which disagrees with the results of the current study. There is a need to conduct more studies to investigate the best-fit model for prediction of egg weight in other broiler breeder chicken breeds.

4.5 Conclusion

Egg weight significantly influenced all the measured external and internal egg quality traits in Ross 308 chicken. The study also revealed the correlation between weight of the egg and its quality traits, and the results revealed that egg weight is positively correlated with

egg width, egg length, shell weight, unit surface shell weight, albumen weight, yolk ratio and yolk/albumen of Ross 308 broiler breeder chickens. Pearson's correlation technique revealed that egg weight influences yolk weight, albumen weight, albumen ratio, yolk ratio, yolk/albumen, egg length, egg width, shell weight, shell index, shell surface area, unit surface shell weight and shell ratio. Results of the stepwise regression revealed that the model, including yolk weight, yolk ratio, albumen weight and albumen ratio had the highest R^2 and lowest MSE. Therefore, it was selected as the best fit model for predicting egg weight of Ross 308 broiler breeder chicken. This suggests that egg weight might be improved by making selection based on these traits during breeding. The study would be helpful to broiler farmers during selection to improve egg weight during breeding.

4.6 References

- Abanikanda O, Olutogun O, Leigh AO, Ajayi LA. (2007). Statistical modeling of egg weight and egg dimensions in commercial layers. *International Journal of Poultry Science*, 6(1): 59–63.
- Alkan, S., Galiç, A., Karsli, T. and Karabağ, K. (2014). Effects of egg weight on egg quality traits in partridge (*Alectoris Chukar*). *Journal of Applied Animal Research*, 43(4): 450–456.
- Celik, S., Sengul, T., Inci, H., Sodgut, B., Sengul, A.Y., Kuzu, Ç. and Ayasan, T. (2018). Estimation of egg weight from some external and internal quality characteristics in quail by using various data mining algorithms. *Indian Journal of Animal Sciences*, 87(12): 1524–1530.
- Hegab, I., and Hanafy, A. (2019). Effect of Egg Weight on External and Internal Qualities, Physiological and hatching success of Japanese Quail eggs (*Coturnix japonica*). *Brazilian Journal of Poultry Science*, [online] 21(3):109.
- Kgwatalala PM, Bolebano L, Nsoso SJ (2013). Egg quality characteristics of different varieties of domesticated helmeted guinea fowl (*Numida meleagris*). *International Journal of Poultry Science*, 12(4): 245-250.

- Khan M, Khatun M, Kibria A. (2004). Study the quality of eggs of different genotypes of chicken under scavenging system at Bangladesh. *Pakistan Journal of Biological Sciences*, 7(12): 2163–6.
- Orhan, H., Eydurán, E., Tatliyer, A. and Saygici, H. (2016). Prediction of egg weight from egg quality characteristics via ridge regression and regression tree methods. *Revista Brasileira de Zootecnia*, 45(7): 380–385.
- Portillo-Salgado, R., Cigarroa-Vázquez, F., Ruiz-Sesma, B., Mendoza-Nazar, P., Hernández-Marín, A., Esponda-Hernández, W. and Bautista-Ortega, J. (2021). Prediction of egg weight from external egg traits of Guinea fowl using Multiple Linear Regression and Regression Tree methods. *Brazilian Journal of Poultry Science*, 23(3): 78-109.
- Ross Breeders (2018). Parent Stock Management Handbook. https://en.aviagen.com/assets/Tech_Center/Ross_PS/RossPSHandBook2018.pdf
- Shi, S.R., Wang, K.H., Dou, T.C. and Yang, H.M. (2009). Egg weight affects some quality traits of chicken eggs. *Journal of Food, Agriculture and Environment*, 7(2): 432-434.
- Tumova, E., Skřivan, M., Englmaierová, M. and Zita, L. (2009). The effect of genotype, housing system and egg collection time on egg quality in egg type hens. *Czech Journal of Animal Science*, 54(1):17–23.
- Tyasi TL, Qin N, Jing Y, Mu F, Zhu H, Liu D and Xu R. (2017). Assessment of relationship between body weight and body measurement traits of indigenous Chinese Dagu chickens using path analysis. *Indian Journal of Animal Research*, 51(3): 588-593.
- Tyasi, T.L., Ngorima, L. and Hlokoé, V.R. (2024). Predicting egg weight from egg quality traits of the Lohmann brown chicken breed using Stepwise Regression. *Advances in Animal and Veterinary Sciences*, 12(3): 5-11.
- Tyasi, T.L., Rashijane, L.T., Mokoena, K., Molabe, K.M., Mathapo, M.C., Hlokoé, V.R., Selala, L.J., Maswana, M. and Bila, L. (2022). Effects of egg's weight on egg quality

traits of the. *Pakistan Journal of Zoology*, 54(4): 1973-1976. Potchefstroom
Koekoek chicken genotype

Ukwu, H.O., Ezihe, C.O., Asaa, S.K. and Anyogo, M.E. (2017). Effect of egg weight on external and internal egg quality traits of Isa Brown egg layer chickens in Nigeria. *Journal of Animal Science and Veterinary Medicine*, 2(4): 126–132.

CHAPTER 5

GENERAL CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The results of the current study indicated that there is a relationship between egg weight and other egg quality traits of Ross 308 broiler breeder chickens. The studied egg quality traits showed different findings in different broiler breeders. Thus, the study suggests that more studies must be conducted to characterise the egg quality characteristics of other chicken breeds.

Furthermore, the study investigated how egg weight affected the traits of egg quality and further predicted the weight of the egg from the egg quality traits of Ross 308 broiler breeder chickens. There is a statistically significant difference among egg weight groups on all measured egg quality traits. Correlation between the weight of the egg and its quality traits was revealed, and the results showed that egg weight is positively correlated with egg length, egg width, shell weight, unit surface shell weight, albumen weight, yolk ratio, and yolk/albumen of Ross 308 broiler breeder chickens.

Pearson's correlation technique showed that egg weight influences yolk weight, albumen weight, albumen ratio, yolk ratio, yolk/albumen, egg length, egg width, shell weight, shell index, shell surface area, unit surface shell weight and shell ratio. Stepwise regression revealed that the model, including yolk weight, yolk ratio, albumen weight and albumen ratio, had the highest R^2 and lowest MSE. Therefore, it was selected as the best fit model for predicting egg weight of Ross 308 broiler breeder chicken. This suggests that egg weight might be improved by making selection based on these traits during breeding. The study would be helpful to broiler farmers during selection to improve egg weight during breeding.

5.2 Recommendations

The findings of this study suggest that yolk weight, albumen weight, egg length, egg width, shell weight, shell index, unit surface and shell weight should be considered when breeding for egg weight, since they increase with increasing egg weight.

It is recommended that egg length, egg width, shell weight, unit surface shell weight, albumen weight, yolk weight, yolk ratio and yolk/albumen be utilized in the selection criteria during breeding to improve egg weight of Ross 308 broiler breeder chickens.

It is highly recommended that farmers who breed Ross 308 broiler chickens use the regression model with yolk weight, yolk ratio, albumen weight and albumen ratio for estimating egg weight using egg quality traits for greater accuracy.

There is still a need for further investigations into the use of the Stepwise regression technique across various chicken breeds. Further research on the egg quality traits of Ross 308 broiler breeder chickens will be useful to the broiler breeders.